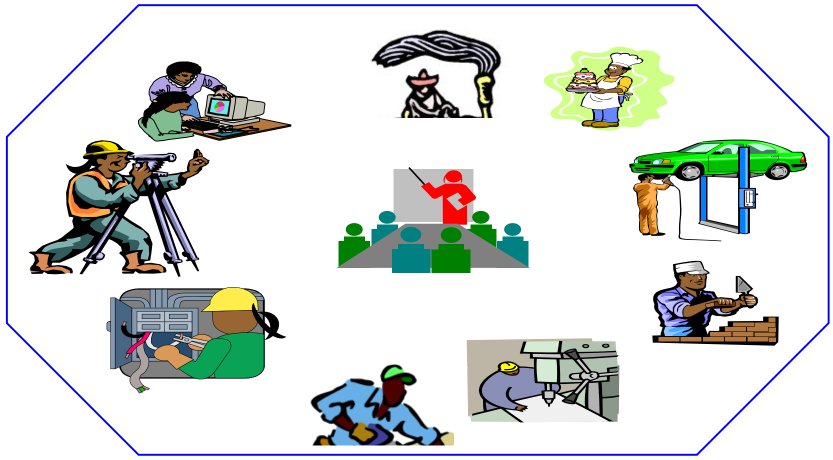

NATURAL RESOURCES CONSERVATION AND DEVELOPMENT

LEVEL III

Based on March, 2018, Version 3 Occupational standards

Module Title: Supporting Water Harvesting Technologies Application

LG Code: AGR NRC3 M15 LO (1-3) LG (67-69)

TTLM Code: AGR NRC3 TTLM 15 21v1

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East Africa Skills for Transformation and Regional Integration Project (EASTRIP)

Table of Contents

LG #67	LO# 1- Design and construct micro-catchment's water harvesting structures

Instruction sheet
This learning guide is developed to provide you the necessary information regarding the following content coverage and topics: • Identifying and using Relevant sources of information • Identifying OHS requirements • Water harvesting technology principles • Principles of hydrology • Micro-catchment water harvesting structures • Enhancing community awareness and participation • Setting design criteria and specification • Constructing designed structures This guide will also assist you to attain the learning outcomes stated in the cover page. Specifically, upon completion of this learning guide, you will be able to: • Understand how to Identify and use Relevant sources of information as well as OHS requirements • Apply principles of Water harvesting technology and hydrology • Identify Micro-catchment water harvesting structures • Enhancing community awareness and participation • Understand how to Set design criteria, specification and Construct the designed structures
Learning Instructions:

1. Read the specific objectives of this Learning Guide.
2. Follow the instructions described below.
3. Read the information written in the "Information Sheets". Try to understand what are being discussed. Ask your trainer for assistance if you have hard time understanding them.
4. Accomplish the "Self-checks" which are placed following all information sheets.
5. Ask from your trainer the key to correction (key answers) or you can request your trainer to correct your work. (You are to get the key answer only after you finished answering the Self-checks).
6. If you earned a satisfactory evaluation proceed to "Operation sheets
7. Perform "the Learning activity performance test" which is placed following "Operation sheets" ,
8. If your performance is satisfactory proceed to the next learning guide,
9. If your performance is unsatisfactory, see your trainer for further instructions or go back to "Operation sheets".

Information Sheet 1- Identifying and using relevant sources of information

1.1. Identifying and using Relevant sources of information

Gathering information on indigenous practice for water harvesting development and assessment information must be gathered using various survey techniques. These survey techniques should assess and investigate the;

- Traditional knowledge that exists in target areas
- Best practices make them more attractive and valuable for the intended purpose
- Successful management practices of societies
- Adaptability to new technologies and management styles.

1.1.1. Survey techniques to gathering information

Information can be gathered come from a range of sources. Likewise, there are a variety of techniques to use when gathering primary data. Listed below are some of the most common data collection techniques.

- Interviews
- Questionnaires and Surveys
- Observations
- Focus Groups
- Ethnographies, Oral History, and Case Studies
- Documents and Records

1.1.2. Collecting data from metrological station

The weather variables for driving the hydrological balance are precipitation, air temperature, solar radiation, wind speed and relative humidity. Required daily data are precipitation, max and min air temperature, solar radiation, wind speed and humidity. These metrological data were collected from local meteorological station.

Rainfall data

Rainfall in dry areas is characterized by short duration, high intensity and poor distribution. The low duration high intensity combination is conducive to high runoff production. The great rainfall variation with time presents the biggest challenge to dry land agriculture. Cropping seasons are usually longer than the rainfall seasons, and drought within the growing season is a common feature of most growing seasons. In water harvesting design, the aim is to use a rainfall figure that will meet the water requirement and produce a crop with a level of certainty. Those factors that affect run off are listed below.

Climatic or characteristics of precipitation- plays an important role in determining the amount of consequent runoff. It includes:

Type of precipitation

- ➢ Intensity of precipitation
- ➢ Duration of precipitation
- ➢ Distribution of precipitation
- ➢ Frequency of precipitation

Watershed characteristics (physiographic factors): on which water (rain) falls also plays a significant part in determining the quantity of runoff. It includes:

Character of catchment surface (its geological formation)

- ➢ Soil moisture
- ➢ Topography
- ➢ Land use
- ➢ Shape and size of the catchment
- ➢ Vegetal cover

1.1.3. Social data relevant for water harvesting

- Community acceptance and participation
- Understanding of needs and aspiration of the community
- Prioritization of community needs
  - Drinking water
  - Livestock
  - Crop production
- Appropriate technology
  - To skill of people
  - To the environment
- Proper planning and studies
  - Construction materials
  - Construction skill
  - Construction method
  - Operation and maintenance

- Low cost but long lasting/durability
- Cost and benefit
- Skill
- Data collection
- Adaptive field research

- Agronomic Aspects
  - Crop
  - Soil condition
- Environmental Aspect

1.1.4. Sources of Information May include, but not limited to:

- Organizational rules, regulation and guidelines
- Internet, related books and related materials
- Technical manuals
- Workplace guidelines

Self-check 1	Written test

Name…………………………………………… ID……………………….. Date…….

Directions: Answer all the questions listed below. Examples may be necessary to aid some explanations/answers.

Test II: Short Answer Questions

1. Write the information required to apply a given water harvesting techniques. (10points)

   ____

   ____

   ____

   ____

2. List of the most common data collection techniques.(5points)

   ____

   ____

3. What is the importance of analyzing Rainfall data?. (5 points)

   ____

   ____

You can ask you teacher for the copy of the correct answers.

Note: Satisfactory rating - 10 points and above Unsatisfactory - below 10 points

Answer Sheet

Score = ___________

Rating: ____________

Name: _________________________ Date: _______________

Information Sheet 2- Identifying OHS requirements

2.1. Identifying OHS requirements

Occupational health and safety

Occupational health and safety is a discipline with a broad scope involving many specialized fields. In its broadest sense, it should aim at:

- The promotion and maintenance of the highest degree of physical, mental and social well-being of workers in all occupations;
- the prevention among workers of adverse effects on health caused by their working conditions;
- the protection of workers in their employment from risks resulting from factors adverse to health;
- the placing and maintenance of workers in an occupational environment adapted to physical and mental needs;
- The adaptation of work to humans

2.2. Hazard Identification And Risk Assessment

Hazard: is a source or potential source of human injury, ill health or disease. Anything which might cause injury or ill health to anyone at or near a workplace.

Hazard Identification

There are a number of quite simple methods used to identify workplace hazards. For example:

- Workplace inspections, using a formal checklist or spot checks
- Referring to information recorded in incident/injury report of previous occurrences
- Communication with employees and through OH&SC consultation
- Observing work areas, work tasks, work processes or work methods
- Sharing information with other internal workgroups
- Information supplied by the HR Manager or General Manager Operations, Work Cover Authority or other safety organizations

What are the most common workplace hazards?

There are many types of workplace hazards, which tend to come under four main categories:

- physical hazards – the most common workplace hazards, including vibration, noise and slips, trips and falls;
- ergonomic hazards – physical factors that harm the musculoskeletal system, such as repetitive movement, manual handling and poor body positioning;
- chemical hazards – any hazardous substance that can cause harm to your employees;
- biological hazards – bacteria and viruses that can cause health effects,

Risk Assessment

Risk assessment is simply a further analysis of the hazard by breaking it down into more specific component parts to evaluate the nature of the hazard. Assessing the risk associated with the hazard by specifically defining its nature will assist in determining its:

- Probability or likelihood of causing injury or damage
- Exposure levels of employee/s i.e. number of employees exposed, time exposed, frequency of exposure
- Consequence/s or severity of outcome

2.3. Personal protective clothing and equipment may include:

- boots
- hat/hard hat
- overalls
- gloves protective eyewear
- hearing protection
- respirator or face mask
- sun protection, e.g., sun hat, sunscreen

Self-Check – 2	**Written test**

Name…………………………………………… ID……………………….. Date…….

Directions: Answer all the questions listed below. Examples may be necessary to aid some explanations/answers.

Test I: Short Answer Questions

1. What is occupational health and safety?(2pts)

____

____

2. Define hazard and risk..(5pts)

____

____

3. Write down the types hazards. (4pts)

____

____

4. Discuss the methods we used to identify workplace hazards. (5pts)

____

____

5. Write the required personal protective equipment. (4pts)

____

____

Note: Satisfactory rating – 10 points and above Unsatisfactory - below 10points

You can ask you teacher for the copy of the correct answers.

Answer Sheet

Score = ___________

Rating: ____________

Name: ____________________________ Date: _______________

3.1. Water harvesting technology principles

Definition

Water harvesting in its broadest sense can be defined as the collection of runoff for its productive use. Runoff may be collected from **roofs** and **ground surfaces** as well as from **seasonal streams**. Water harvesting systems which harvest runoff from roofs or ground surfaces fall under the term **rainwater harvesting** while all systems which collect runoff from seasonal streams are grouped under the term **flood water harvesting**.

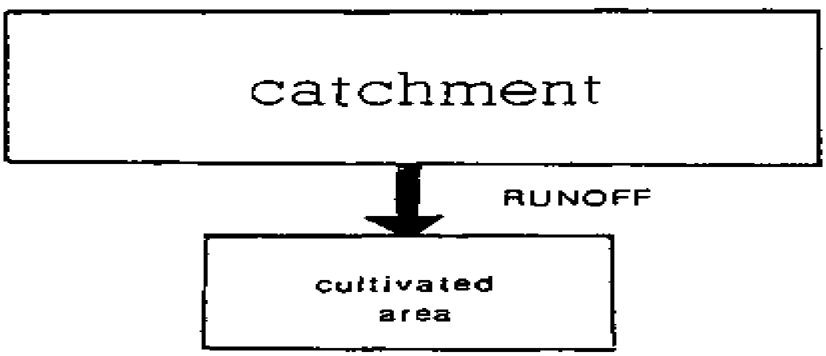


Figure 1. The principle of water harvesting

A certain amount of land, the **catchment area**, is deliberately left uncultivated. Rainwater runs off this catchment area to the zone where crops are grown, the **cultivated area**. The runoff is ponded in the cultivated area. Water harvesting involves the transfer of runoff water from a catchment area that is not cropped to supplement the rainfall received directly on the area that is cultivated

What Are The Goals and Benefits Of Water Harvesting?

The Main Goals of Water Harvesting

To secure water supply in dry areas where other water resources (surface or groundwater) are not available or uneconomical to develop, in order to:

- Increase the productivity of arable and grazing land which suffers from inadequate rainfall
- Increase yields of rain-fed farming

- Minimize the risk of crop failure in drought prone areas

- combat desertification by afforestation, fruit tree planting or agro forestry
- supply drinking water for animals
- supply domestic water for people

Benefits of Water Harvesting

- Higher productivity (higher yield and lesser risk)
- Crop production in areas where it is normally not feasible
- Soil conservation (for macro catchments or cropping area only) i.e., less erosion
- Pasture improvement = more livestock
- Improved re-afforestation = less desertification
- Suppression of salinity in soil = more productive land
- Water conservation (tapping unused water)
- Ground water recharge = more water available

3.2. Conditions for water harvesting

I. Climates

Water harvesting is particularly suitable for semi-arid regions (300-700 mm average annual rainfall). It is also practiced in some arid areas (100-300 mm average annual rainfall).

II. Slopes

Water harvesting is not recommended on slopes exceeding 5% because of the uneven distribution of runoff, soil erosion and high costs of the structure required

III. Soils and soil fertility management

Soils in the cultivated area should be deep enough to allow sufficient moisture storage capacity and be fertile. Soils in the catchment area should have a low infiltration rate. For most water harvesting systems soil fertility must be improved, or at least maintained, in order to be productive and sustainable

IV. Crops

One of the main criteria for the selection of a water harvesting technique is its suitability for the type of plant one wants to grow. However, the crop can also be adapted to the structure. The basic difference between perennial (e.g. trees) and annual crops is that trees require the concentration of water at points, whereas annual crops usually benefit most from an equal distribution of water over the cultivated area.

3.3. Application and limitation of water harvesting systems:

Theoretically, water-harvesting program is feasible at any place where water runs off a catchment and could be collected

The system is practicable mostly in the arid and semiarid regions where rainfall agriculture is limited by erratic rainfall

Limiting factors to water-harvesting techniques

- Rainfall
- Slope - The ground slope is the main limiting factor for water harvesting. This technique is not recommended on steep slope areas greater than 5%, the main reason being large volume of earthwork and an uneven distribution of run-off.
- Soil type - The soil should be deep, fertile, and free from salinity problems, good water holding capacity and be with good infiltration rate that is preferably medium of fine soil texture.
- Cost - The cost of the system selected can be affected by the quantity and type of structure/earth or stone work/ involved. Labor and its financial implication may be a limiting factor to implement the system especially on a self-help basis.

3.4. Basic categories of Water harvesting

1. Micro-catchments Water harvesting (rainwater harvesting)

(sometimes referred to as "Within-Field Catchment System")

Main characteristics:

- overland flow harvested from short catchment length
- catchment length usually between 1 and 30 meters
- runoff stored in soil profile
- ratio catchment: cultivated area usually 1:1 to 3:1
- normally no provision for overflow
- plant growth is even

Typical Examples:

- Negarim Micro catchments (for trees)

- Contour Bunds (for trees)
- Contour Ridges (for crops)
- Semi-Circular Bunds (for range and fodder)

2. Macro-catchment Water harvesting (rainwater harvesting)

(Long Slope Catchment Technique)

Main Characteristics:

- overland flow or rill flow harvested
- runoff stored in soil profile
- catchment usually 30 - 200 meters in length
- ratio catchment: cultivated area usually 2:1 to 10:1
- provision for overflow of excess water
- uneven plant growth unless land leveled

Typical Examples:

- Trapezoidal Bunds (for crops)
- Contour Stone Bunds (for crops)

3. Floodwater harvesting (Floodwater farming)

(often referred to as "Water Spreading" and sometimes "Spate Irrigation")

Main Characteristics:

- turbulent channel flow harvested either (a) by diversion or (b) by spreading within channel bed/valley floor
- runoff stored in soil profile
- catchment long (may be several kilometers)
- ratio catchment: cultivated area above 10:1
- provision for overflow of excess water

Typical Examples:

- Permeable Rock Dams (for crops)
- Water Spreading Bunds (for crops)

Self-Check – 3	Written test

Name…………………………………………… ID……………………….. Date…….

Directions: Answer all the questions listed below. Examples may be necessary to aid some explanations/answers.

Test I: Short Answer Questions

1. Define water harvesting.(2pts)

____

____

2. What do you think about principle of water harvesting?(5pts)

____

____

3. What are the goals and benefits of water harvesting?(3pts)

____

____

____

4. Discuss the basic categories of Water Harvesting and their main characteristics. (5pts)

____

____

5. Write the main characteristics of the basic categories of Water Harvesting. (10points)

____

____

***Note:* Satisfactory rating - 10points & above** **Unsatisfactory - below 10 points**

You can ask you teacher for the copy of the correct answers.

Answer Sheet

Score = ___________

Rating: ____________

Name: _________________________ Date: _______________

Information Sheet 4- Principles of hydrology

4.1. Principles of hydrology

Hydrology and Hydrologic Cycle

Hydrology is the science, which deals with the occurrence, distribution and disposal of water on the planet earth; it is the science which deals with the various phases of the hydrologic cycle. Hydrologic cycle is the water transfer cycle, which occurs continuously in nature; the three important phases of the hydrologic cycle are: **(*a*) Evaporation** and **evapo-transpiration** (*b*) **precipitation** and (*c*) **runoff**. Evaporation from the surfaces of ponds, lakes, reservoirs. ocean surfaces, etc. and transpiration from surface vegetation *i.e.,* from plant leaves of cropped land and forests, etc. take place. These vapors rise to the sky and are condensed at higher altitudes by condensation nuclei and form clouds, resulting in droplet growth. The clouds melt and sometimes burst resulting in precipitation of different forms like rain, snow, hail, sleet, mist, dew and frost. A part of this precipitation flows over the land called runoff and part infiltrates into the soil which builds up the ground water table. The surface runoff joins the streams and the water is stored in reservoirs. A portion of surface runoff and ground water flows back to ocean.

Again evaporation starts from the surfaces of lakes, reservoirs and ocean, and the cycle repeats. Of these three phases of the hydrologic cycle, namely, evaporation, precipitation and runoff, it is the 'runoff phase', which is important to a civil engineer since he is concerned with the storage of surface runoff in tanks and reservoirs for the purposes of irrigation, municipal water supply hydroelectric power etc.

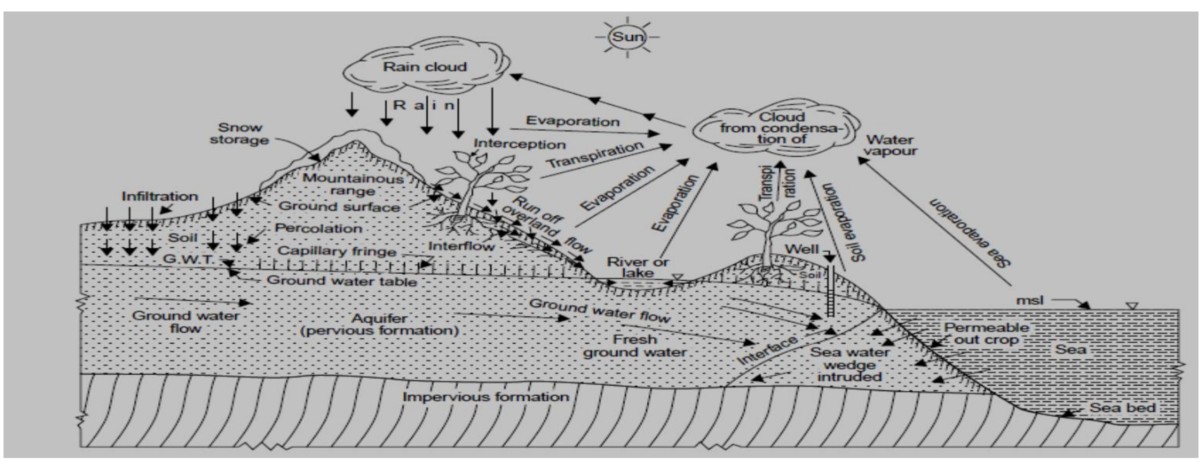


Fig.2. hydrological cycle

Scope Of hydrology

The study of hydrology helps us to know

(*i*) the maximum probable flood that may occur at a given site and its frequency; this is required for the safe design of drains and culverts, dams and reservoirs, channels and other flood control structures.

(*ii*) the water yield from a basin—its occurrence, quantity and frequency, etc; this is necessary for the design of dams, municipal water supply, water power, river navigation, etc.

(*iii*) the ground water development for which a knowledge of the hydrogeology of the area, *i.e.,* of the formation soil, recharge facilities like streams and reservoirs, rainfall pattern, climate, cropping pattern, etc. are required.

(*iv*) the maximum intensity of storm and its frequency for the design of a drainage .

Hydrological Data

For the analysis and design of any hydrologic project adequate data and length of records are necessary. A hydrologist is often posed with lack of adequate data. The basic hydrological data required are:

(*i*) Climatologically data

(*ii*) Hydro meteorological data like temperature, wind velocity, humidity, etc.

(*iii*) Precipitation records

(*iv*) Stream-flow records

(*v*) Seasonal fluctuation of ground water table or piezometric heads

(*vi*) Evaporation data

(*vii*) Cropping pattern, crops and their consumptive use

(*viii*) Water quality data of surface streams and ground water

Catchment yield (Water potential)

- Catchment characteristics (runoff coefficient computation)
- Dependable rainfall computation
- Monthly yield computation

Self-Check – 4	Written test

Name…………………………………………… ID……………………….. Date…….

Directions: Answer all the questions listed below. Examples may be necessary to aid some explanations/answers.

Test I: Short Answer Questions

1. What is hydrology and hydrological cycle?(5pts)

____

____

2. Explain the scope of hydrology?(5pt)

____

____

____

____

3. Write the relevant hydrological data required analysis and design of water harvesting structures. (10pts)

____

____

____

____

Note: **Satisfactory rating - 10points & above** **Unsatisfactory - below 10 points**

You can ask you teacher for the copy of the correct answers.

Answer Sheet

Score = ___________

Rating: ____________

Name: _________________________ Date: _______________

5.1. Micro-catchment water harvesting structures

Micro catchment water harvesting systems (Also known as within field catchment) is a series of units, each of which is separated from the surrounding operates independently and collects run-off within its own basin or catchment or field.

Typical types of micro-catchment water harvesting structures are discussed below.

1. **Negarim micro-catchments**

Background

Negarim micro-catchments are diamond-shaped basins surrounded by small earth bunds with an infiltration pit in the lowest corner of each. Runoff is collected from within the basin and stored in the infiltration pit. Micro-catchments are mainly used for growing trees or bushes. This technique is appropriate for small-scale tree planting in any area which has a moisture deficit. Besides harvesting water for the trees, it simultaneously conserves soil.

Technical details

I. Suitability

Negarim micro-catchments are mainly used for tree growing in arid and semi-arid areas.

Rainfall: can be as low as 150 mm per annum.

Soils: should be at least 1.5 m but preferably 2 m deep in order to ensure adequate root development and storage of the water harvested.

Slopes: from flat up to 5.0%.

Topography: need not be even - if uneven a block of micro-catchments should be subdivided.

ii. Overall configuration

Each micro-catchment consists of a catchment area and an infiltration pit (cultivated area). The shape of each unit is normally square, but the appearance from above is of a network of diamond shapes with infiltration pits in the lowest corners.

iii. Limitations

While Negarim micro-catchments are well suited for hand construction, they cannot easily be mechanized. Once the trees are planted, it is not possible to operate and cultivate with machines between the tree lines.

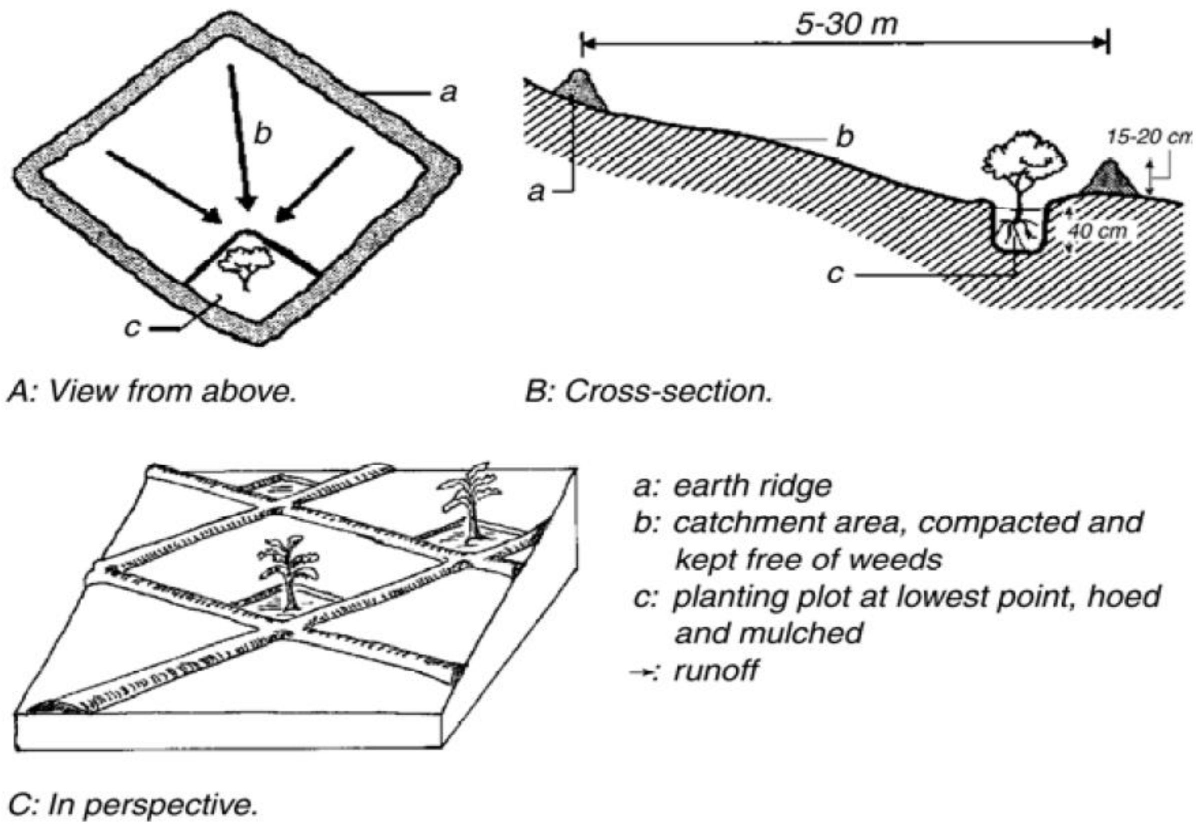


Figure 3. Negarim micro-catchments

2. **Contour bunds for trees**

Background

Contour bunds for trees are a simplified form of micro-catchments. As its 11 indicates, the bunds follow the contour, at close spacing, and by provision of small earth ties the system is divided into individual micro-catchments.

Figure 4. Contour bunds for trees

Technical details

I. Suitability

Contour bunds for tree planting can be used under the following conditions:

Rainfall: 200 - 750 mm; from semi-arid to arid areas.

Soils: Must be at least 1.5 m and preferably 2 m deep to ensure adequate root development and water storage.

Slopes: from flat up to 5.0%.

Topography: must be even, without gullies or rills.

II. Limitations

Contour bunds are not suitable for uneven or eroded land as overtopping of excess water with subsequent breakage may occur at low spots.

III. Overall Configuration

The overall layout consists of a series of parallel, or almost parallel, earth bunds approximately on the contour at a spacing of between 5 and 10 metres. The bunds are formed with soil excavated from an adjacent parallel furrow on their upslope side. Small earth ties perpendicular to the bund on the upslope side subdivide the system into micro-catchments. Infiltration pits are excavated in the junction between ties and bunds..

3. Semi-circular bunds

Background

Semi-circular bunds are earth embankments in the shape of a semi-circle with the tips of the bunds on the contour. Semi-circular bunds, of varying dimensions, are used mainly for rangeland rehabilitation or fodder production. This technique is also useful for growing trees and shrubs and, in some cases, has been used for growing crops.

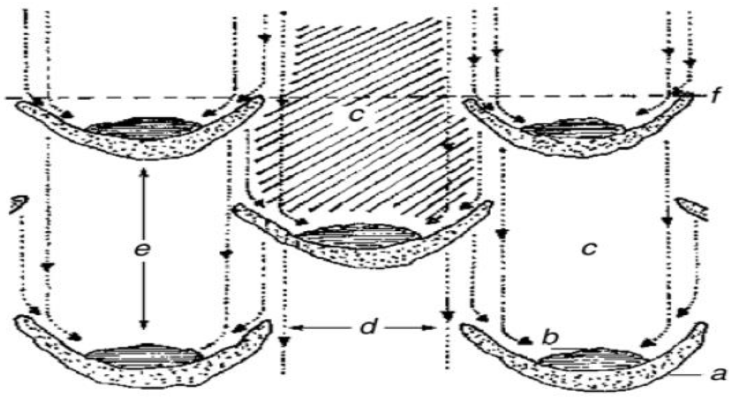


Fig 5. semi-circular bund

Technical details

I. Suitability

Semi-circular bunds for rangeland improvement and fodder production can be used under the following conditions:

Rainfall: 200 - 750 mm: from arid to semi-arid areas.

Soils: all soils which are not too shallow or saline.

Slopes: below 2%, but with modified bund designs up to *5%.*

Topography: even topography required, especially for design "a" (see below).

II. Overall configuration

The two designs of semi-circular bunds considered here differ in the size of structure and in field layout. Design "a" has bunds with radii of 6 meters, and design "b" has bunds with radii of 20 metres. In both designs the semi-circular bunds are constructed in staggered lines with runoff producing catchments between structures.

4. Contour ridges for crop

Background

Contour ridges, sometimes called contour furrows, are small earthen banks, with a furrow on the higher side which collects runoff from an uncultivated strip between the ridges. Through their shape, soil moisture is increased under the ridge and the furrow, in the vicinity of plant roots.

Technical details

I. Suitability

Contour ridges for crop production can be used under the following conditions:

Rainfall: 350 - 750 mm.

Soils: all soils which are suitable for agriculture. Heavy and compacted soils may be a constraint to construction of ridges by hand.

Slopes: from flat up to 5.0%.

Topography: must be even - areas with rills or undulations should be avoided.

II. Limitations

Contour ridges are limited to areas with relatively high rainfall, as the amount of harvested runoff is comparatively small due to the small catchment area.

III. Overall configuration

The overall layout consists of parallel, or almost parallel, earth ridges approximately on the contour at a spacing of between one and two meters. Soil is excavated and placed down slope to form a ridge, and the excavated furrow above the ridge collects runoff from the catchment strip between ridges. Small earth ties in the furrow are provided every few meters to ensure an even storage of runoff. A diversion ditch may be necessary to protect the system against runoff from outside.

Self-Check – 5	**Written test**

Name…………………………………………… ID……………………….. Date…….

Directions: Answer all the questions listed below. Examples may be necessary to aid some explanations/answers.

Test I: chose the best answer

1. ____ are diamond-shaped basins surrounded by small earth bunds with an infiltration pit in the lowest corner of each.(3pts)
   A. Contour bund micro catchment C. Negarims micro catchment
   B. Semi-circular micro catchment D. None
2. ______are earth embankments in the shape of a semi-circle with the tips of the bunds on the contour. .(2pts)
   A. Semi-circular micro catchment C. Negarims micro catchment
   B. Contour bund micro catchment D. None

Test I: Short Answer Questions

1. Discuss about the suitable area condition for contour bund micro-catchment. (5pts)

____

____

____

2. Discuss about the suitable area condition for semi-circular bund micro-catchment.(5pts)

____

____

3. Write the difference between contour bund and contour ridge bund.(5pts)

____

____

***Note:* Satisfactory rating - 10 points & above Unsatisfactory - below 10points**

You can ask you teacher for the copy of the correct answers.

Score = ____________	
Rating: _____________	

Answer Sheet

Name: _________________________ Date: _______________

Information Sheet 6- Enhancing community awareness and participation

6.1. Enhancing community awareness and participation

Generally, community is formed to achieve certain goals or gains. Community refers to a group of people who live in a particular geographical location and work for common goals rather than for specific interests.

6.1.1. Community participation

What is community participation? The term community participation in development indicates a vast arena, where people of every level are encouraged to participate in development activities spontaneously by building awareness on their needs, problems, roles and responsibilities. The awareness and spontaneity make them self-confident. As a result they themselves take the initiative to solve their own problems.

To ensure peoples' participation in development we should know the forms of community participation. Here ten forms of community participation are given.

1. To get informed:
2. Giving opinion.
3. Consultation
4. Participate in providing data:
5. Periodical functional linkage:
6. Developing long-term functional relations:
7. Establishing organization with external interventions:
8. Participatory decision-making:
9. Getting organized at own initiative:.

Community participation thus implies the ensuring of their participation at all levels and showing respect to their decisions. So far all development interventions have been supply driven. As a result expected results could not be achieved and the people did not come up to play any active role to sustain those .For that reason now attempts are being made to make all development programmer demand-driven. For a demand driven development process community participation is a pre-requisite.

Participation in problem identification and ranking

1. **Problem identification**

It will be most effective to conduct problem identification exercise together with the community's members in order to identify the most important problems which face farmers and to put their possible solutions. Community participation is a problem oriented approach. It is important that major problem be carefully defined at the beginning (the 1st step) of the planning process.

2. **Problem ranking and analysis**

Rank or scoring means placing something in order. Ranking can be used as part of an interview, or as analytical tool by itself. Ranking reveals differences in priorities and help to understand the criterion used in doing so

6.1.2. Creating Awareness for Community

This is way encouraging the community to act (and therefore learn and become stronger), the mobilize must make the community members aware of specific realities. These include: If they remain passive and expectant of government or other outside help, then they will remain with the burden of poverty and weakness; No community is totally poor; if there are live humans in it then it has resources and potentials, including labor, creativity, life, desires, and survival skills and living attributes;

6.2. Socio-economic factors related to water harvesting

Socio-economic factors are particularly important in the community awareness and participation in the design and construction of micro-catchments water harvesting structures. Obviously, if the small scale farmer is the "customer" or beneficiary, then she/he must understand and be happy with a system which is appropriate, and which she/he is able to manage and maintain.

Some socio-economic factors:-

- People's priorities
- Participation
- Adoption of systems
- Area differences
- Gender and equity
- Land tenure
- Village land use management

People's priorities

If the objective of rainwater harvesting projects is to assist resource-poor farmers to improve their production systems, it is important that the farmer's/agro pastoralist's priorities are being fulfilled, at least in part. Otherwise success is unlikely. If the local priority is drinking water supply, for example, the response to water harvesting systems for crop production will be poor

Participation

It is becoming more widely accepted that unless people are actively involved in the development projects which are aimed to help them, the projects are doomed to failure. It is important that the beneficiaries participate in every stage of the project. .

Adoption of systems

Widespread adoption of water harvesting techniques by the local population is the only way that significant areas of land can be treated at a reasonable cost on a sustainable basis. It is therefore important that the systems proposed are simple enough for the people to implement and to maintain. .

Area differences

It is tempting to assume that a system which works in one area will also work in another, superficially similar, zone. However there may be technical dissimilarities such as availability of stone or intensity of rainfall, and distinct socio-economic differences also. For example a system which is best adapted to hand construction may not be attractive to people who normally till with animals. If a system depends on a crop well accepted in one area - sorghum for example - this may be a barrier to acceptance where maize is the preferred food grain.

Gender and equity

If water harvesting is intended to improve the lot of farmers in the poorer, drier areas, it is important to consider the possible effects on gender and equity. In other words, will the introduction of water harvesting be particularly advantageous to one group of people, and exclude others? Perhaps water harvesting will give undue help to one sex, or to the relatively richer landowners in some situations. .

Land tenure

Land tenure issues can have a variety of influences on water harvesting projects. On one hand it may be that lack of tenure means that people are reluctant to invest in water harvesting structures on land which they do not formally own. Where land ownership and rights of use are complex it may be difficult to persuade the cultivator to improve land that someone else may use later..

Village land use management

The whole question of land management by village communities has recently been acknowledged to be extremely important. Degraded land in and around villages can only be improved if land use management issues are faced by the communities themselves.

Self-Check – 1	**Written test**

Name…………………………………………… ID………………………… Date…….

Directions: Answer all the questions listed below. Examples may be necessary to aid some explanations/answers.

Test I: Short Answer Questions

1. Define community.(5pt)

____

____

2. Define community. Participation. .(5pt).

____

____

3. What is the importance of Creating Awareness for Community .(5pt)

____

____

4. Write the Socio-economic factors related to water harvesting.(5pt)

____

____

____

____

***Note:* Satisfactory rating - 10 points & above** **Unsatisfactory - below 10points**

You can ask you teacher for the copy of the correct answers.

Answer Sheet

Score = ____________

Rating: _____________

Name: __________________________ Date: _______________

Information Sheet 7- Setting design criteria and specification

7.1. Setting design criteria and specification micro catchments

The design of water harvesting system for specific area requires detailed analysis. Information will be needed on rainfall, existing water sources, and availability of materials and harvesting surface or area.

The design specification of typical micro catchments water harvesting structures discussed below.

1. **Negarim Micro catchment**

I. Size of the catchment

The area of each unit is either determined on the bases of a calculation of the plant/tree water requirement or more usually, an estimation of this. Size of micro-catchment(per unit) normally range between 10m2 and 100m2 depending on the species of tree to be planted but large sizes are also feasible, particularly when more than one trees will be grown within one unit.

II. Design of bunds

The bund height is primarily dependent on the prevailing ground slope and the selected size of the micro-catchment. It is recommended to construct bunds with a height of at least 25 cm in order to avoid the risk of over-topping and subsequent damage. Where the ground slope exceeds 2.0%, the bund height near the infiltration pit must be increased.

Size Unit Micro catchment	**Ground slope**			
(m^2)	**2%**	**3%**	**4%**	**5%**
3x3	even bund height			
4x4	of 25 cm			30
5X5			30	35
6X6			35	45
8X8		35	45	55
10X12	30	45	55	
12X12	35	50	not recommended	
15 X 15	45			

Table 1. Bund heights (cm)

III. Size of infiltration pit

A maximum depth of 40 cm should not be exceeded in order to avoid water losses through deep percolation and to reduce the workload for excavation. Excavated soil from the pit should be used for construction of the bunds.

2. Contour bund for trees

I. Unit micro catchment size

The size of micro catchment per tree is estimated in the same way as for Negarim micro catchment. However the system is more flexible, because adding or removing the cross ties within the fixed spacing of the bunds can easily alter the micro catchment size. Common sizes of micro-catchment area around 10-50m2 for each tree

II. Bund and infiltration pit design

The bund height varies from 30-50m depending on the prevailing slope. It is recommended not to be less than 40cm in height base width must be at least 75cm. Bund should be spaced at either 5m or 10m apart. Cross-tie should be at least 2m long at spacing of 2-10meters. It is recommended to provide 6m spacing between the bunds on the slope of up to 10% and 4m on steeper slopes. Excavated soil from the infiltration pit is used to form the ties. The pit is excavated in the junction of the bund and the cross tie. A pit size of 80cm x 80cm and 40cm deep is usually sufficient. The diversion ditch is aligned on a 0.25%slope and a common dimension is 50cm deep and 1- 1.5m wide, with the soil pile down slope.

3. Semi-circular bund

Two specific designs of semicircular bund

Design "a" comprises small structures, closely spaced. It is suitable for the relatively "wetter" semi-arid areas but requires low slopes and even terrain.

Design "b", with larger and wider spaced bunds, is more suitable for drier areas, and does not need such even topography.

I. Overall configuration

The two designs of semi-circular bunds considered here differ in the size of structure and in field layout. **Design "a"** has bunds with radii of 6 metres, and **design "b"** has bunds with radii of 20 metres. In both designs the semi-circular bunds are constructed in staggered lines with runoff producing catchments between structures.

Design "a" is a short slope catchment technique, and is not designed to use runoff from outside the treated area, nor to accommodate overflow. **Design "b"** is also a short slope catchment system, but can accommodate limited runoff from an external source. Overflow occurs around the tips of the bund which are set on the contour.

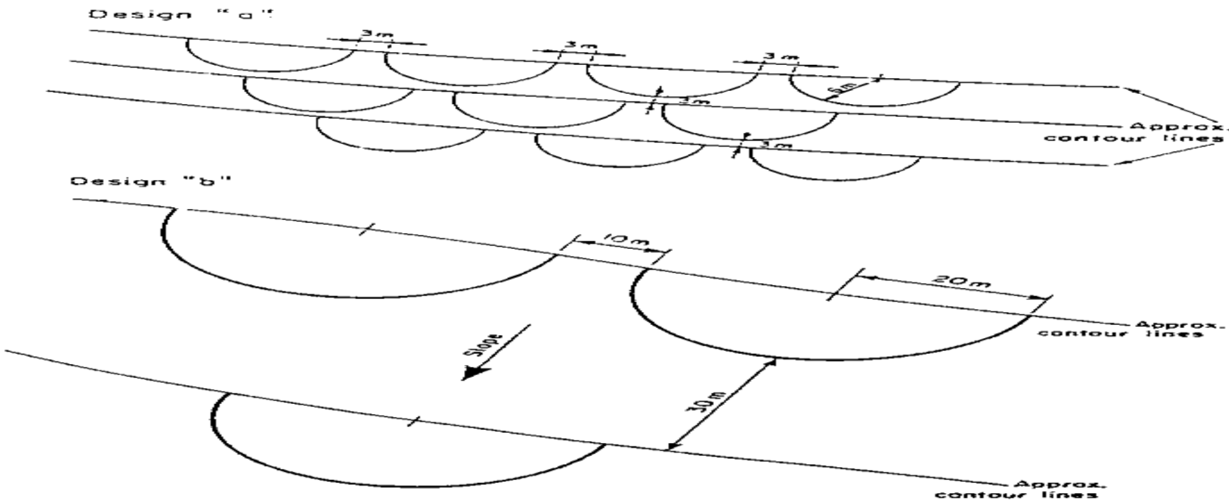


Fig.7. Field layout of **Design "a"** and **Design "b"**

II. Catchment: cultivated area ratio

Design "a" as described here has a C:CA ratio of only 1.4:1, and does not require provision for overflow. **Design "b"** has a C:CA ratio of 3:1, and therefore provision for overflow around the tips of the bunds is recommended, though occurrence of overflow is usually rare.

III. Bund design

Design "a":

This design, suitable for slopes of 1% or less, consists of a series of small semi-circular bunds with radii of 6 meters. Each bund has a constant cross section over the whole length of 19 m. The recommended bund height is 25 cm with side slopes of 1:1 which result in a base width of 75 cm at a selected top width of 25 cm.

The tips of each bund are set on the contour, and the distance between the tips of adjacent bunds in the same row is 3 meters. Bunds in the row below are staggered, thus allowing the collection of runoff from the area between the bunds above. The distance between the two rows, from the base of bunds in the first line to tips of bunds in the second, is 3 meters. At this spacing 70-75 bunds per hectare are required.

Design "b"

The radius of the semi-circle is 20 meters. The cross-section of the bund changes over its length. At the wing tip, the bund is only 10 cm high, but the height increases towards the middle of the base to 50 cm with side slopes of 3:1 (horizontal: vertical), and a top width of 10 cm. Corresponding base widths are 70 cm and 3.10 meters, respectively.

As with design "a", the bunds must be arranged in a staggered configuration. Due to the larger dimensions of the bunds there are only 4 structures required per hectare. The distance between the tips of two adjacent structures in one row is 10 m while 30 meters are recommended between the base of the upper structure and the tips of the lower one. As already mentioned above, radii and distances between the structures can be increased or decreased according to the selected C:CA ratio. Design "b" is recommended on slopes up to 2%. For higher slopes, smaller radii are required. For example, on a slope of 4%, the radius should be reduced to 10 meters and the distance between two adjacent rows from 30 meters to 15 meters while the tips of two adjacent structures should be 5 m apart instead of 10 m. The number of structures required for one hectare would thus increase to 16 which maintains the C:CA ratio of 3:1.

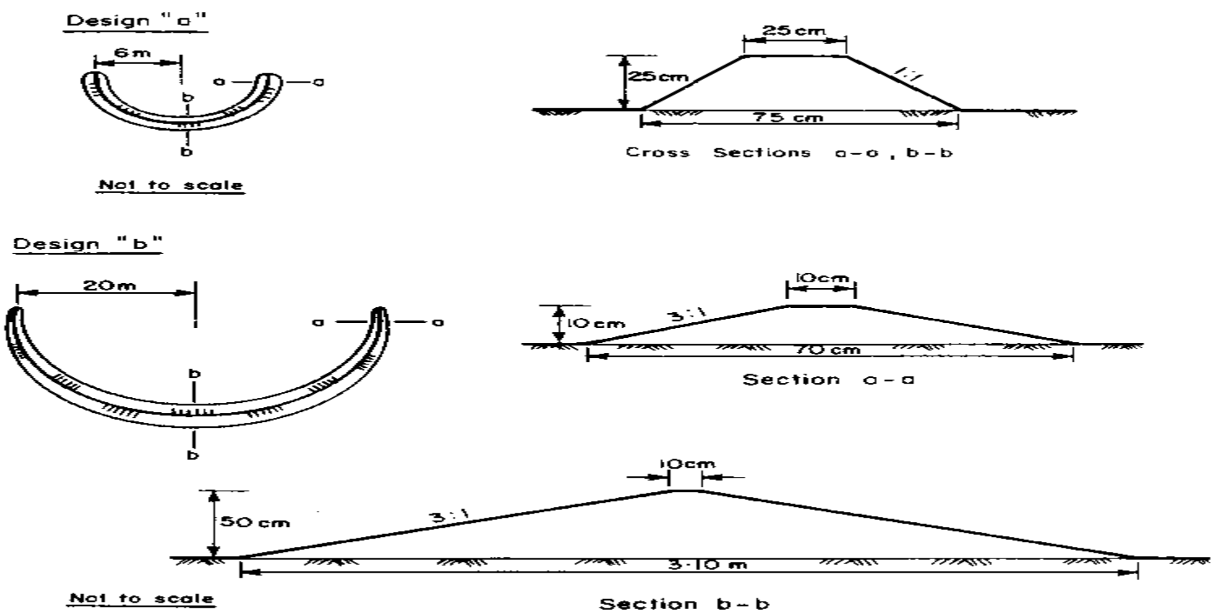


Fig. 8. Bund design of **Design "a"** and **Design "b"**

4.Contour ridges for crops

I. Overall configuration

The overall layout consists of parallel, or almost parallel, earth ridges approximately on the contour at a spacing of between one and two meters. Soil is excavated and placed down slope to form a ridge, and the excavated furrow above the ridge collects runoff from the catchment strip between ridges. Small earth ties in the furrow are provided every few meters to ensure an even storage of runoff. A diversion ditch may be necessary to protect the system against runoff from outside.

II. Catchment: cultivated area ratio

The cultivated area is not easy to define. It is a common practice to assume a 50 cm strip with the furrow at its centre. Crops are planted within this zone, and use the runoff concentrated in the furrow. Thus for a typical distance of 1.5 m between ridges, the C:CA ratio is 2:1; that is a catchment strip of one meter and a cultivated strip of half a meter. A distance of 2 meters between ridges would give a 3:1 ratio. The C: CA ratio can be adjusted by increasing or decreasing the distance between the ridges.

In practice a spacing of 1.5 - 2.0 meters between ridges (C: CA ratios of 2:1 and 3:1 respectively) is generally recommended for annual crops in semi-arid areas.

III.Ridge design

Ridges need only be as high as necessary to prevent overtopping by runoff. As the runoff is harvested only from a small strip between the ridges, a height of 15 -20 cm is sufficient. If bunds are spaced at more than 2 meters, the ridge height must be increased.

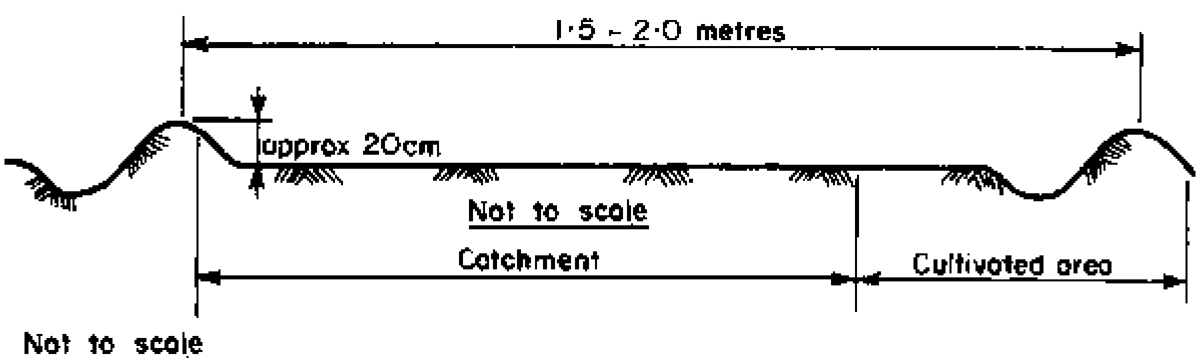


Figure 9. Contour ridge dimensions

Self-Check – 7	**Written test**

Name…………………………………………… ID………………………… Date……

Directions: Answer all the questions listed below. Examples may be necessary to aid some explanations/answers.

Test I: Short Answer Questions

1. Write the difference between the two specific designs of semicircular bund(10pts)

   ____

   ____

2. Discuss the design criteria and specification of negarims micro catchment(10pts).

   ____

   ____

***Note:* Satisfactory rating - 10 points** **Unsatisfactory - below 10 points**

You can ask you teacher for the copy of the correct answers.

Answer Sheet

Score = ___________

Rating: ____________

Name: _________________________ Date: _______________

Information Sheet 8- Constructing designed structures

8.1. Constructing designed structures

According to their design and specification the lay out and construction of the different types of typical micro catchment water harvesting structures such as ,Negarim Micro catchments (for trees),, Contour Bunds (for trees), Contour Ridges (for crops), Semi-Circular Bunds (for range and fodder) .

1. **Negarims micro-catchment**

i. **Layout and construction**

The first step is to find a contour line using a line level or other equipment's. The first line at the top of the block is marked, if the topography is very uneven, separate small block of micro catchment should be considered. By means of tape measure the tips of the bund are now marked along the straight contour. The first line should be open ended. The distance between a-b depends on the selected catchment size, the formula to find the distance a-b is, ab2=ac2+bc2 for 25 meter selected catchment, length of the catchment will be 5mx5m micro catchment, is held at one tip(a) and the second string of the same length at other tip(b) they will exactly meet at apex (c). the apex is now marked with a peg and the catchment sides (a-c) and (b-c) marked on the ground alongside the string with a hoe. This procedure will be repeated until bund alignment in the first row has been determined. The next row of micro catchments is staked out. The apex of the bunds of the upper row will be the tip for for the second row and the corresponding apex will be found according the first step. Repeat the procedure for the third row.

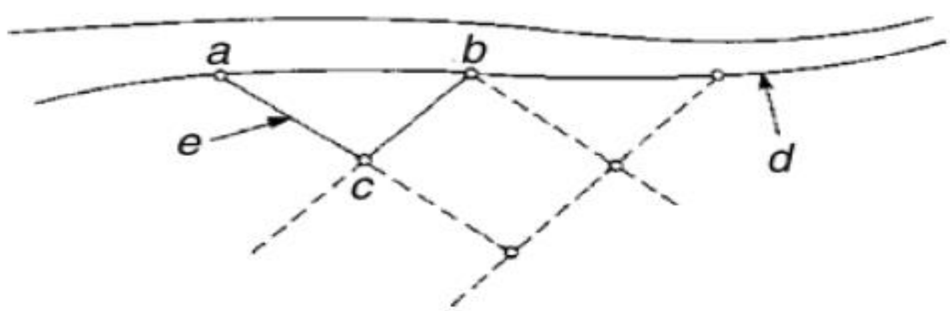


Fig.10 layout of negarims

ii. **Quantities of Earthworks**

Quantities per unit include only the infiltration pit and two sides of the catchments, while the other two bunds are included in the micro catchments above. When a diversion ditch is required additional earthworks of 62.5 m^3 per 100 m length of ditch will be needed.

(1)	(2)	(3)	(4)	(5)	(6) [
Size Unit Micro catchments (m^2)	Size Infiltration Pit (m)	Ground Slopes Suitable for 25 cm Bund	Volume Earthwork Per Unit**	No. Units Per ha	Earthworks m^3/ha
Sides (x) Area	Sides,(y) Depth	Height*	(m^2)		
3 m x 3 m = 9 m^2	1.4 x 1.4 x 0.4	up to 5%	0.75	1110	835
4 m x 4 m = 16 m^2	1.6 x 1.6 x 0.4	up to 4%	1.00	625	625
5 m x 5 m = 25 m^2	1.8 x 1.8 x 0.4	up to 3%	1.25	400	500
6 m x 6 m = 36 m^2	1.9 x 1.9 x 0.4	up to 3%	1.50	275	415
8 m x 8 m = 64 m^2	2.2 x 2.2 x 0.4	up to 2%	2.00	155	310
10 m x 10 m = 100 m^2	2.5 x 2.5 x 0.4	up to 1%	2.50	100	250
12 m x 12 m = 144 m^2	2.8 x 2.8 x 0.4	up to 1%	3.25	70	230
15 m x 15 m = 225 m^2	3.0 x 3.0 x 0.4	up to 1%	3.50	45	160

Table 2. Quantities of Earthworks for Negarim Micro catchments

* These ground slopes allow construction of a bund of 25 cm height throughout its length. Above these gradients the bund should be constructed relatively higher at the bottom (below the pit) and lower upslope. Table 2 gives the height of the bund below the pit for given micro catchments sizes.

** Calculation of earthworks per unit includes only two of the sides around the catchments: the other two sides are included in the micro catchments above. Does not include earthworks required for diversion ditch (which is 62.5 m^3 for each 100 meter length).

ii. Maintenance

Maintenance will be required for repair of damages to bunds, which may occur if storms are heavy soon after construction when the bunds are not yet fully consolidated. The site should be inspected after each significant rainfall as breakages can have a great effect if left unrepaired.

Figure:11- Negarim Micro Catchment.

2. contour bund micro-catchment

I. Layout and construction

Contour lines are marked every 40 to 50 m on the slope . The contour lines are smoothed to a gentle curve. The ridges are staked out using pegs or a hoe at the selected spacing. The ridges are made by excavating the soil on both sides of the ridge, but with the emphasis on the higher side of the ridge. Compaction of the bunds is recommended, this is done by foot or with a barrel filled with sand. An infiltration pit is dug in the furrow above the bund. The cross-ties are constructed perpendicular to the ridges, using the excavated material from the planting pit. The cross-ties are also compacted like the ridges. The distance between the cross-tie and the planting pit is at least 30 cm. The seedling will be planted in this space. A cut-off drain (diversion ditch) is constructed above the block of contour ridges if there is a risk of damage being caused by runoff from outside the system.

Size Unit Microcatchment			Volume Earthworks per Unit	No. Units per ha	Earthworks m^3/ha
Bund spacing	Tie spacing	Area (m^2)	(m^3)		
5m	2m	10	0.5	1000	500
5m	5m	25	0.9	400	360
5m	10m	50	1.5	200	300
10m	2.5m	25	0.6	400	240
10m	5m	50	0.9	200	180

Table 3. quantities of earth work

II. Maintenance

As with Negarim micro catchments, maintenance will in most cases be limited to repair of damage to bunds early in the first season. It is essential that any breaches -which are unlikely unless the scheme crosses existing rills - are repaired immediately and the repaired section compacted. Damage is frequently caused if animals invade the plots. Grass should be allowed to develop on the bunds, thus assisting consolidation with their roots.

3. semi-circular bund micro-catchment

I. Layout and construction

Start by marking out the contour lines on which the tips of the bunds will be located. The distance between the contour lines marked out depends on the size of the structures to be made. Because the structures are free standing, the contour lines need not to be smoothed. Measure the distance between the tips of one structure on the highest contour line. Measure and mark out the distance from one tip to the next structure (on the same contour line), and again the distance between the tips of one structure. Mark out the tips of all the structures on the first contour line in this way. The tips on the second contour line are marked out following the same procedure, but in such a way that the centre point of the structure lies between the tips of two neighboring structures on the first contour line. In this way a staggered layout is obtained. Mark out the position of the bund of each structure using a string. The string has a length equal to the radius of the structure. Mark out the centre point (the point in the middle of the tips of one structure, on the contour line). Then, holding one end of the string at this point, mark out a half circle from one tip to the other, using the other end. Dig out earth to build the bund from inside the enclosed area. Begin with a small trench, followed by even excavation from the whole enclosed area in order to ensure even distribution of the collected runoff water. It is important that the bunds are constructed in layers of 10-15 cm, compacting each before the next layer is placed on top of it. For the larger structures (radius greater than 6 m) the tips of the bunds made with stones as protection against erosion. Grass planted on the bunds increases the stability.

II. Quantities of earthworks

It should be noted that where a diversion ditch is required (Design "a" only), 62.5 m3 for each 100 meters of length has to be added to the figures in column 6.

Land slope	Radius (m)	Length of bund (m)	Impounded area per bund (m^2)	Earthworks per bund (m^3)	Bunds per ha	Earthworks per ha (m^3)
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
Design "a" up to 1.0%	6	19	57	2.4	73	175
Design "b" up to 2.0%	20	63	630	26.4	4	105
4.0%	10	31	160	13.2	16	210

Table 4. Quantities Of Earthworks For Semi-Circular Bunds.

III. Design variations

Semi-circular bunds can be constructed in a variety of sizes, with a range of both radii and bund dimensions. Small radii are common when semi-circular bunds are used for tree growing and production of crops. A recommended radius for these smaller structures is 2 to 3 meters, with bunds of about 25 cm in height.

IV. Maintenance

The critical period is during the first rainstorms after construction. Any breakages must be repaired immediately. If the damage is widespread, a diversion ditch must be dug above the whole system, if this is not already in place. If erosion occurs at the tips of the bunds, the tips can be protected with stones. The structures have to be dug out again after five years. Deposited silt and earth have to be regularly removed from around trees. The catchment area should be kept clear of vegetation.

.

Semi-circular Bunds

Fig. 12 semi-circular bund

4. contour ridges micro-catchment

I. Layout and construction

The overall layout consists of parallel, earth ridges approximately on the contour at a spacing of between one and two meters. Contour key lines should be staked out every 10 or 15 meters. The alignment for the ridges is then marked in between the key lines according to selected spacing. On uneven trains the contour may come closer together at one point or widen at other points. Soil is excavated and placed down slope to form a ridge and the excavated furrow above the ridge collects runoff from the catchment strip between ridges. Small earth ties in the furrow are provided every few meters to ensure uneven storage of runoff. The ties are 15-20cm high and 50- 70cm long. Ridges need only be as high as necessary to prevent over topping by runoff. For slopes up to 5% as runoff is harvested only from a small strip between the ridges, a height of15-20cm is sufficient. If slope is exceeding 5% and if bunds are spaced at more than two meters the ridge height must be increased. On flat slopes up to 5% ridge can be made by “Sefidigir” by ploughing and deepening furrow twice. This kind of techniques have been practiced at Kobo north wollo and it gives a good result in conserving sufficient moisture and provide a yield difference than before for teff crop. A diversion ditch may be necessary above the block of contour ridge to protect the system against runoff from outside.

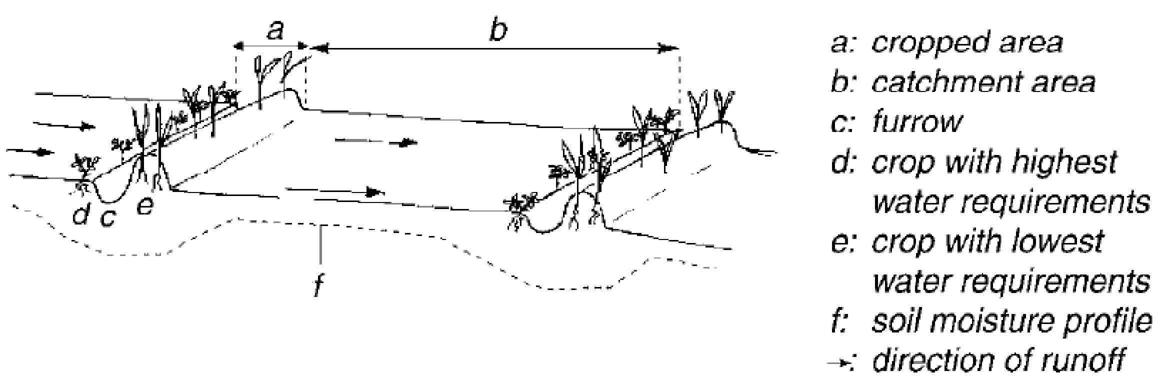


Fig 13. contour ridges micro-catchment

II. Quantities Of Earthwork For Contour Ridges

Ridge spacing	Ridge & Tie height	Earthworks per ha
(m)	(cm)	(m^3)
1.5	15	270
1.5	20	480
2.0	20	360

Table 5. Quantities Of Earthwork For Contour Ridges

III. Maintenance

If contour ridges are correctly laid out and built, it is unlikely that there will be any overtopping and breaching. Nevertheless if breaches do occur, the ridges or ties must be repaired immediately. The uncultivated catchment area between the ridges should be kept free of vegetation to ensure that the optimum amount of runoff flows into the furrows.

Self-Check – 8	**Written test**

Name…………………………………………… ID………………………… Date…….

Directions: Answer all the questions listed below. Examples may be necessary to aid some explanations/answers.

Test I: Short Answer Questions

1. Discuss shortly how to construct Negarims micro catchment?.(10pts)

____

____

____

____

2. Write the procedures we used to construct semi circular micro catchment.(10 pts)

____

____

____

____

3. Write the difference between contour bund micro catchment and contour ridge micro catchment.(10pts)

____

____

Note: **Satisfactory rating - 15points & above** **Unsatisfactory - below 15 points**

You can ask you teacher for the copy of the correct answers.

Answer Sheet

Score = ___________

Rating: ____________

Name: _________________________ Date: _______________

Operation Sheet 1- Constructing Negarim micro-catchment

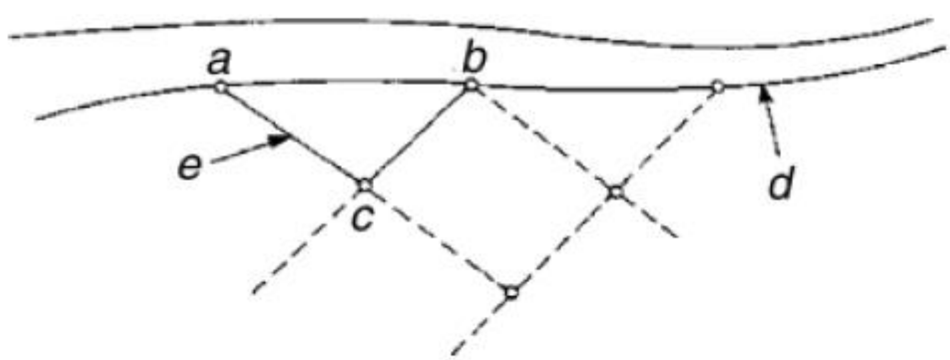
Objective:- To develop design and construction skills of micro catchment structure

Tools and Equipment required

- Line level/A-frame, String, Ranging pole, Clinometers, pegs, rope, measuring tape, Digging instruments.

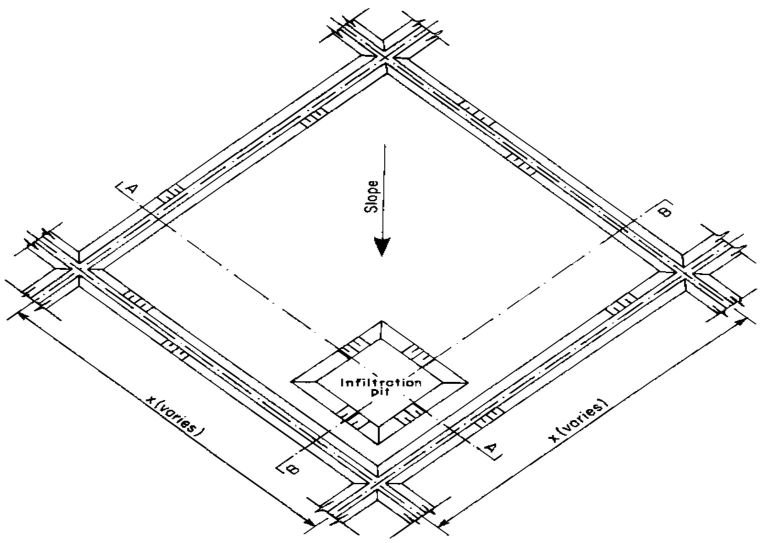
Procedures;

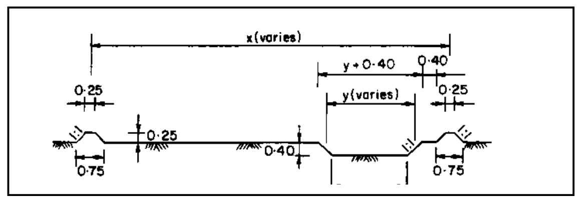
1. Select and wear your personal protective equipment
2. Select and collect the require tools and equipment
3. Identifying the site
4. stake out contour line
5. mark the tips of the bunds along the "straightened contour"
6. A piece of string as long as the side length of the catchment is held at one tip (a) and a second string of the same length at the other tip (b). They will exactly meet at the apex (c).



7. The apex is now marked with a peg and the catchment sides (a-c) and (b-c) marked on the ground alongside the strings with a hoe.
8. This procedure will be repeated until all bund alignments in the first row have been determined.
9. The next row of micro catchments can now be staked out. The apexes of the bunds of the upper row will be the tips for the second row and the corresponding apex will be found according to no. 6.
10. When the second row of micro catchments has been marked, repeat the same procedure for the third row, etc.
11. The final result will be a block of diamond-shaped micro catchments, with a first row which is open at the upslope end.
12. The size of the infiltration pit is staked out and the pit is excavated.

13. Before constructing the bunds, the area within the micro catchments should be cleared of all vegetation
14. The excavated material from the pit is used to form the bund.
15. The bunds should be compacted during construction





Front view **Cross-sectional view**

Operation Sheet 2- Constructing of Contour bund micro-catchment

- **Objective:-** To develop design and construction skills of micro catchment structure

- **Tools and Equipment required**

Line level/A-frame, String, Ranging pole, measuring tape, digging instruments, pegs, Rope.

- **Procedures;**

1. Select and wear your personal protective equipment
2. Select and collect the required tools and equipment
3. Identifying the site
4. Stake out the contour line by means of a simple surveying instrument,
5. Mark the alignment of each bund on the ground before construction(under "bund design" the bunds should be set at a spacing of 10 m for slopes up to 0.5% and 5 m for steeper slopes.).
6. The catchment size required for each seedling determines the spacing between cross-ties.
7. Built a lateral bund of 25 - 30 cm height at each side of the block prevent loss of runoff out of the system
8. Dug an infiltration pit of 80 cm x 80 cm and 40 cm deep is in the furrow above the bund.

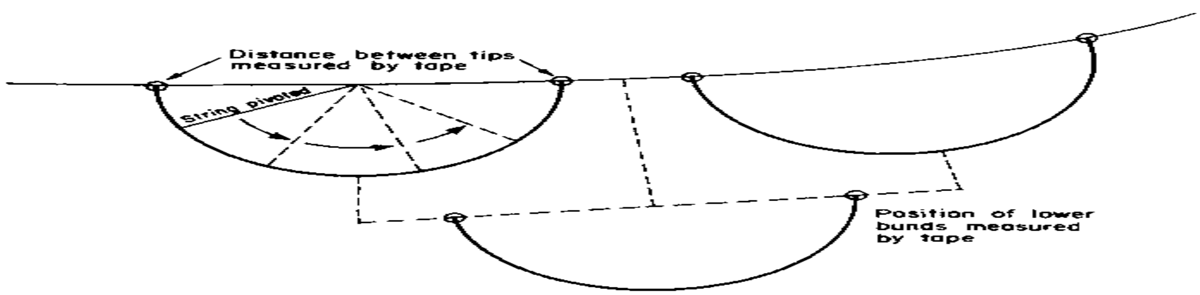
Operation Sheet 3- Constructing of Semi-circular bunds micro-catchment

- **Objective:-** To develop design and construction skills of Semi-circular bunds micro catchment structure
- **Tools and Equipment required**

- Line level/A-frame, String, Ranging pole, measuring tape, Digging instruments, pegs, Rope.

➢ **Procedures;**

1. Select and wear your personal protective equipment
2. Select and collect the require tools and equipment
3. Identifying the site
4. stake out the contour line
5. Mark the tip of the semicircular bund on the contour
6. Mark the center point between the tips of each semicircular un
7. Fix a string as long as the selected radius at the center point by a means of pegs
8. Hold the string tight at the other end and define the alignment of the semi-circle by swinging the end of the string from one end to the other.
9. Mark the alignment by pegs
10. construct bund with excavation of small trench inside



Semicircular bund lay out

Operation Sheet 4- Constructing of Contour ridge micro-catchment

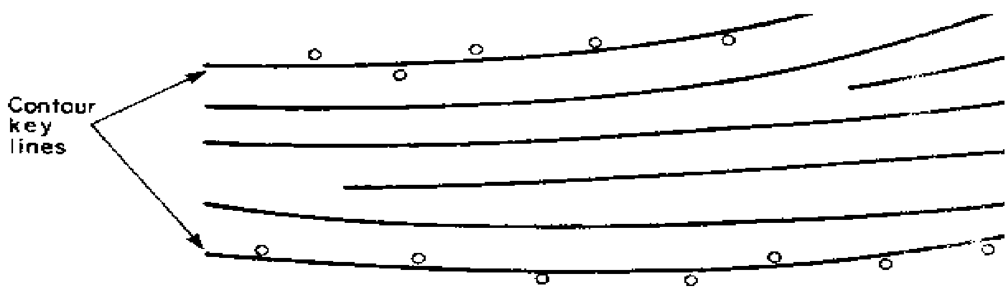
➢ **Objective:-** To develop design and construction skills of Contour ridge micro catchment structure

➢ **Tools and Equipment required**

- Line level/A-frame, String, Ranging pole, measuring tape, Digging instruments, pegs, Rope.

➢ **Procedures;**

1. Select and wear your personal protective equipment
2. Select and collect the require tools and equipment
3. Identifying the site
4. staked out Contour key lines every 10 or 15 meters
5. mark the alignment for the ridges between the key lines according to selected spacing.
6. Excavate the furrows parallel to the marked alignments and use placed the excavated soil down slope to form a ridge.
7. built small cross-ties are at intervals of about 5 metres which divides each furrow into a number of segments.(the ties are 15-20 cm high and 50 - 75 cm long).



LAP TEST	**Performance Test**

Name……………………………….   ID……………………………..

Date……………………………………

Time started: ________________________ Time finished: ________________

Instructions: Given necessary templates, tools and materials you are required to perform the following tasks within **10** hour. The project is expected from each student to do it.

You are required to perform any of the following:

Task-1 Design, layout and construction of Negarim micro catchments,

Task-2 Design, layout and construction of Contour bund for trees,

Task-3 Design, layout and construction of Semi-circular bunds

Task-4 Design, layout and construction of Contour ridges for crops

LG #68	**LO #2- Design and construct macro-catchments techniques**

Instruction sheet
This learning guide is developed to provide you the necessary information regarding the following content coverage and topics:

- Identifying Different macro catchments types
- Crop type and crop water requirement
- Designing identified macro catchments
- Selecting Materials, tools and equipment
- Constructing designed structures
- Harvesting and supplying water

This guide will also assist you to attain the learning outcomes stated in the cover page. Specifically, upon completion of this learning guide, **you will be able to**:

- Identify Different macro catchments types
- Understand how to select Crop type and estimate crop water requirement
- Undertake Designing the identified macro catchments
- Select Materials, tools and equipment
- Conduct constructing the designed structures
- Carryout harvesting and supplying water

Learning Instructions:

1. Read the specific objectives of this Learning Guide.
2. Follow the instructions described below.
3. Read the information written in the "Information Sheets". Try to understand what are being discussed. Ask your trainer for assistance if you have hard time understanding them.
4. Accomplish the "Self-checks" which are placed following all information sheets.
5. Ask from your trainer the key to correction (key answers) or you can request your trainer to correct your work. (You are to get the key answer only after you finished answering the Self-checks).
6. If you earned a satisfactory evaluation proceed to "Operation sheets
7. Perform "the Learning activity performance test" which is placed following "Operation sheets" ,
8. If your performance is satisfactory proceed to the next learning guide,
9. If your performance is unsatisfactory, see your trainer for further instructions or go back to "Operation sheets".

Information Sheet 1- Identifying Different macro-catchments types

1.1. Identifying Different macro-catchments types

Macro-catchment and floodwater-harvesting systems are characterized by having runoff water collected from a relatively large catchment. Often the catchment is a natural rangeland, the steppe, or a mountainous area. Catchments for these systems are mostly located outside farm boundaries, where individual farmers have little or no control over them.

1.1.1 Trapezoidal bunds macro-catchments water harvesting structures

Background

Trapezoidal bunds are used to enclose larger areas (up to 1ha) and to impound larger quantities of runoff which is harvested from an external or “long slope” catchment. The name is derived from the layout of the structure which has the form of a trapezoid a base bund connected to two side bunds or wing walls. Crops are plants within the enclosed area of over flow discharges around the tips of the wing wall.

Technical details

I. Suitability

Trapezoidal bunds can be used for growing crops, trees and grasses. Their most common application is for crop production under the following site conditions.

Rain fall: -250-500mm arid to semi-arid areas

Soils: agricultural soils with good constructional properties

Slopes: - from 0.25%-1.5%, but most suitable below 0.5%.

Topography: -area within bunds should be even

ii. <u>Limitations</u>

This technique is limited to low ground slopes. Construction of trapezoidal bunds on slopes steeper than 1.5% is technically feasible, but involves prohibitively large quantities of earthwork.

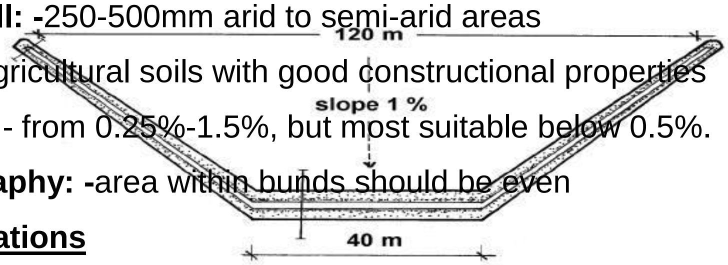


Figure 14. Trapezoidal bunds: field layout for 1% ground slope

1.1.2. Contour stone bunds

Background

Contour stone bunds are used to slow down and filter runoff, thereby increasing infiltration and capturing sediment. The water and sediment harvested lead directly to improved crop performance. This technique is well suited to small scale application on farmer's fields and, given an adequate supply of stones, can be implemented quickly and cheaply.

Improved construction and alignment along the contour makes the technique considerably more effective. The great advantage of systems based on stone is that there is no need for spillways, where potentially damaging flows are concentrated. The filtering effect of the semi-permeable barrier along its full length gives a better spread of runoff than earth bunds are able to do. Furthermore, stone bunds require much less maintenance

Stone bunds follow the contour, or the approximate contour, across fields or grazing land. The spacing between bunds ranges normally between 15 and 30 meter depending largely on the amount of stone and labor availability.

Technical details

i. Suitability

Contour Stone bunds for crop production can be used under the following conditions:

Rainfall: 200 mm - 750 mm; from arid to semi-arid areas.

Soils: agricultural soils.

Slopes: preferably below 2%.

Topography: need not be completely even.

Stone availability: must be good local supply of stone.

Self-Check – 1	**Written test**

Name…………………………………………… ID………………………… Date…….

Directions: Answer all the questions listed below. Examples may be necessary to aid some explanations/answers.

Test I: Short Answer Questions

1. What does the external/rain water harvesting structure mean? Explain it. (10 pts)

   ____

   ____

2. List and explain the main types of macro-catchment rain water harvesting structures? (10pts)

   ____

   ____

***Note:* Satisfactory rating - 10 points** **Unsatisfactory - below 10points**

You can ask you teacher for the copy of the correct answers.

Answer Sheet

Score = ___________

Rating: ____________

Name: ___________________________ Date: ________________

Information Sheet 2- Crop type and crop water requirement

2.1. Crop type and crop water requirement

The growth and yield of any vegetation is related to the amount of water it transpires. When the crop is disease free, and enough water is available to fully meet the transpiration demand, the crop can grow and yield at its full potential. The rate of growth and yield is lowered by reduction of water available for transpiration and when this amount becomes too small, the plant wilts and dies.

2.1.1. Crop water requirements

Crop water requirements are the amount of water that a certain crop needs in a full growing season. For the design of water harvesting systems, it is necessary to assess the water requirement of the crop intended to be grown.

Factors influencing crop water requirements

I. Influence of crop type on crop water needs

The influence of the crop type on the crop water need is important in two ways Each type of crop has its own water requirements. For example a fully developed maize crop will need more water per day than a fully developed crop of onions . Within one crop type however, there can be a considerable variation in water requirements. The crop water requirements consist of transpiration and evaporation usually referred to as evapotranspiration. The crop water requirements are influenced by the climate in which the crop is grown. For example a certain maize variety grown in a cool and cloudy climate will need less water per day than the same maize variety grown in a hot and sunny climate.

Table 6: Water requirements, growing period and sensitivity to drought of some crops

Crop	Total growing period (days)	Crop water requirement (mm/growing period)	Sensitivity to drought
Bean	95 110	300- 500	medium -high
Maize	125 180	500 - 800	Medium- high
Melon	120 160	4 00- 600	medium -high
Millet	105 140	450- 650	low
Onion	150 210	350- 550	medium -high
Rice (paddy)	90 150	450 - 700	high
Sorghum	120 130	450- 650	low
Sunflower	125 - 130	600 - 1000	low - medium

The length of the total growing season of each crop is different and hence the total water requirements for the growing season depends on the crop type. For example, while the daily water need of melons may be less than the daily water need of beans, the seasonal water need of melons will be higher than that of beans because the duration of the total growing season of melons is much longer. The above Table gives an indication of the total growing season for some crops. In general the growing season of a crop is longer when the climate is cool.

II. Influence of climate

A certain crop grown in a sunny and hot climate needs more water per day than the same crop grown in a cloudy and cooler climate. There are, however, apart from sunshine and temperature, other climatic factors which influence the crop water need. These factors are humidity and wind speed. When it is dry, the crop water needs are higher than when it is humid. In windy climates, the crops will use more water than in calm climates.

The highest crop water needs are thus found in areas which are hot, dry, windy and sunny. The lowest values are found when it is cool, humid and cloudy with little or no wind.

Climatic factor	Crop water need	
	High	Low
Sunshine	sunny (no clouds)	cloudy (no sun)
Temperature	hot	cool
Humidity	low (dry)	high (humid)
Wind speed	windy	little wind

Table 7 - effect of major climatic factors on crop water needs

Calculation of crop water requirements

The calculation of crop water requirements by means of the two methods described in this section is relatively simple. The basic formula for the calculation reads as follows:

ETcrop = kc x Eto

where:

ETcrop = the water requirement of a given crop in mm per unit of time e.g. mm/day, mm/month or mm/season.

kc = the "crop factor"

ETo = the "reference crop evapotranspiration" in mm per unit of time e.g. mm/day, mm/month or mm/season.

ii. <u>ETo - reference crop evapotranspiration</u>

The reference crop evapotranspiration ETo (sometimes called potential evapotranspiration, PET) is defined as the rate of evapotranspiration from a large area covered by green grass which grows actively, completely shades the ground and which is not short of water. The rate of water which evapotranspirates depends on the climate. The highest value of ETo is found in areas which are hot, dry, windy and sunny whereas the lowest values are observed in areas where it is cool, humid and cloudy with little or no wind.In many cases it will be possible to obtain estimates of ETo for the area of concern (or an area nearby with similar climatic conditions) from the Meteorological Service. However, where this is not possible, the values for ETo have to be calculated. Two easy methods will be explained below:

a. Pan evaporation method

With this method, ETo can be obtained by using evaporation rates which are directly measured with an evaporation pan. This is a shallow pan, containing water which is exposed to the evaporative influence of the climate. The standard pan is the Class A Pan, It has a diameter of 1.21 m, a depth of 25 cm and is placed 15 cm above the ground.

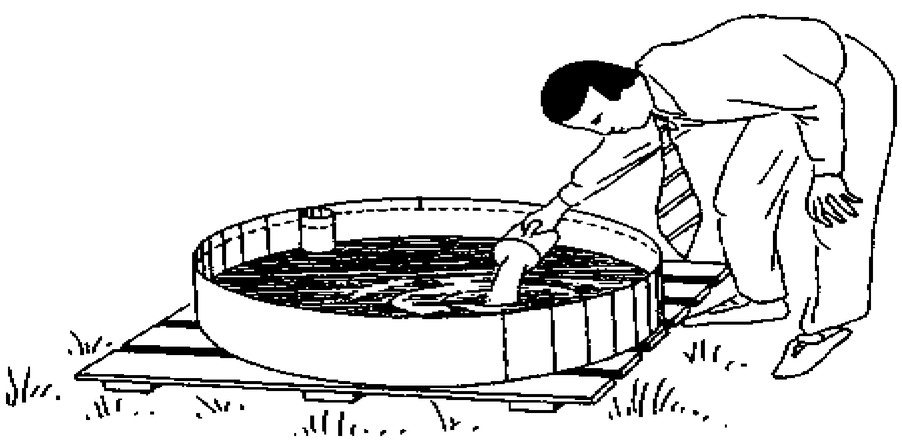


Figure 14. Class A evaporation pan

An evaporation pan is easy to construct and in most situations the material can be found locally.

The principle of obtaining evaporation rates from the pan is as follows:

- the pan is installed in the field 15 cm above the ground;
- the pan is filled with water 5 cm below the rim;
- the water is allowed to evaporate during a certain period of time (usually 24 hours). For example, each morning at 7.00 hours a measurement is taken. Rainfall, if any, is measured simultaneously;
- after 24 hours, the water depth is measured again;

- the amount of water which has evaporated in a given time unit is equal to the difference between the two measured water depths. This is the pan evaporation rate: Epan (mm/24 hours).

The readings taken from the pan (Epan) however do not give ETo directly, but have to be multiplied by a "Pan Coefficient" (Kpan).

thus: ETo = Epan x Kpan

For the Class A evaporation pan, Kpan varies between 0.35 and 0.85, with an average of 0.70. If the precise pan factor is not known, the average value (0.70) can be used as an approximation.

b. The Blaney-Criddle Method

If no measured data on pan evaporation are available, the Blaney-Criddle method can be used to calculate ETo. This method is straightforward and requires only data on mean daily temperatures. However, with this method, only approximations of ETo are obtained which can be inaccurate in extreme conditions.

The Blaney-Criddle formula is: ETo = p(0.46Tmean + 8) where:

ETo = reference crop evapotranspiration (mm/day)

T mean = mean daily temperature (° C)

p = mean daily percentage of annual daytime hours.

The Blaney-Criddle Method always refers to mean monthly values, both for the temperature and the ETo. If in a local meteorological station the daily minimum and maximum temperatures are measured, the mean daily temperature is calculated as follows:

$$Tmax = \frac{\text{sum of all T max values during the month}}{\text{number of days of the month}}$$

$$Tmin = \frac{\text{sum of all T min values during the month}}{\text{number of days of the month}}$$

$$Tmean = \frac{Tmax + Tmin}{2}$$

To determine the value of p. To be able to obtain the p value, it is essential to know the approximate latitude of the area: the number of degrees north or south of the Equator.

Table 8 - mean daily percentage (p) of annual daytime hours for different latitudes

Latitude:												
North	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sept	Oct	Nov	Dec
South	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June
60°	.15	.20	.26	.32	.38	.41	.40	.34	.28	.22	.17	.13
55	.17	.21	.26	.32	.36	.39	.38	.33	.28	.23	.18	.16
50	.19	.23	.27	.31	.34	.36	.35	.32	.28	.24	.20	.18
45	.20	.23	.27	.30	.34	.35	.34	.32	.28	.24	.21	.20
40	.22	.24	.27	.30	.32	.34	.33	.31	.28	.25	.22	.21
35	.23	.25	.27	.29	.31	.32	.32	.30	.28	.25	.23	.22
30	.24	.25	.27	.29	.31	.32	.31	.30	.28	.26	.24	.23
25	.24	.26	.27	.29	.30	.31	.31	.29	.28	.26	.25	.24
20	.25	.26	.27	.28	.29	.30	.30	.29	.28	.26	.25	.25
15	.26	.26	.27	.28	.29	.29	.29	.28	.28	.27	.26	.25
10	.26	.27	.27	.28	.28	.29	.29	.28	.28	.27	.26	.26
5	.27	.27	.27	.28	.28	.28	.28	.28	.28	.27	.27	.27
0	.27	.27	.27	.27	.27	.27	.27	.27	.27	.27	.27	.27

For example, when p = 0.29 and T mean = 21.5 °C**,** the ETo is calculated as follows:

ETo = 0.29 (0.46 x 21.5 + 8) = 0.29 (9.89 + 8) = 0.29 x 17.89 = 5.2 mm/day.

Table9 - Indicative Values Of Eto (mm/day)

Climatic zone	Mean daily temperature		
	15°	15-25°C	25°
Desert/arid	4-6	7-8	9-10
Semi-arid	4-5	6-7	8-9
Sub-humid	3-4	5-6	7-8
Humid	1-2	3-4	5-6

c. <u>Indicative values of ETo</u>

The above table contains approximate values fur ETo which may be used in the absence of measured or calculated figures.

iii. Crop Factor - Kc

In order to obtain the crop water requirement ETcrop the reference crop evapotranspiration, ETo, must be multiplied by the crop factor, Kc. The crop factor (or "crop coefficient") varies according to the growth stage of the crop. There are four growth stages to distinguish:

- the initial stage: when the crop uses little water;
- the crop development stage, when the water consumption increases;
- the mid-season stage, when water consumption reaches a peak;
- the late-season stage, when the maturing crop once again requires less water.

Table 10 contains crop factors for the most commonly crops grown under water harvesting.

Table 10 - CROP FACTORS (Kc)

Crop	Initial stage	(days)	Crop dev. stage	(days)	Mid-season stage	(days)	Late season	(days)	Season average.
Cotton	0.45	(30)	0.75	(50)	1.15	(55)	0.75	(45)	0.82
Maize	0.40	(20)	0.80	(35)	1.15	(40)	0.70	(30)	0.82
Millet	0.35	(15)	0.70	(25)	1.10	(40)	0.65	(25)	0.79
Sorghum	0.35	(20)	0.75	(30)	1.10	(40)	0.65	(30)	0.78
Grain/small	0.35	(20)	0.75	(30)	1.10	(60)	0.65	(40)	0.78
Legumes	0.45	(15)	0.75	(25)	1.10	(35)	0.50	(15)	0.79
Groundnuts	0.45	(25)	0.75	(35)	1.05	(45)	0.70	(25)	0,79

Table 10 also contains the number of days which each crop takes over a given growth stage. However, the length of the different crop stages will vary according to the variety and the climatic conditions where the crop is grown. In the semi-arid/arid areas where WH is practiced crops will often mature faster than the figures quoted in Table..

iv. Calculation of ETcrop

While conventional irrigation strives to maximize the crop yields by applying the optimal amount of water required by the crops at well determined intervals, this is not possible with water harvesting techniques. As already discussed, the farmer or agro pastoralist has no influence on the occurrence of the rains neither in time nor in the amount of rainfall. The crop water requirement for a given crop is calculated according to the formula:

ETcrop = Kc x ETo

Since the values for ETo are normally measured or calculated on a daily basis (mm/day), an average value for the total growing season has to be determined and then multiplied with the average seasonal crop factor Kc as given in the last column of Table.

Example:

Crop to be grown: Sorghum

- length of total growing season: 120 days (sum of all 4 crop stages according to Table)

- ETo: average of 6.0 mm/day over the total growing season (from measurement, calculation or Table 9)

Crop water Requirement:

ET crop = kc x Eto

ET crop = 0.78 x 6 = 4.68 mm per day

ET crop = 4.68 x 120 days = approx. 560 mm per total growing season

2.1.2. Select crop type for water harvesting

Choices of Crops for WHT

Water harvesting helps crops by providing extra moisture at different stages of growth although timing cannot be controlled. Periods when the extra moisture can make a significant difference are: Around sowing time when germination and establishment can be improved; During a mid-season dry spell when a crop can be supported until the next rains; While the crop is at the vital stages of flowering and grain fill.

Crop choice

The most common cereal crops grown under water harvesting are:

Sorghum (Sorghum bicolor) is the most common grain crop under water harvesting systems. It is a crop of the dry areas, and in addition to its drought adaptation, it also tolerates temporary water logging - which is a common occurrence in some water harvesting systems.

Pearl Millet (Pennisetum typhoides) is grown in the drier areas of West Africa and India, and apart from being drought tolerant, it matures rapidly.

Maize (Zea mays) is occasionally grown under water harvesting but is neither drought adapted nor water logging tolerant

Legumes are less frequently grown under water harvesting but should be encouraged because of their ability to fix nitrogen and improve the performance of other crops. Suitable legumes are cowpeas (Vigna unguiculata), green grams (Vigna radiana), lablab (Lablab purpureus), and groundnut (Arachis hypogea). All are relatively tolerant of drought and are fast maturing.

Perennial trees must with stand long periods of drought such as carob.

Self-Check – 2	**Written test**

Name…………………………………………… ID………………………… Date…….

Directions: Answer all the questions listed below. Examples may be necessary to aid some explanations/answers.

Test I: Short Answer Questions

1. Define Crop water requirements. (5 pts)

   ____

   ____

2. Discuss those factors that influence crop water requirements (10pts)

   ____

   ____

3. Discuss about soil requirement for water harvesting.(5pts)

   ____

   ____

Note: **Satisfactory rating - 10 points** **Unsatisfactory - below 10points**

You can ask you teacher for the copy of the correct answers.

Answer Sheet

Score = ___________

Rating: ____________

Name: _________________________ Date: _______________

Information Sheet 3- Designing identified macro-catchments

3.1. Designing identified macro-catchments

Macro-catchment systems are sometimes referred to as “water harvesting from long slopes” or as “harvesting from an external catchment.” Depends on required criteria different macro-catchment systems design specification discussed below.

1. Contour stone bunds

I. Overall configuration

Stone bunds follow the contour, or the approximate contour, across fields or grazing land. The spacing between bunds ranges normally between 15 and 30 meter depending largely on the amount of stone and labor availability. There is no need for diversion ditches or provision of spillways.

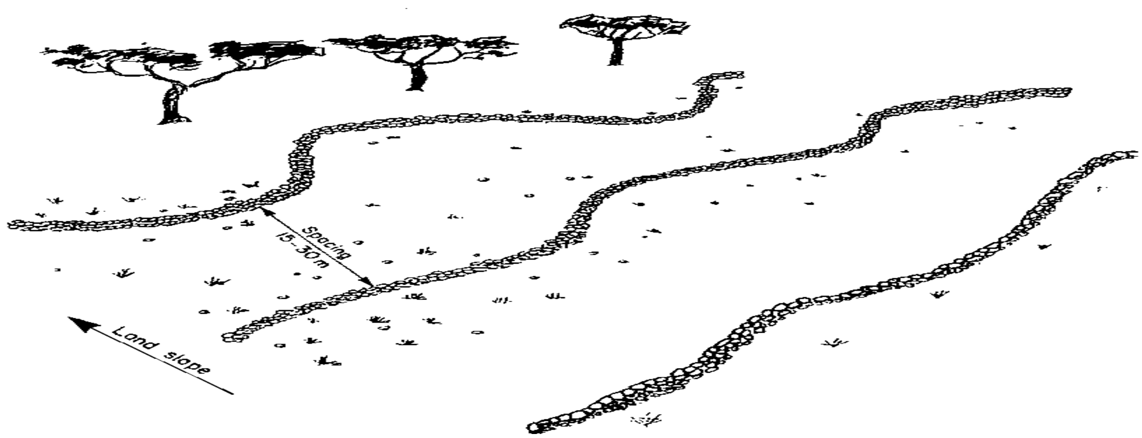


Fig.15. Field layout of contour stone bund

II. Size and layout

Contour Stone bunds follow the contour more or less. The distance between the bunds is usually 10 to 30 m, depending on the slope and the amount of stones and labor available. If the objective is to form natural terraces over the years, the stone bunds sometimes have wings at an angle of less than $45^0$to the contour line. These wings have to be at least 2 m long. They lead runoff into the catchment area and protect the bunds against gully formation by excess water.

The height difference between two stone bunds is usually 25 cm. On the basis of the slope gradient (s) and the vertical distance between two bunds (h), the spacing (d) between the bunds can be estimated

using the following formula:

*d = (h *100)/s*

d = distance between two bunds over the ground (in metres)

h = height difference between stone bunds (in metres)

s = gradient of slope (%)

In fact with this formula the horizontal distance (L) is calculated instead of d, but on very gentle slopes d is equal to L.

III. Bund design

Although simple stone lines can be partially effective, an initial minimum bund height of 25 cm is recommended, with a base width of 35 - 40 cm. The bund should be set into a shallow trench, of 5 - 10 cm depth, which helps to prevent undermining by runoff. As explained in the construction details, it is important to incorporate a mixture of large and small stones. A common error is to use only large stones, which allow runoff to flow freely through the gaps in-between. The bund should be constructed according to the "reverse filter" principle - with smaller stones placed upstream of the larger ones to facilitate rapid siltation.

Bund spacing of 20 meters for slopes of less than 1%, and 15 meters for slopes of 1-2%, are recommended.

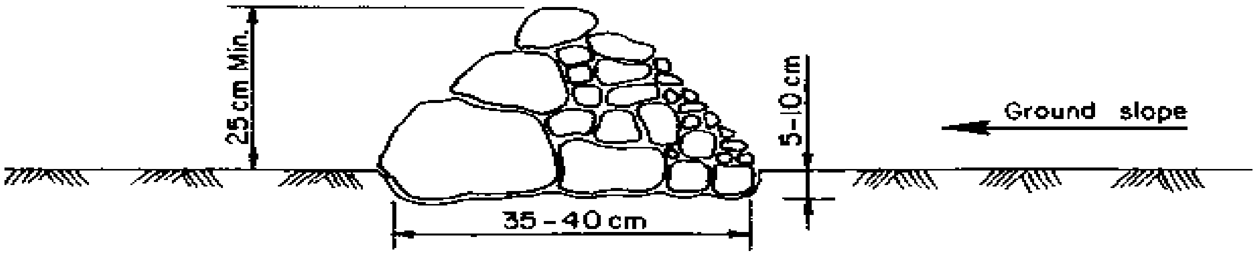


Figure 16. Contour stone bund: dimensions

IV. C:CA ratio

The cultivated area is determined in an experimental way. In the first years a small strip above the stone bunds is cultivated, and if possible, extended up the slope in the following years.

V. Ridge design

A bund height of at least 25 cm is recommended with a base width of 30 to 40 cm. Large stones are first placed in a shallow trench which helps to prevent undermining by runoff. The stones are carefully packed with the large stones on the lower side and the smaller stones on the higher side of the slope. The smaller stones on the higher side act as a filter. If only large stones are used, the runoff water is not stopped but will flow freely through the stone bund.

VI. Design variations

Where there is not enough stone readily available, stone lines can be used to form the framework of a system. Grass, or other vegetative material, is then planted immediately behind the lines and forms, over a period of time, a "living barrier" which has a similar effect to a stone bund. Alternatively, earth contour bunds can be constructed, with stone spillways set into them.

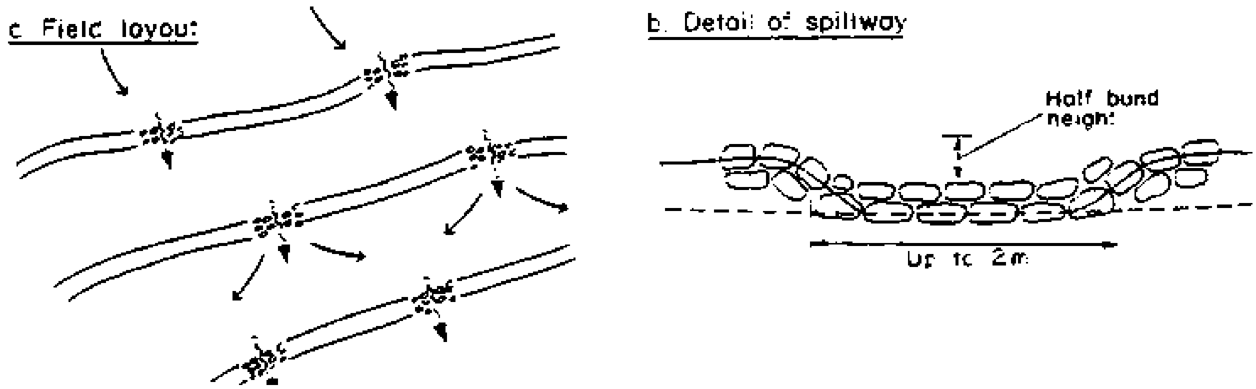


Figure 17. Design variation: contour earth bunding with stone spillway

2. Trapezoidal bunds

The general layout, consisting of a base bund connected to wing walls. The concept is similar to the semi-circular bund technique: in this case, three sides of a plot are enclosed by bunds while the fourth (upslope) side is left open to allow runoff to enter the field. The simplicity of design and construction and the minimum maintenance required are the main advantages of this technique.

I. Overall configuration

Each unit of trapezoidal bunds consists of a base bund connected to two wing walls which extend upslope at an angle of 135 degrees. The size of the enclosed area depends up on the slope and can vary from 0.1 to 1ha.they are arranged in staggered configuration when several trapezoidal bunds are constructed. A common distance between the tips of adjacent bunds within one row is 20m with 30m spacing between the tips of the lower row and the base bunds of the upper row. It is not recommended to build more than two rows because the third and the fourth rows receive significantly less runoff. The configuration of bund is dependent on land slope, and is determined by the designed maximum flooded depth of 40cm at the base bund. Consequently as the gradient becomes steeper the wing walls extended less far up slope.

Slope%	Length of base bund (m)	Length of wing wall(m)	Distance between tips (m)	Earth works per bund(m^3)	Cultivated area per bund(m^2)	Earth works per ha cultivated(m^3)
0.5	40	114	200	355	9600	370
1	40	57	120	220	3200	670
1.5	40	38	94	175	1800	970

Table.11 Trapezoidal bunds design specification

Catchment: cultivated area (C: CA) ratio

It is necessary to determine the necessary catchment size for a required cultivated area. It is sometimes more appropriate to approach the problem the other way round, and determine the area and number of bunds which can be cultivated from an existing catchment.

$$\frac{\text{(CROP WATER REQUIREMENT)} - \text{(DESIGN RAIN FALL)}}{\text{DESIGN RAIN FALL X RUNOFF COEFF X EFF FACTOR}} = \frac{\text{CATCHMENT AREA}}{\text{CULTIVATED AREA}}$$

Example:

Calculate the number of trapezoidal bunds needed to utilize the runoff from a catchment area of 20 ha under the following conditions:

Slope:	1%
Crop water requirement:	475 mm per season
Design rainfall:	250 mm per season
Runoff coefficient:	0.25
Efficiency factor:	0.50

From the formula given above: $\frac{C}{CA} = \frac{475-250}{250\times 0.5\times 0.25} = \frac{225}{31.25} = 7.2$

But C = 20 ha

Thus $CA = \frac{20}{7.2} = 2.8ha$

the area available for cultivation within one trapezoidal bund on a 1% slope is 3200 m^2 = 0.32 ha.

Therefore, number of bunds required: N = 2.8/0.32 = 8

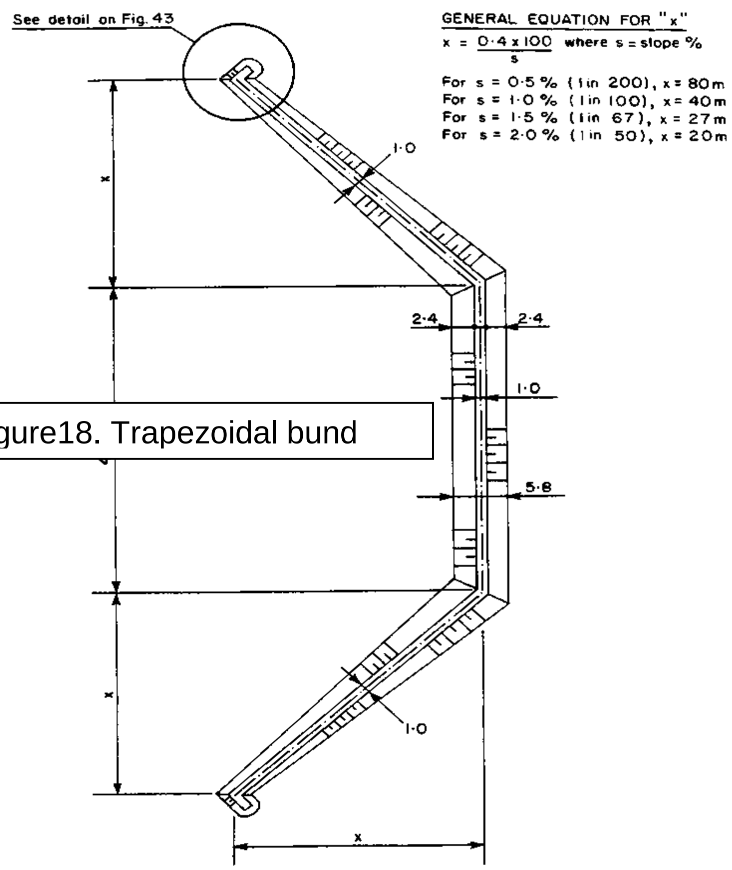


Figure18. Trapezoidal bund

Self-Check – 3	**Written test**

Name…………………………………………… ID……………………….. Date…….

Directions: Answer all the questions listed below. Examples may be necessary to aid some explanations/answers.

Test I: Short Answer Questions

1. Discuss overall configuration of Contour Stone bunds . (6 pts)

2. Discuss the Size and layout of Contour Stone bunds. (10pts)

Note: **Satisfactory rating - 8 points Unsatisfactory - below 8points**

You can ask you teacher for the copy of the correct answers.

Answer Sheet

Score = ___________

Rating: ____________

Name: ___________________________ Date: ________________

Information Sheet 4- Selecting Materials, tools and equipment

4.1. Selecting Materials, tools and equipment

Equipment can be defined as:-

- Are especially made for purpose.
- Equipment is a set of tools.

- Equipment is basically to "equip" somebody. You cannot equip someone with a spanner or a screwdriver.

Tool can be defined as:-

- Tools are objects to work.
- Tools in a non-literal sense are devices to use to do something.
- Tools are commonly used for machinery.
- Tools are generally small, hand held, common items.

4.2. Organizing all tools &equipment

Tools and equipment

Surveying and Leveling equipment,

- Line level/A-frame, String, Graduated staff, Clinometers, Altimeter, compass, Measuring tape, Digging instruments, plum bob, Ranging pole, Strings, Pegs, , Compass, GPS, Aerial photographs, Top maps, Automatic level,

Irrigation equipment,

- water can, Nozzles, Main and lateral lines, Emitters, Filter, Take-off valves, Flow control valves, Water tank /pump, Current meter

sampling and measuring equipment

- Soil auger, Double-ring infiltro meter, Soil sampler(Auger), Stopwatch,

Equipment for detecting

- salinity level (PH meter, etc.),EC meter

hand tools

- pick axe, shovel, spade, rake, hoe,

4.3. Conducting Checks on all materials, tools and equipment

It is essential to check irrigation system, tools and equipment's for damage or malfunction and shall report damage or malfunction to the authorized representative in writing. If failed to maintain the broken or malfunctioning irrigation system components within few days of the breakage or malfunction, there will be a loss due to damages resulting from the broken irrigation system component.

Hence, it is necessary to check the system, materials and equipment's. In addition, maintenance of the system has to be carried out regularly.

Self-Check – 4	**Written test**

Name…………………………………………… ID……………………….. Date…….

Directions: Answer all the questions listed below. Examples may be necessary to aid some explanations/answers.

Test I: Short Answer Questions

1. Write the required tools and equipment for water harvesting structure construction . (20 pts)

Note: Satisfactory rating - 10 points Unsatisfactory - below 10points

You can ask you teacher for the copy of the correct answers.

Answer Sheet

Score = ___________

Rating: ____________

Name: _________________________ Date: _______________

Information Sheet 5- Constructing designed structures

5.1. Constructing designed structures

The success of water harvesting schemes and the productive marriage of hydrology and agriculture depend on the identification of suitable systems and the correct application of known engineering principles in the field. In this section aspects of the latter are covered.

1. Trapezoidal bund macro catchment

Layout and construction

Step one: When the site for the bund has been decided, the first thing to do is to establish the land slope using line level. The dimensions of bund vary with the slope of the area. Starting at the top of the field a peg is placed which will be the tip of one of the wing walls. The second wing wall tip is at the same ground level at the distance obtained from table above.

Step two: Stake out the four dimensions of the bund and measure the right angle using a wooden right angle triangular template

Step three: - The accuracy of the setting can be checked by measuring the distances between points 40cm.

Step four: Having the main points of the bund it is necessary to set out pegs or stones to mark the earth work limits.

Step five: Construction of a set of trapezoidal bunds must start with the row furthest up-slope. The bund is constructed in two layers each having a maximum thickness of 0.3m, the thickness of the first layer will gradually taper off to zero as filling proceeds up slope along the wing bunds.

Step six: -The tips of the bunds are only 20 cm high and exceed runoff drains around them. To prevent erosion of the tips they should be shaped with a small extension or “lip” to lead water away.

Step seven: Where the catchment is large in relation to the bunded area it is advisable to construct a diversion ditch to prevent excess water or inflow to the bunds. This ditch usually50cm deep and of 1-1.5 meters width, and is usually graded at 0.25%.

Table12. Quantities of Earthworks for Trapezoidal Bund

Slope (%)	Length of base bund (m)	Length of wing wall (m)	Distance between tips (m)	Earthworks per bund (m^3)	Cultivated area per bund (m^2)	Earthworks per ha cultivated (m^3)
0.5	40	114	200	355	9600	370
1.0	40	57	120	220	3200	670

1.5	40	38	94	175	1800	970

Note: Where diversion ditches or collection arms are required these add 62.5 m3 for each 100 m l

2. Contour stone bund macro catchment

I. Layout and construction

Step One

The average slope of the field is determined by a simple surveying instrument such as a water level or a line level to decide on the spacing of the bunds. Each contour line is then set out and pegged individually. A horizontal spacing of approximately 20 meters apart is recommended for slopes of up to 1%, and 15 meters apart for 1 - 2% slopes. Because of variations in the slope, the lines may come closer together, or diverge at some points. The horizontal spacing recommended are the average distances apart. If labor is a limiting factor, farmers can start with a single bund at the bottom of their fields and work progressively upslope in seasons to come.

Step Two

After the exact contour is laid out, the line should be smoothed by moving individual pegs up or down slope. As a guideline, for ground slopes of up to 1.0 % pegs can be moved 2 meters upslope or down slope to create a smoother curve. Not only will a gentle curve be easier to follow while ploughing, but also the amount of stone used for construction will be reduced.

Step Three

A shallow trench is now formed along the smoothed contour. The trench is made by hand tools, or ploughed by oxen and then excavated by hand. The trench need only be 5 -10 cm deep and equal to the base width of the bund (35 - 40 cm). The excavated soil is placed upslope.

Step Four

Construction begins with large stones laid down at the base and the down slope side of the trench, and then smaller stones laid in front and on top of this "anchor" line. Small stones should be used to plug gaps between the larger ones. Where possible, a line of small or gravelly stones should run along the upslope face of the bund to create a fine filter. The key to a successful stone bund is to eliminate any large gaps between stones. In some areas it will be necessary to break large stones to produce the correct sizes of material.

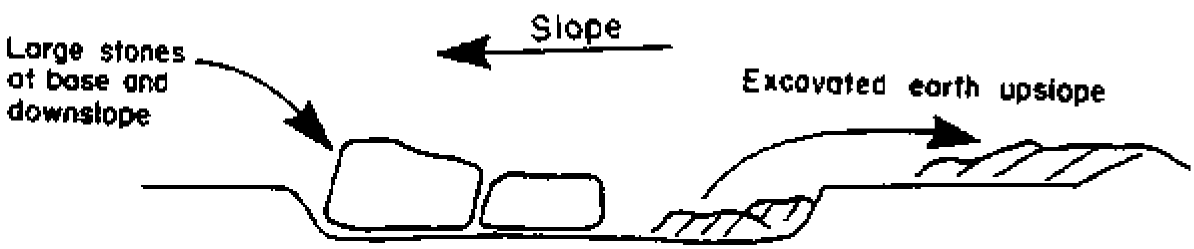


Figure 19. Construction of stone bund

II. Maintenance

During heavy runoff events stone bunds may be overtopped and |some stones dislodged. These should be replaced. A more common requirement is to plug any small gaps with small stones or gravel where runoff forms a tunnel through.

Eventually stone bunds silt-up, and their water harvesting efficiency is lost. It normally takes 3 seasons or more to happen, and occurs more rapidly where bunds are wider apart, and on steeper slopes. Bunds should be built up in these circumstances with less tightly packed stones, to reduce siltation, while maintaining the effect of slowing runoff.

On-farm stone bunding for crop production is quickly appreciated and adopted by farmers. The techniques involved, including simple surveying, can be easily learned. The amount of labor required is reasonable, and where groups are organized to work in turn on individual member's farms, fields can be transformed in a single day. The benefits of stone bunding are often clearly seen already in the first season - and this helps to make the system popular.

Nevertheless there are some problems which must be faced. Relatively rich farmers can make use of wage labor to treat their fields, and poorer farmers may lag behind. Differing availabilities of stones can lead to inequalities between neighboring areas: not everyone can benefit in the same way. This leads to another problem - to what extent is the cost of stone transport justified?

Table 13. Quantities and Labour Requirements for Contour Stone Bunds

	Bund size	Bund spacing = 15 m		Bund spacing = 20 m	
		Vol. stone m^3/ha	Person days/ha	Vol. stone m^3/ha	Person days/ha
Stones available in field	Small (cross-section 0.05 m^2)	35	70	25	50
	Medium (cross-section 0.08 m^2)	55	110	40	80
Stones transported locally	Small (cross-section 0.05 m^2)	35	105	25	75
(Wheel barrow etc.)	Medium (cross-section 0.08 m^2)	55	165	40	120

Self-Check – 5	**Written test**

Name…………………………………………… ID……………………….. Date…….

Directions: Answer all the questions listed below. Examples may be necessary to aid some explanations/answers.

Test I: Short Answer Questions

1. Discuss Layout and construction of trapezoidal bunds . (10 pts)

   ____

   ____

   ____

   ____

2. Discuss Layout and construction of Contour Stone bunds(10pts)

   ____

   ____

3. How do you maintain the contour bund? (5 point)

   ____

   ____

4. How do you maintain the trapezoidal bund? (5point)

   ____

   ____

Note: **Satisfactory rating - 15points** **Unsatisfactory - below 15points**

You can ask you teacher for the copy of the correct answers.

Answer Sheet

Score = ___________

Rating: ____________

Name: _________________________ Date: _______________

Information Sheet 6- Harvesting and supplying water

6.1. Harvesting and supplying water

How much runoff can be collected (generated) from a certain catchment area?

Runoff yield varies with the size and texture of the catchment area. In principle, 1mm of rainfall on an impervious catchment area, can generate 1 liter of runoff water per square meter. However, due to several factors the rainfall on a particular catchment must not be totally resulted as runoff. The expected runoff is therefore, the expected design rainfall multiplied by the runoff coefficient and the area of the catchment.

R = K x P x A

Where R= annual runoff (m3)

K= runoff coefficient =R/P

P= annual rainfall (design R.F) m

A = area of catchment (m2)

Runoff coefficient denotes the percent of rain water which flows down the land slope as surface runoff.

Factors influencing runoff coefficient

- ✓ Rainfall characteristics (amount, intensity, duration)
- ✓ Infiltration rate of the soil
- ✓ Slope gradient of the catchment
- ✓ Soil moisture content
- ✓ Vegetative cover
- ✓ Soil type
- ✓ Geology
- ✓ Size of the catchment

How much Water needed in the Cultivated Area (CA) and Water harvested in the Catchment area (C).

Rainfall and runoff

Only a part of the rainfall on the catchment area becomes runoff. The size of the proportion of rainfall that becomes runoff depends on the different factors mentioned preceding to this paragraph. If the rainfall intensity of a rainstorm is below the infiltration capacity of the soil, no runoff will occur. The proportion of total rainfall which becomes runoff is called the runoff factor. E.g. a runoff factor of 0.20 means that 20% of all rainfall during the growing season becomes runoff. Every individual rainstorm has it's own runoff factor. The seasonal (or annual) runoff factor however, R, is important for the design of a water harvesting system.

Efficiency

The runoff water from the catchment area is collected on the cultivated area and infiltrates the soil. Not all ponded runoff water can be used by the crop because some of the water is lost by evaporation and deep percolation (see Appendix 1 for these concepts). The utilization of the harvested water by the crop is called the efficiency of the water harvesting system and is expressed as an efficiency factor. E.g. an efficiency factor of 0.75 means that 75% of the harvested water is actually used by the crop. The remaining 25% is lost. The consequence for the design of a water harvesting system is that more water has to be harvested to meet the crop water requirements: the catchment area has to be made larger.

Storage capacity

The harvested water is stored in the soil of the cultivated area. The capacity of a soil to store water and to make it easily available to the crop is called the *available water storage capacity*. This capacity depends on (i) the number and size of the soil pores (texture) and (ii) the soil depth. The available water storage capacity is expressed in mm water depth (of stored water) per meter of soil depth, mm/m.

The available water storage capacity and the soil depth have implications for the design of a water harvesting system. In a deep soil of, for example, 2 m with a high available water capacity of 150 mm/m the water storage capacity is 300 mm of water and there is no point in ponding runoff water on the cultivated area to depths greater than 300 mm (30 cm). Any quantity of water over 30 cm deep will be lost by deep drainage and will also form a potential water logging hazard.

Calculation of C:CA ratio

Calculation of crop water requirements

The water requirements of a certain crop depend on both the crop type and the climatic conditions under which the crop is cultivated. To facilitate the calculation of the crop water requirements under certain climatic conditions, grass has been taken as a standard or reference crop. The water requirements of the reference crop are called the reference evapo transpiration, ETo which is expressed in mm water depth per day, mm/day.

There are more sophisticated ways to determine the reference evapotranspiration, but for the design of water harvesting system an estimation using the above Table is sufficient. Accurate data on the ETo are best obtained locally. By using the water requirements of the reference crop as starting point for calculation of the crop water requirements, the influence of the climate has already been taken into account.

What remains is to relate the water requirements of the reference crop to those of the crop you want to grow. This is done by using the crop factor, Kc, a factor by which the water requirements of the reference crop are multiplied in order to obtain the water requirements of the crop to be grown. In formula:

ETcrop = Kc × ETo

where

ETcrop = the crop evapotranspiration in mm/day

Kc = the crop factor

ETo = the reference evapotranspiration in mm/day.

The crop water requirements vary with the growth stages of the crop. With water harvesting, the farmer has little control over the quantity of water supplied, let alone the timing. Therefore, it makes little sense to calculate how much water is required by the crop at each of its growth stages. For the design of a water harvesting system it is sufficient to calculate the total amount of water which the crop requires over the entire growing season. ETcrop is calculated using the formula ETcrop = Kc × ETo, with average values of Kc and ETo for the total growing season

The design rainfall

For the design of a water harvesting system you have to know then quantity of rainfall during the growing season of the crop. The quantity of rainfall according to which a water harvesting system is designed, is called the *design rainfall*. The difficulty with selecting the right design rainfall is the high variability of rainfall in (semi-)arid regions. While the average annual rainfall might be 400 mm there may be years without any rain at all, and 'wet' years with 500 - 600 mm of rain or even more. If the actual rainfall is less than the design rainfall, the catchment area will not produce enough runoff to satisfy the crop water requirements; if the actual rainfall exceeds the design rainfall there will be too much runoff which may cause damage to the water harvesting structure. When starting with water harvesting techniques, it is recommended that you design your systems on the 'safe side' to test if your design can withstand flooding. Use crops which are resistant to drought to minimize the risk of crop failure in years when your design rainfall does not fall. We recommend you try drought resistant varieties which are cultivated already in your area in order to compare their performance in the new water harvesting scheme.

Determination of the runoff factor

The first way to determine the R-factor is by making an educated guess, and following it up by trial and error. The value of the seasonal (or annual) runoff factor, R, is usually between 0.20 and 0.30 on slopes of less then 10%. It may be as high as 0.50 on rocky natural catchments. The runoff factor R is often estimated and evaluated in the light of the results of the first experimental water harvesting systems. The second, more accurate but also more laborious, way to determine the R-factor is to measure first the r-factor for individual rainstorms after which the seasonal (annual) runoff factor is calculated. For the measurement of the r-factor, runoff plots are established. These are plots sited in a representative part of the area where the water harvesting scheme is planned. With the runoff plots it is possible to measure the quantity of runoff for each individual rainstorm. It is also possible to use seasonal runoff factors determined for nearby areas, but this must be done with care. The runoff factor is highly dependent
on local conditions.

The efficiency factor.

The part of the harvested water which can be actually used by the crop is expressed by the efficiency factor. Efficiency is higher when the cultivated area is leveled and smooth. As a rule of thumb the efficiency factor ranges between 0.5 and 0.75. When measured data are not available (check nearby irrigation schemes) the only way is to estimate the factor on the basis of experience: trial and error.

The formula to calculate the C:CA ratio:

1. Water needed in the Cultivated Area (CA) = Water harvested in the Catchment area (C)

2. Water needed in the Cultivated Area (CA) = [Crop Water Requirements - Design rainfall] × CA (m^2) and Water harvested in Catchment area (C) = R × Design rainfall × Efficiency factor × C (m^2)
3. Therefore:

$$C : CA = \frac{\text{[Crop Water Requirements - Design rainfall]}}{R * \text{Design rainfall} * \text{Efficiency factor}}$$

Self-Check – 6	**Written test**

Name…………………………………………… ID………………………… Date…….

Directions: Answer all the questions listed below. Examples may be necessary to aid some explanations/answers.

Test I: Fill in the blank space

1. ______________________denotes the percent of rain water which flows down the land slope as surface runoff.(5pts)
2. _________________________is the water requirements of the reference crop(5pts)

Test II: Short Answer Questions

1. What is design rain fall. (5pts)

   ____

   ____

2. What is crop factor.(5pts)

   ____

   ____

1.

***Note:* Satisfactory rating - 10 points** **Unsatisfactory - below 10 points**

You can ask you teacher for the copy of the correct answers.

Answer Sheet

Score = ___________

Rating: ____________

Name: _________________________ Date: _______________

Operation Sheet 1- Constructing of trapezoidal bund macro-catchment

Objective:- To develop design, layout and construction skills of trapezoidal bund macro catchment structure.

Tools and Equipment required

- Line level/A-frame, ranging pole, rope, ,measuring tape, Digging tools, pegs, right angle triangular template

Procedures;

1. Select and wear your personal protective equipment
2. Select and collect the require tools and equipment
3. Identifying the site
4. Establish the land slope using an line level/A-frame.
5. Mark the tip of one of the wing wall at the top of the field with peg
6. Mark the second wing wall tip along the same ground level at the distance obtained from table above
7. Stake out the four dimensions of the bund
8. Check the accuracy of the setting by measuring the distances between points 4ocm.
9. Set out pegs or stones to mark the earth work limits.
10. Start construction of a set of trapezoidal bunds with the row (from furthest up-slope.)

Operation Sheet 2- Constructing of Contour stone bund macro-catchment

Objective:- To develop design and construction skills of Contour stone bund macro-catchment

Tools and Equipment required

- Line level/A-frame, String, ranging pole, rope, Measuring tape, Digging instruments

Procedures;

1. Identifying the site
2. Select and wear your personal protective equipment
3. Select and collect the require tools and equipment
4. determine the average slope gradient , using a water tube-level ,
5. decide and mark the spacing The of the bunds
6. mark out at each location contour lines where a bund is to be made
7. excavate a shallow trench is along the contour line: 5-10 cm deep , width equal to the base width of the bund, 30-40 cm.
8. place the excavated soil upslope
9. construct the bund

LAP TEST	**Performance Test**

Name………………………………. ID……………………………..

Date…………………………………….

Time started: ________________________ Time finished: ________________

Instructions: Given necessary templates, tools and materials you are required to perform the following tasks within **1** hour. The project is expected from each student to do it.

You are required to perform any of the following:

Task-1 Design, layout and construction of trapezoidal bund macro catchment water harvesting structure

Task**-**2 Design, layout and construction of contour stone bund macro catchment water harvesting structure

Instruction sheet
This learning guide is developed to provide you the necessary information regarding the following **content coverage** and topics:

- Identifying different flood water harvesting types
- . Designing identified flood water harvesting
- Constructing designed structures
- Harvesting and supplying water

This guide will also assist you to attain the learning outcomes stated in the cover page. Specifically, **upon completion of this learning guide, you will be able to**:

- Perform in Identifying different flood water harvesting types
- Undertake design identified flood water harvesting
- Conduct constructing the designed structures
- Carryout harvesting and supplying water

Learning Instructions:

1. Read the specific objectives of this Learning Guide.
2. Follow the instructions described below.
3. Read the information written in the "Information Sheets". Try to understand what are being discussed. Ask your trainer for assistance if you have hard time understanding them.
4. Accomplish the "Self-checks" which are placed following all information sheets.
5. Ask from your trainer the key to correction (key answers) or you can request your trainer to correct your work. (You are to get the key answer only after you finished answering the Self-checks).
6. If you earned a satisfactory evaluation proceed to "Operation sheets
7. Perform "the Learning activity performance test" which is placed following "Operation sheets" ,

8. If your performance is satisfactory proceed to the next learning guide,
9. If your performance is unsatisfactory, see your trainer for further instructions or go back to “Operation sheets”.

1.1. Identifying different flood water harvesting types

Floodwater farming (floodwater harvesting) often referred to as "Water Spreading" and sometimes "Spate Irrigation." Main Characteristics:- turbulent channel flow harvested either (a) by diversion or (b) by spreading within channel bed/valley floor

1.1.1. Permeable Rock Dams

Permeable rock damns are a floodwater fanning technique where runoff waters are spread in valley bottoms for improved crop production. Developing gullies are healed at the same time. The structures are typically long, low dam walls across valleys.

Technical Details

Suitability

Permeable rock dams for crop production can be used under the following conditions:

Rainfall: 200 -750 mm; from arid to semi-arid areas.

Soils: all agricultural soils - poorer soils will be improved by treatment.

Slopes: best below 2% for most effective water spreading.

Topography: wide, shallow valley beds.

L**imitation-** The main limitation of permeable rock dams is that they are particularly site-specific, and require considerable quantities of loose stone as well as the provision of transport.

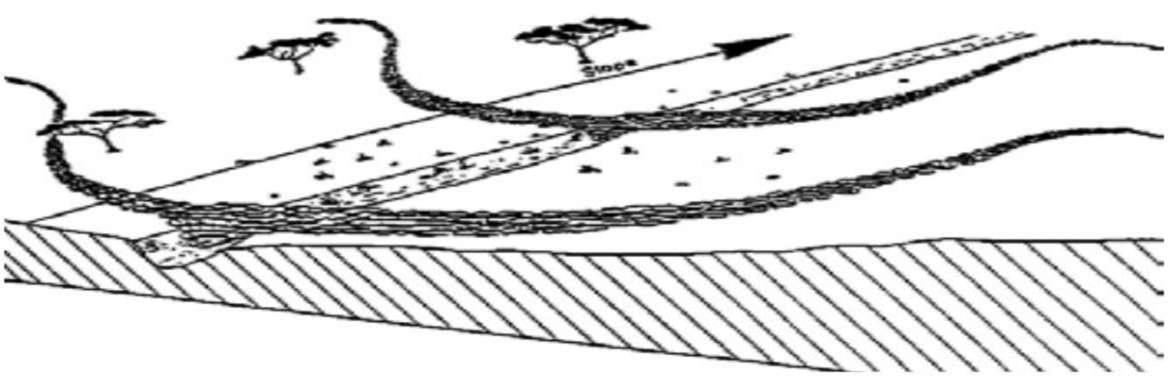


FIG 20.Permeable Rock Dams

1.1.2. Water Spreading Bunds

Water spreading bunds are often applied in situations where trapezoidal bunds are not suitable, usually where runoff discharges are high and would damage trapezoidal bunds or where the crops to be grown are susceptible to the temporary water logging, which is a characteristic of trapezoidal bunds. The major characteristic of water spreading bunds is that, as their name implies, they are intended to spread water, and not to impound it. They are usually used to spread floodwater which has either been diverted from a watercourse or has naturally spilled onto the floodplain. The bunds, which are usually made of earth, slow down the flow of floodwater and spread it over the land to be cultivated, thus allowing it to infiltrate.

Technical Details

Suitability

Water spreading bunds can be used under the following conditions:

Rainfall: 100 mm - 350 mm; normally hyper-arid/arid areas only.

Soils: alluvial fans or floodplains with deep fertile soils.

Slopes: most suitable for slopes of 1% or below.

Topography: even.

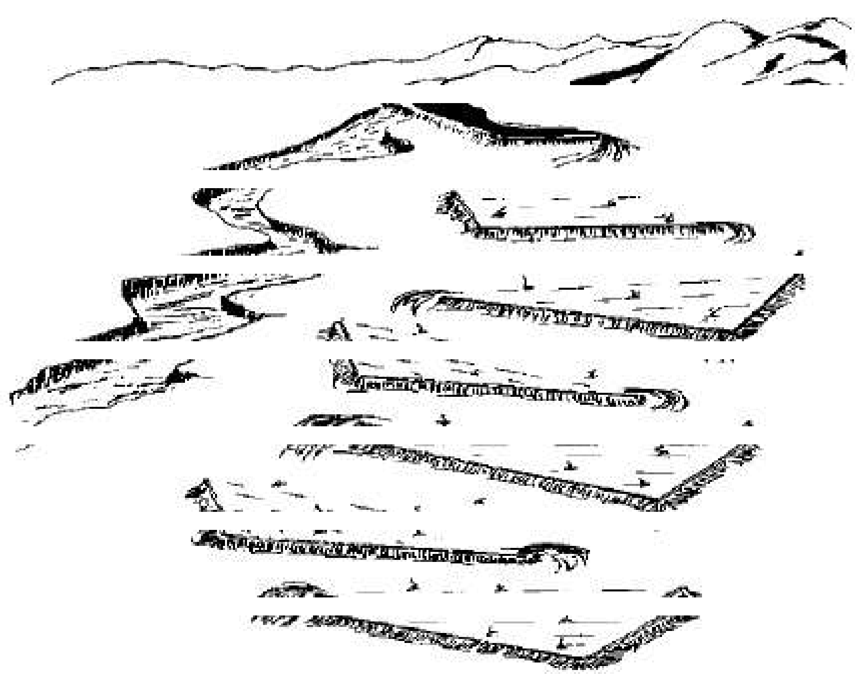


Figure 21 . Flow diversion systems with water spreading bunds

Self-Check – 1	**Written test**

Name…………………………………………… ID………………………… Date…….

Directions: Answer all the questions listed below. Examples may be necessary to aid some explanations/answers.

Test I: Short Answer Questions

1. What is the difference between macro catchment and flood WH?(5pts)

   ____

   ____

2. Write the types of flood WH?(5pts)

   ____

   ____

Note: **Satisfactory rating - 5 points** **Unsatisfactory - below 5 points**

You can ask you teacher for the copy of the correct answers.

Answer Sheet

Score = ___________

Rating: ____________

Name: _________________________ Date: _______________

2.1. Designing identified flood water harvesting

Design of Permeable Rock Dams

Dam design

The main part of the dam wall is usually about 70 cm high although some are as low as 50 cm. However, the central portion of the dam including the spillway (if required) may reach a maximum height of 2 in above the gully floor. The dam wall or “spreader” can extend up to 1000 meters across the widest valley beds, but the lengths normally range from 50 to 300 meters. The amount of stone used in the largest structures can be up to 2000 tons. The dam wall is made from loose stone, carefully positioned, with larger boulders forming the “framework” and smaller stones packed in the middle like a “sandwich”. The side slopes are usually 3:1 or 2:1 (horizontal: vertical) on the downstream side, and 1: 1 or 1:2 on the upstream side. With shallower side slopes, the structure is more stable, but more expensive.

The horizontal spacing between adjacent dams can be determined from the selected and the prevailing land slope according to the formula.

$$HI = \frac{(VI \times 100)}{\%\ slope}$$

Where:

HI= horizontal interval (m)

VI= vertical interval (m)

%Slope= land gradient expressed as a percent

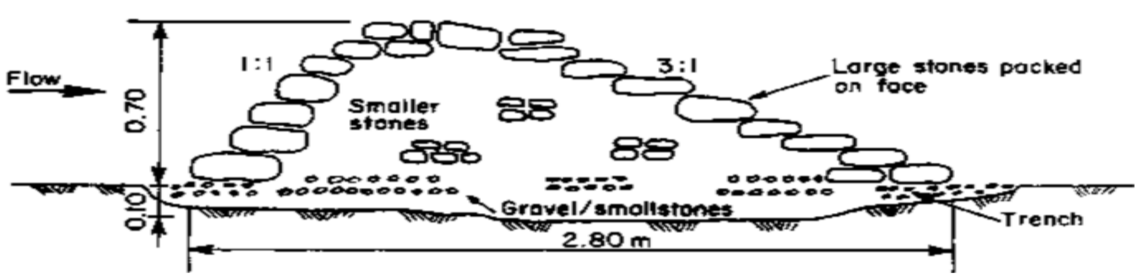


Figure 22 Dimension of dam

Design of Water spreading bunds

Bund design

a. Slopes of less than 0.5%

Where slopes are less than 0.5%, straight bunds are used to spread water. Both ends are left open to allow floodwater to pass around the bunds, which are sited at 50 meters apart. Bunds should overlap - so that the overflow around one should be intercepted by that below it. The uniform cross section of the bunds is recommended to be 60 cm high, 4.1 meters base width, and a top width of 50 cm. This gives stable side slopes of 3:1. A maximum bund length of 100 meters is recommended.

b. Slopes of 0.5% to 1%

In this slope range, graded bunds can be used (Figure 35). Bunds, of constant cross section, are graded along a ground slope of 0.25%. Each successive bund in the series down slope is graded from different ends. A short wing wall is c constructed at 135° to the upper end of each bund to allow interception of the flow around the bund above. This has the effect of further checking the flow. The spacing between bunds depends on the slope of the land.

Self-Check – 2	**Written test**

Name…………………………………………… ID……………………….. Date…….

Directions: Answer all the questions listed below. Examples may be necessary to aid some explanations/answers.

Test I: Short Answer Questions

1. What is flood water harvesting? (3 pints)

____

____

2. What are the different types of flood water harvesting? (5 points)

____

____

3. Write the limitation the different types of flood water harvesting(4pts)

____

____

Note: **Satisfactory rating - 8 points** **Unsatisfactory - below 8 points**

You can ask you teacher for the copy of the correct answers.

Answer Sheet

Score = ___________

Rating: ____________

Name: ___________________________ Date: _______________

3.1. Constructing designed structures

1. Permeable rock dams

Step One

Site selection depends both on the beneficiaries and the technicians. Theoretically it is best to start at the top of the valley, though this may not always be the people's priority. After site identification it is necessary to determine whether the structure needs a defined spillway: as a rule of thumb no spillway is required if the gully is less than one meter deep. For greater depths ,a spillway is recommended.

Step Two

Where a spillway is required, this should be built first. Gabions are best for spillways, as loose stone is easily destabilized by heavy floods. The following should be noted:

a. A foundation of small stones, set in a trench, is required.

b. An apron of large rocks is needed to break the erosive force of the overflow.

c. The downstream banks of the watercourse should be protected by stone pitching to prevent enlargement of the gully.

Step Three

The alignment of the main dam walls can be marked out, starting at the centre of the valley (where there may/may not be a spillway). This alignment is ideally along the contour, or as close to the contour as possible. Thus the extension arms sweep backwards in an arc like the contours of a valley on a map. The arms end when they turn parallel to the watercourse.

Step Four

The first action after aligning the extension arms of the dam is to dig a trench at least 10 cm deep and 280 cm wide (according to the base width of the bund). The earth should be deposited upslope and the trench filled with gravel or small stones.

Step Five

The skill of construction is in the use of large stones (preferably of 30 cm diameter or more) for the casing of the wall. This should be built tip gradually following the required side slope, and the centre packed with smaller stones. The whole length of the bund should be built simultaneously, in layers. This layered approach reduces the risk of damage by floods during construction.

Step Six

If a series of permeable rock dams is to be built, an appropriate vertical interval (VI) should be selected. Technically speaking it is correct to:

a.start at the top of the valley and work down;

b. use a VI equal to the height of the structure level as the base of the one above it Therefore for dams of 70 cm height, the VI should theoretically be 70 cm. However in practice this may not be practicable due to the amount of stone and labour involved. As a compromise, a V.I. of 100 cm might be more realistic. Even wider spacing could be adopted, and the "missing" structures "filled in" afterwards. The vertical interval can be determined most easily by the use of a line-level.

The horizontal spacing between adjacent dams can be determined from the selected VI and the prevailing land slope according to the formula:

$$HI = \frac{(VI \times 100)}{\%slope}$$

where:

HI = horizontal interval (m)

VI = vertical interval (m)

% slope = land gradient expressed as a percentage.

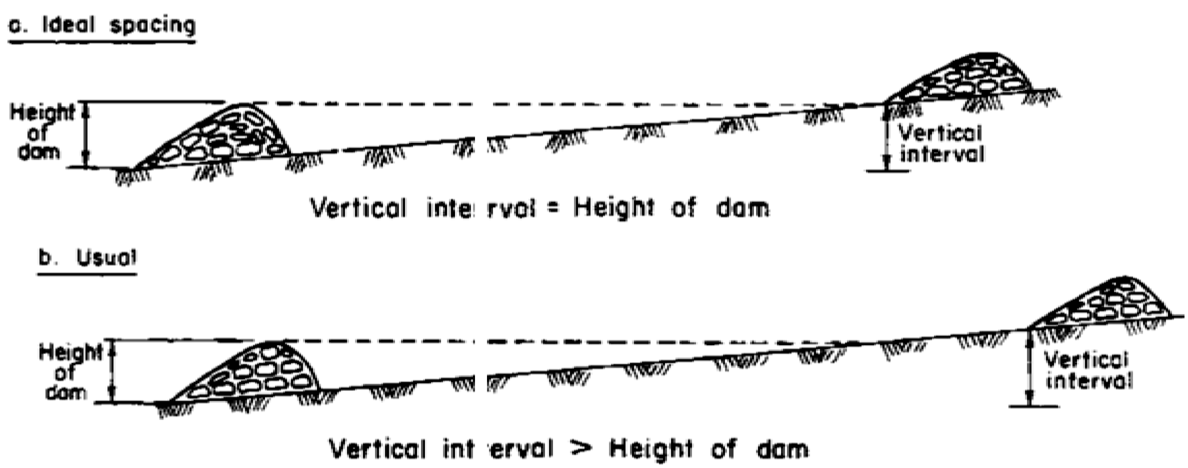


Figure 23. Spacing of rock dams

2. Water spreading bunds

Steps of construction of Water spreading bunds

Step One

The first step is to measure the slope of the land, in order to select the appropriate bunding system.

Step Two

Straight bunds are used for ground slopes of less than 0.5% and are spaced at 50 m intervals. The bunds should, however, be staggered as shown on Figure 58, which also illustrates the setting out procedure.

Having selected the starting point at the upslope end of the bund system point A is marked with a peg. Using a line or water level and, if necessary, a tape, point B is pegged on the contour 100 m away from A. Line AB is then the centre line of the first bund and should be marked with pegs or stones.

Point C is 50 m down slope from point B and can be established by marking of a right angle perpendicular to AB, using a wooden triangular right angle frame (sides: 100 cm, 60 cm, 80 cm) and a tape. Point D is then established with level and tape at the same ground level as C, at a distance of 25 m from C to allow overlap with AB. Point D is then pegged. Point E is also on the same ground level as point C, but 75 m distant in the opposite direction to point D. The line DE is the centre line of the second bund and should be marked with pegs or stones. Point F is 50 m down slope of point E and is established in a similar manner as point C. Point G is then established on the same ground level as point F but 25 m distant to allow overlap with DE. Similarly point H is at the same ground level as point F but 75 m distant, in the opposite direction to point G.

This process can be repeated down the slope to lay out the field of bunds.

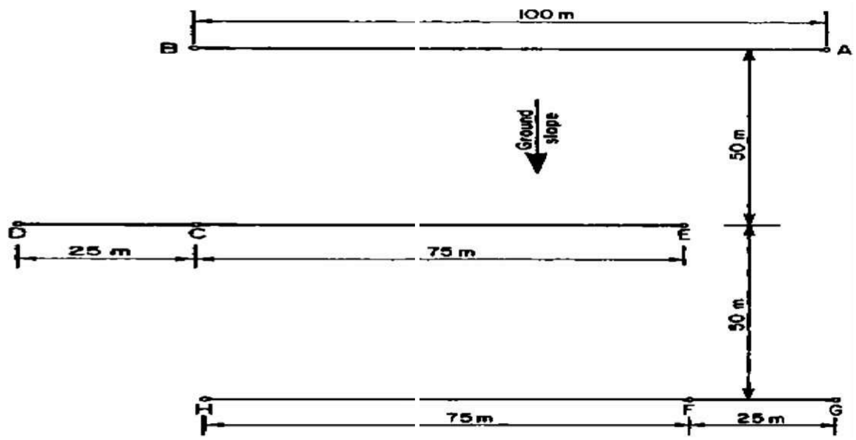


Figure .24 Setting out of level bunds

Step Three

For ground slopes above 0.5% bunds aligned with a 0.25% gradient are used and are termed “graded bunds”.

Having selected the starting point (A) at the upslope end of the bund system, it is marked with a peg. Using a line, or water level, and a tape, the line AB is set out on a 0.25% gradient. As the distance AB is 100 in, the ground level at B is 25 cm below that at A. Point B is then marked with a peg and the line AB, forming the centre line of the first bund, is marked with pegs or stones.

Point C, on the centre line of the second bund, is at a distance of 25 m immediately down slope of point B. It is most easily found by using the line or water level to establish the maximum field gradient between B and C, and by measuring from B through that point a distance of 25 m. Having established C the 0.25% slope line is again established and point D located along that line 25 in from C. Note that point D will be at a slightly higher ground level than point C and should provide overlap with the line AB, as shown in Figure below. The other end of the bund centre line, point F, is 75 m on the opposite side of C along the 0.25% slope line. The points D and F should be pegged and mark the centre line of the second bund. The wing bund always starts from the overlapping end of the base bund, in this case point D. The wing bund is 25 in long and at an angle of 135° to the base bund. It is most easily found by extending the line ED a distance of 17.7 m from D to give point X. Point Y is then a distance of 17.7m upslope from point X, and at a right angle to the line XDE. It can be located using a tape and right angle template as described above. The first point on the next bund line, point F, is located in a similar manner to point E and the bend centre line HFG can be set out as above. The end of the wing bund, W, can be located in a similar manner as Y. This process is continued down the field.

Step Four

Having marked out the centre lines of the bunds, the limits of fill can be marked by stakes or stones placed at a distance of 2.05 m on either side of the centre lines.

Step Five

Construction begins at the top of the field as in all water harvesting systems. Earth should be excavated from both sides to form the bunds, and in the shallow trenches formed, earth ties should be foreseen at frequent intervals to prevent scouring. The earth beneath the bunds should be loosened to ensure a good mating with the bund. The bunds are constructed in two layers of 30 cm each, and compaction by trampling is recommended on the first course and again when the bund is complete.

Step Six

At the ends of the contour bunds, and at the tip of the wing walls of the graded bunds, stone pitching should be placed - if loose stone is available - to reduce potential damage from flow around the bunds.

Self-Check – 3	**Written test**

Name…………………………………………… ID……………………….. Date…….

Directions: Answer all the questions listed below. Examples may be necessary to aid some explanations/answers.

Test I: Short Answer Questions

1. Discuss about the lay out of permeable rock dam?(10pts)

____
____
____
____

2. Discuss about the lay out of water spreading bund.(10pts)

____
____
____
____

Note: **Satisfactory rating - 3 points** **Unsatisfactory - below 3 points**

You can ask you teacher for the copy of the correct answers.

Answer Sheet

Score = ___________

Rating: ____________

Name: _________________________ Date: _______________

Information Sheet 4- Harvesting and supplying water

4.1. Harvesting and supplying water

The main activities included construction of:

- Diversion of small rivers or streams using gabion or masonry weir,
- Main canals and distribution system,
- Flood protection embankments and drainage systems,
- Land leveling and demarcation

4.1.1. Storage of harvested water

The need for storage will in many cases be dictated by characteristics of both the runoff and the intended use of water. However, the most important limiting factor would be the cost. Viability of the schemes is in fact normally lowered if there is a need for large and long-term storage of water.

There are mainly three most important decisions that a planner will be faced with:

- Is storage necessary?
- What storage methods and size should be used?
- How should problems associated with storage systems be avoided?

4.1.2. When is storage necessary?

The intended use of harvested water is the most important determinant of whether storage is necessary or not. RWH for flood control requires storage. If water is being harvested for purposes of supplying water for livestock or game, then it is necessary to have storage facilities. The next type of use where storage is necessary, is in vegetable production. Finally, storage, other than in the soil may be required for arable crops. In most cases, storage outside the growth medium is not necessary for land conservation, range development, forestry or ground water recharge. Another determinant of the need for storage is the frequency of rainfall. If the rain is received over a very short period and rainstorms are interspersed by long dry spells, then storage of the harvested water becomes important even for trees and arable crops.

4.1.3. Supply and distribution

The runoff which concentrates in the centre of the valley, creating a gully, will be spread across the whole valley floor, thus making conditions more favorable for plant growth. Excess water filters through the dam, or overtops during peak flows. Gradually the dam silts up with fertile deposits. Usually a series of dams is built along the same valley floor, giving stability to the valley system as a whole. The calculation of the C: CA ratio is not necessary as the catchment area and the extent of the cultivated land are predetermined. However, the catchment characteristics will influence the size of structure and whether a spillway is required or not.

Self-Check – 4	**Written test**

Name…………………………………………… ID……………………….. Date……

Directions: Answer all the questions listed below. Examples may be necessary to aid some explanations/answers.

Test I: Short Answer Questions

1. How do you harvest a water?(10pts)

   ____

   ____

2. How do you supply a water?(10pts)

   ____

   ____

Note: **Satisfactory rating - 10 points** **Unsatisfactory - below 10points**

You can ask you teacher for the copy of the correct answers.

Answer Sheet

Score = ___________

Rating: ____________

Name: _________________________ Date: _______________

Operation Sheet 1- Constructing permeable rock dam

Objective:- To develop design and construction skills of permeable rock dam Flood Water Harvesting structure

Tools and Equipment required

- Line level/A-frame, String, ranging pole, rope, Measuring tape, Digging instruments

Procedures;

1. Select and wear your personal protective equipment
2. Select and collect the require tools and equipment
3. Identifying the site
4. Identify the site for spillway
5. Construct the spillway first
6. Set a trench for foundation
7. Construct an apron
8. Mark the alignment of the dam wall
9. dig a trench at least 10 cm deep and 280 cm wide
10. deposit the soil upslope and fill the trench with gravel or small stones.
11. Use preferably of 30 cm diameter or more for the casing of the wall.
12. Pack the centre with smaller stones
13. built the whole length of the bund simultaneously, in layers.

Operation Sheet 2- Constructing of water spreading bund

Objective:- To develop design and construction skills of water spreading bund

Tools and Equipment required

- Line level/A-frame, String, ranging pole, rope, Measuring tape, Digging instruments

Procedures;

1. Select and wear your personal protective equipment
2. Select and collect the require tools and equipment
3. Identifying the site
4. Laying out the structure to be constructed (Use the steps from your TTLM)
5. Construct the structure based on the dimensions

LAP TEST	**Performance Test**

Name………………………………. ID……………………………..

Date……………………………………

Time started: ________________________ Time finished: ________________

Instructions: Given necessary templates, tools and materials you are required to perform the following tasks within **10** hour. The project is expected from each student to do it.

You are required to perform any of the following:

Task-1 Design, layout and construction of permeable rock dam flood water harvesting structure

Task-2 Design, layout and construction of water spreading bund flood water harvesting structure

Reference Materials

Book:

1. John W.Gowing, Geophrey J.Kajiru, Evelyn A.Lazaro, Omari B.Mzirai, Johan Rockström, Filbert B.Rwehumbiza,"***Rainwater Harvesting For Natural Resources Management,*** Sida's Regional Land Management Unit, 2000
2. Justine A., Antoinette K., Marc N., Rob de N., Ton van de Ven," ***Water harvesting and soil moisture retention***", Agromisa Foundation, Wageningen, 2003
3. Mitiku H., ***The Experience of Water Harvesting in the Dry lands of Ethiopia: Principles and practices*** **,** Mekelle University ,Ethiopia , 2001.
4. Chow V.T., (E.d) hand book of ***Applied Hydrology***, McGraw-Hill, New York,NY,1964

WEB ADDRESSES

1. http://www.fao.org/docrep/u3160E/u3160E0p,"Water harvesting manual

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The trainers who developed the learning guide

No	Name	Qualification	Educational background	Region	E-mail
1	Belay Beyene	B	NRM	Oromia	belaybe.bb@gmail.com
2	DerejeSiyoum	B	Agr. Engineering	Oromia	derejeseyoum99@yahoo.com
3	AbunaAliberki	B	SWC	oromia	abuyaali459@gmail.com
4	Mohamed Kabo	B	NRM	Oromia	mohakabo.kabo1@gmail.com
5	Sekata Kenea	A	NRM	Oromia	sekata.ken@gmail.com
6	Terefa Adugna	A	NRM	Oromia	terefa1234@gmail.com