THE UNITED REPUBLIC OF TANZANIA

MINISTRY OF WATER

GUIDELINES FOR RAINWATER HARVESTING IN TANZANIA

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FOREWORD

Freshwater is a basic natural resource, which sustains life and provides for various social and economic needs. Tanzania is blessed with abundant freshwater resources in the form of rivers, lakes, groundwater aquifers, ponds, reservoirs and wetlands. Despite its numerous water bodies, Tanzania still experiences severe and rampant water shortages in many areas because of climate variability and uneven temporal and spatial distribution of the resource itself. In some areas water supply is either, unavailable; inadequate; and or unreliable. Rainwater Harvesting (RWH) has thus regained its importance as a valuable alternative or supplementary to available water supplies in underserved areas. RWH is not a new technique rather it has been used throughout the history.

In order to facilitate proper RWH practices, the Government has decided to prepare RWH Guidelines to promote its usage in the country. The Guidelines are intended to advocate, guide and enable the proper application of rainwater harvesting techniques to optimize quantity and quality of the harvested rainwater for social-economic development. The RWH Guidelines are in line with the National Water Policy (2002) under Section II, sub-section 4.2 & 4.6 which states that, “where feasible and necessary, rainwater harvesting will be employed as a means of increasing the availability of water resources and that the role of the Ministry is to promote, guide and encourage RWH technologies”. Moreover, the Water Resources Management Act No. 11 of 2009, section 12, give citizens the right to establish individual rainwater harvesting system for domestic purposes within their premises.

These Guidelines have been prepared with the intention to assist responsible parties in the planning, designing, construction, operation and maintenance of rainwater harvesting systems in Tanzania. Parties include individuals, consultants, contractors, government and non-government institutions, private sectors including all other stakeholders as far as rainwater harvesting is concerned. Therefore, these Guidelines summarize the knowledge and or requirements on planning, designing, construction, operation and maintenance, and water quality of rainwater harvesting systems by using roofs, roads, small dams, sand dams, and lined water ponds.

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PREFACE

The biggest challenge that the 21st Century is currently overcoming is the growing water shortages due to ever increasing water demands caused by a number of factors such as increase in population, rapid urbanization, over utilization coupled with inadequate management and development of water resources. Actual or potential water shortages can be relieved if Rainwater Harvesting (RWH) is practiced more widely by our communities. In some localities where rainfall is in excess and frequent, rainwater harvesting technology can be relied on as a sole water source. Alternatively, it can be performed as a dual water supply practice, and as a supplement.

The National Water Policy (2002) states that, the objective of the Water Resources Management is to develop a comprehensive framework for promoting the optimal, sustainable and equitable development and use of water resources for the benefit of all Tanzanians, based on a clear set of guiding principles. Likewise, Part X of the Water Recourses Management act No 11 of 2009, provides directive on the procedures to follow when developing large scale rainwater harvesting like dams including the safety of the same. Thus, these Guidelines are developed to set a guiding principles in rainwater harvesting practices.

The Guidelines are intended to be used as a reference and guiding document which contain information on basic requirements for selection and construction of RWH systems, and appropriate operational and maintenance practices. In these Guidelines, rainwater harvesting techniques is divided into two basic groups which are rooftop catchment techniques and ground catchment techniques. Safety of a rainwater harvesting system, in terms of risk of contamination or pollution and possibility of structural failure for storage systems are important considerations during rainwater harvesting planning are described in these Guidelines.

This document has mostly concentrated on improving knowledge and skills on RWH techniques which are commonly applied in the country, with the expectation that it will enable increase in the extent and efficiency of the RWH techniques. Where necessary, the use of these guidelines shall be supplemented with information from the following documents: Water Supply and Sanitation Design Manual prepared by Ministry of Water (2020), the Tanzania Drinking Water Quality Standards and other national and internationally accepted references.

ACKNOWLEDGEMENT

The Ministry of Water would like to thank all who indirectly and directly contributed to the preparation of the contents of these guidelines.

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EXECUTIVE SUMMARY

Rainwater harvesting (RWH) is simply collecting, storing and purifying the naturally soft and pure rainfall that fall upon the roof and or land surfaces. The harvested rainwater may be utilized for both potable and non-potable requirement such as drinking, cooking, laundry, landscape irrigation and even other economic activities depending on the scale of the harvest. The application of an appropriate rainwater harvesting technology can make possible the utilization of rainwater as a valuable and necessary water resource. Rainwater harvesting has been practiced for years in rural areas where there is appreciable amount of rainfall but not used in centralized water supply systems. In recent years, RWH has started to be practiced in urban and peri-urban areas to supplement the existing water supplies. The practice has been applied for various type of building such as housing, institutional and commercial. Even though the application of RWH has been ongoing, there were no specific guidelines in designing and maintaining RWH systems. Therefore, the Government has decided to come up with these Guidelines for the purposes of promoting the application of RWH.

RWH systems are diverse and complex in nature, with catchment surface area ranging from few square meters to hundreds of square kilometers. Depending on the nature of the catchment, conveyance and storage facility, the harvested water can highly vary in terms of quantity and quality. As such, it is imperative to properly guide contractors, consultants, individual land owners, and others in planning RWH systems. Communities and individuals can meet their daily water demand under dual water supply practice, with RWH as a prime source. In planning for RWH system, there are essential parameters which have to be considered, including climate, catchment, safety, water demand and storage capacity. Several criteria may be necessary to consider when planning for development of RWH such as cost (investment; operation; and maintenance) which usually varies depending on the materials and infrastructures used in various techniques, location and topography. RWH infrastructures should be free from other uses and catchments which are close to pollution sources and lands of that nature should be avoided. Moreover, hydrological and hydrogeological conditions including social & environmental considerations should be considered in selecting appropriate type of RWH.

Design and construction of rainwater harvesting systems can be categorized in deferent types such as roof rainwater harvesting system which is mainly tank-based, small earth dam, rainwater runoff water harvesting into open water bodies mostly pond like structures, rain water collection from road and by using sand dams. Maintenance is key aspect in sustaining the RWH system. With the initial investment in installing the RWH, the organization must be able to monitor their investment in the form of maintenance performance, which will ensure that, the building owner achieves the value for money.

In order to have sustainable rainwater harvesting systems, this document provides guideline on design, operation and maintenance of RWH system, knowledge and formalized measures to protect rain water from contaminations, risk assessment and quality control mechanism. Also, community involvement in terms of awareness creations and technology transfer is part of these guidelines.

Dr. George V. Lugomela
DIRECTOR OF WATER RESOURCES

LIST OF ABBREVIATIONS

HH	House Hold
Lpd	Liters per Day
LGAs	Local Government Authorities
LDPE	Low Density Polyethylene
LVEMP	Lake Victoria Environmental Management Project
MoW	Ministry of Water
NAWAPO	National Water Policy
NGO	Non-Governmental Organization
NTU	Nephelometric Turbidity Unit
O&M	Operations and Maintenance
PVC	Polyvinyl Chloride
RWH	Rainwater Harvesting
RWS	Rural Water Supply
SODIS	Solar Disinfection
WASH	Water, sanitation and hygiene
WHO	World Health Organization
WSDP	Water Sector Development Program

DEFINITION OF TERMS

Agri-film is a tough, wide width black low density polyethylene (LDPE) film tailor made for lining applications.

Catchment

A catchment is any surface or land from which water is collected.

Cistern

A Cistern is an above or below ground tank used to store water, generally made of galvanized metal, plastic, fiberglass, Ferro cement or concrete.

Chlorination

The use of chlorine for disinfection of water

Contaminant

Any harmful or undesirable substance found in water. Contaminants include dust particles, microorganisms, dissolved naturally occurring minerals, human-generated chemicals, and radiological materials.

Contamination

Contamination is the presence of pollutants or other unwanted materials in water, in a concentration that makes the water unfit for its intended use.

Dam

Is a barrier constructed in a watercourse to hold backwater and raise its level.

Filtration

Is a physical removal of water contaminants by means of physical separation from the outflow. The process is carried out by passing water through a permeable layer of inert material (mostly sand) housed in a media filter. Also, through fibrous material.

First flush

It is the initial runoff from a catchment following the start of a rainfall event which contains higher loads of contaminants.

Pollutant

Is defined as a foreign substance that adversely affects water quality

Pollution

Water pollution occurs when waste products or other substances, e.g. effluent, litter, refuse, sewage or contaminated runoff, change the physical, chemical, biological or thermal properties of the water, adversely affecting water quality, living species and beneficial uses

Rainwater

Are drops of fresh water that fall as precipitation from the clouds.

Rainwater harvesting

It is the gathering, or accumulating and storing of rainwater for different uses.

Rainwater harvesting system

Water system for utilizing rainwater, consisting of a cistern, pipe, fittings, pumps and/or other plumbing appurtenances, required for and/or used to harvest, store and distribute rainwater

Run-off

Run-off is the term applied to the water that flows downslope after falling on the surface in the form of rain.

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CHAPTER ONE: INTRODUCTION

1.1. Background

Water supply in Tanzania is provided through a number of sources. Currently the major sources are boreholes, springs, rivers and lakes. Rainwater harvesting technologies are also implemented in various areas for collecting and storing rainwater for different uses, mostly agricultural and domestic uses.

With the average rainfall received in most areas in Tanzania being relatively high, RWH is an option which is technically feasible, easy to operate and affordable even to poor communities.

Rainwater harvesting is practiced to supplement water supply from the above mentioned sources. With the existing climate change phenomenon whereby the conventional water sources are greatly affected, it is imperative that RWH should be considered as a potential source of water, especially in the rural areas where availability of water from other sources is still a challenge. RWH systems are easy to operate and are affordable even to poor communities. With proper operation, RWH systems involve minimal negative impacts on natural resources and the environment.

In order to facilitate proper RWH practices, the Government has decided to prepare a guiding document, which will enable the proper application of RWH techniques to optimize quantity and quality of the harvested rainwater for social-economic development. These guidelines are intended to be used by all parties involved in RWH including designers, contractors, individual owners and other stakeholders such as NGOs, Investors, Regulators and the general public. The guidelines cover roof, charco dam, sand dam and catchment lined methods of RWH.

1.2. Status of water access in Tanzania

The Water Sector Development Program (WSDP), which has been under implementation since 2006, has considerably improved accessibility of Water Supply Services in the Rural and Urban areas of Tanzania. Currently, an average of 68.5% of the rural population and 84% of the urban population in the country is having access to Water Supply Services (MoW, 2019).

In Tanzania, large scale rainwater harvesting methods as alternative measures towards increasing water supply coverage in rural and urban areas have been in application since 1960s. Currently there are more than 710 dams in Tanzania, which collect rainwater for various purposes, and over 10,000-roof rainwater harvesting systems.

1.3. Rationale for the RWH Guidelines in the Country

The need for establishing RWH Guidelines has emerged as a result of the following factors:

i. Lack of standardized guidance on best practice and techniques for RWH.
ii. Lack of basis for the establishment of legal legitimacy for enforcement of RWH.
iii. Lack of basis for the establishment of RWH standards.
iv. Limited awareness, knowledge, adoption and skills on RWH.

1.4. Objective of the Guidelines

The goals of these guidelines are:

i. To guide on the applicability of the various methods, techniques and facilities of RWH.
ii. To highlight considerations required for ensuring effective and efficient RWH.
iii. To guide on the appropriate selection of RWH storage methods and facilities.
iv. To guide on optimization of the quantity and quality of Harvested Rainwater.
v. To set precedence towards institutionalization of appropriate legal requirements for RWH.

1.5. Scope

These guidelines summarize the knowledge or requirements on planning, designing, construction, operation and maintenance, and water quality of RWH systems by using roofs, roads, small dams, sand dams, and lined water ponds.

CHAPTER TWO: PLANNING FOR RAINWATER HARVESTING

RWH systems are diverse and complex in nature, with catchment surface area ranging from few square meters to hundreds of square kilometers. Depending on the nature of the catchment, conveyance and storage facility, the harvested water can highly vary in terms of quantity and quality. As such, it is imperative to properly guide contractors, consultants, individual land owners, and others in planning RWH systems. Communities and individuals can meet their daily water demand under dual water supply practice, with RWH as a prime source.

2.1 Types of Rainwater Harvesting Techniques

Rainwater harvesting techniques can be divided into two basic groups, rooftop catchment techniques and ground catchment techniques.

Rooftop rainwater harvesting techniques are the most widely used type of RWH especially in urban areas.

Ground catchment techniques enable collection of water from a larger ground surface. They include:

i. **Small dams:** these are dams having maximum capacity of 10,000 m^3 and height of the wall not exceeding 5m. The dams are divided into three main categories namely: Charco dams, Hillside dams and Valley dams.

ii. **Sand dams:** these are structures constructed within a seasonal sandy river or stream to capture and store base flows. This technique is widely used in semi-arid rural areas (i.e. Shinyanga, Simiyu. Singida and Tabora Regions)

iii. **Rainwater collected from roads:** this is one of the technique whereby water flowing through road ditches, side drains, depressions, paved area and culverts is collected and stored for different uses. Pan, ponds and small dams are used to store water collected from roads. Also, such water can serve for groundwater recharging purposes.

iv. **Lined water bodies/ponds:** LDPE and PVC liners are normally used to line the pond footprint area in order to reduce loss of water through seepage. This is normally applicable within the porous geological areas.

v. **Paved Catchment:** the catchment area is paved by either clay (mud) or concrete liners, and rainwater is normally collected into sub-surface storage facilities.

2.2 General Conditions to consider in Planning for RWH

In planning for a RWH technology application there are essential parameters which have to be considered, including the ones highlighted below.

2.2.1 Climate

In planning for RWH, rainfall data for the area under consideration should be obtained in order to estimate the amount of water expected to be harvested and size of RWH system components.

The following rain data are important:

i. Rainfall quantity, intensity
ii. Rainfall trends (daily, monthly, seasonal, annually).

2.2.2 Catchment

Size and runoff coefficient of the rainfall catchment are important criteria in planning for RWH. Roof catchments are often used when collected water is for domestic purposes, and sometimes used as portable water. The relatively high runoff coefficient of the roofing materials enable higher collection efficiency compared to ground catchment techniques. However, catchment condition at a given time may impact on the quality of the rainwater harvested.

For ground catchment techniques, the following catchment specific factors affect the amount and quality of harvested rainwater:

i. Soil type

The porosity of a soil determines the water storage capacity and affects the resistance of water to flow into deeper layers. The highest infiltration capacities are observed in loose, sandy soils, while heavy clay or loamy soils have considerable smaller infiltration capacities. Soils with low infiltration rate has high yield compared to soils with high infiltration rate. The origin and composition of specific soil type affects the quality of water to be collected. To reduce the effect of soil type on the amount of harvested water, lining of the surface is usually done as already mentioned under types of rainwater harvesting techniques.

ii. Vegetation

A dense vegetation cover shields the soil from the raindrop impact and reduces the crusting effect. In addition, the root system as well as organic matter in the soil increases the soil porosity thus allowing more water to infiltrate. Vegetation also retards the surface flow particularly on gentle slopes, giving the water more time to infiltrate and to evaporate. This means that an area densely covered with vegetation, yields less runoff than bare ground.

iii. Slope and catchment size

Usually, steep slope plots yield more runoff than those with gentle slopes. In addition, the quantity of runoff decreases with increasing slope length, mainly due to lower flow velocities and subsequently a longer time of concentration (defined as the time needed for a drop of water to reach the outlet of a catchment from the most remote location in the catchment). This means that the water is exposed for a longer duration to infiltration and evaporation.

Rainfall coefficients:

$$\textbf{Runoff [mm] = K x Rainfall depth [mm]} \tag{2.1}$$

The coefficient K, which describes the percentage of runoff resulting from a rainstorm, is however not a constant factor. Instead its value is highly variable and depends on the above-described catchment-specific factors and on the rainstorm characteristics.

$$K = \frac{Run\ off\,(mm)}{Rainfall\,(mm)} \tag{2.2}$$

As explained above, the runoff coefficient incorporates the effect of evaporation, infiltration, and any additional water loss. In case of rooftop harvesting, additional loss can occur through spills and leaks resulting from poor positioning and/or sizing of gutters and/or pipes.

An average value for a catchment can be found by carrying out actual measurements until a representative range is obtained.

2.3 Safety

Safety of a RWH system, in terms of risk of contamination or pollution and possibility of structural failure for storage systems are important considerations during RWH planning.

2.4 Water Demand

Rainwater harvesting planning needs evaluation of water demand (population to be served) and desires in order to establish dependable numbers for annual, monthly, and daily water usage. Some RWH systems will supply only a portion of water needs for a client while other systems are required to provide all of a client's water demand. Distribution systems vary and may include all or a combination of the following: drinking water, fountains, irrigation, water gardens, and livestock water.

2.5 Storage capacity

The size of storage available for the harvested rainwater impacts on meeting the desired demand for the project. An optimal storage sizing will aim at ensuring rainwater availability for meeting the demand even during the dry season, with effective utilization of rainwater collected (minimal rainwater losses through overflow).

2.6 Factors for selecting type of RWH

Several criteria maybe necessary to assess when considering practicing RWH, these have been summarized below:

2.6.1 Cost (Investment and O&M costs)

The cost of various techniques usually varies depending on the materials and infrastructures used in various techniques. Costs for ground catchment techniques are usually higher than costs for roof catchment techniques. As an alternative, the cost of installing and operating a rainwater harvesting systems should not be substantially higher than other water supply options.

2.6.2 Location and Topography

Location and topography play a vital role in adoption of ground catchment techniques, as they require land with appropriate surrounding and slope.

2.6.3 Land Availability

The land on which RWH infrastructure is, should be free from other uses. Whereas ground catchment techniques are applicable where huge size of land is available, roof catchment techniques can be applied with only small size of land and in a decentralized manner.

2.6.4 Source of Pollutants

Catchments, which are close to pollution sources, should be avoided. These may include rooftops in the proximity of industrial smokes, dust and tree litters, and ground catchments, which are exposed to wastes from animal and human activities. The quality of rainwater should be safe for human consumption.

2.6.5 Hydrological Conditions

Rainfall amount and its trend should be considered in selecting appropriate type of RWH. Ground catchment techniques are appropriate in areas with high amount of rainfall in short periods of the year, whereby huge volume of water can be harvested and stored for use during dry season.

2.6.6 Social & Environmental Considerations

Water harvested for drinking and other purposes has to be culturally accepted by the users. Moreover, the functioning of a RWH system should have minimal negative implication on the environment, and in the long run contribute to improved water cycle, reduced flooding effects and recharge of groundwater sources among others.

2.6.7 Geological Conditions

The amount of water, which can be harvested, on the ground catchment is relative to the nature of soil, whereas physical and chemical composition of soil also affects the quality of water.

CHAPTER THREE: DESIGN AND CONSTRUCTION OF RAINWATER HARVESTING SYSTEMS

3.1 PART A: ROOF RAINWATER HARVESTING SYSTEMS

As stated in a 2012 human settlement survey of the Tanzanian mainland, 61.9% of households had modern roofs, which includes iron sheets, tiles, and concrete, whereas the rest of the households still utilized either grass, thatch, or mud (NBS 2013). As a majority of the roofs are harvestable, there is room for advocating rooftop RWH adoption in households within Tanzania.

3.1.1 Factors determining type or system of roof RWH Water Quantity

The total volume of rainwater available from any roof top surface is a product of total rainfall and the surface area of collection. A runoff coefficient is usually applied to account for infiltration, evaporation and other losses and it varies depending on roof type. For metal rooftops it may vary from 0.8 to 0.95, while for tiled rooftop from 0.6 to 0.9. In order to estimate the average annual runoff from rooftop area in any location runoff coefficients should be established and used in computation.

i. Rainfall Pattern

Rainfall pattern as well as total rainfall, will often determine the feasibility of a rainwater harvesting system. In areas where rainfall occurs regularly throughout the year, implies that the storage requirement is low and hence the system cost will be correspondingly low and vice versa.

ii. Collection Surface Area

For roof top rainwater harvesting, the collection areas are restricted by the size of the roof of the dwelling unit. Sometimes other surfaces such as terrace, balconies and other projections are used to supplement the roof Top collection area.

iii. Storage Capacity

The storage tank is usually the most expensive component of rainwater harvesting system. Hence careful analysis is required for design of storage tank capacity, whose cost may vary depending on the material type selected, tank shape, labour input demanded, operation and maintenance load.

iv. Intensity of Rainfall

The maximum intensity of rainfall will decide the peak flow, which is to be harvested, and depending upon the peak flow, the gutter size for sloping roof and diameter of drainage pipe has to be calculated. This factor is deemed to be vital during sizing of gutter.

3.1.2 Rainfall data collection and analysis

The historical rainfall data is available in Tanzanian Basin Water Board and Tanzania Meteorological Agency (TMA). The rainfall data available in the country are daily rainfall data, which require checkup, and validation before using for RWH system design. From a reasonable time, series, monthly and annual rainfall can be established. A 10-year daily rainfall data is recommended in order to design an effective and sound RWH system.

i. Monthly Rainfall Estimation

Rainfall estimates should always be prepared for a specific locale, using the best data that apply to that area. Monthly rainfall data are more easily available and for longer durations from TMA offices and basin water boards. Two different estimators of monthly rainfall are commonly used: average rainfall and median rainfall. Taking the sum of historical rainfall and dividing by the number of years of recorded data calculates average annual rainfall.

ii. Estimation of quantity of water

The quantity of water to be harvested should be established based on the depth of rainfall, catchment area and runoff coefficient of the roofing materials. Excel is a common tool whereby with input of the parameters shown in the equation below, one can more accurately get estimation for either daily or monthly or annual amount of water available for harvesting.

$$V = K \times A \times D \qquad (3.1)$$

Whereby:

V= the quantity of the harvested water in Cubic meters

K= Runoff coefficient (unit less) that depends on the used roofing materials

A= Catchment (roof) area in square meters

D= Rainfall depth in meters (daily or monthly or annual)

3.1.3 System Components

A roof rainwater harvesting system consists of the following components:

i. Catchment area (roof)
ii. Conveyance system (gutters and down pipes)
iii. Storage (tank or cistern)
iv. Outlet components (treatment, distribution)

3.1.3.1 Catchment (Roof)

Recommended roof configurations and roofing materials

The catchment area is the first point of contact with rainfall. For the vast majority of tank-based rainwater harvesting systems, the catchment area is the roof surface. There are some important factors about the roof to consider when planning for a RWH system. The following are the considerations required to be taken when selecting RWH by using roof.

Roof Material

Rainwater harvesting can be done with any roofing material if it is for non-drinking use only. For potable use of rainwater, the best roof materials are metal, clay, and cement products. Asbestos roof materials should not be part of a system to provide drinking water due to health concerns. Asphalt shingles can contribute grit to the system and need a pre-filter for the water before it enters the tank or cistern. Thatched roof are also not recommended since they are prone to microbiological contamination. Lead materials in any form should not be used in the system.

Slope

The slope of the roof affects how quickly water will runoff during a rain event. A steep roof will shed runoff quickly and more easily clean the roof off contamination. A less-steep, flatter roof will cause the water to move more slowly, raising the potential for contamination to remain on the catchment surface.

Sizing a roof area (Catchment area)

The size of the catchment area or roof will determine the volume of rainwater that can be harvested. The area is based on the “footprint” of the roof, which can be calculated by finding the area of the building and adding the area of the roof’s overhang.

Note: It is important to understand that regardless of the pitch, the shape, or the complexity of any roof surface, it is the overall footprint of the building that determines the collection area.

3.1.3.2 Conveyance system

The conveyance system is a fancy term for the gutters and downspouts. These are basically the networks of pipes that move the water from the roof surface to the storage containers. When selecting gutters and downspouts, it’s important to consider three factors: sizing, proper installation, and aesthetics.

Sizing of conveyance

a) Gutters

The gutters should be sized so that they adequately move rainwater runoff from a 100-year storm event. A 100-year storm event has a 1% chance of happening every year and produces rainfall with great intensities.

Places that have intense storm events would need wider gutters than places with less intense rain events. As a general rule, gutters should be at least 5 inches wide.

b) Downspouts

Provide one square inch of downspout area for every 100 square feet of roof area. For example, a 2″ x 3″ downspout (6 square inches) can accommodate runoff from a 600 square foot roof. A 3″ x 4″ downspout (12 square inches) can accommodate runoff from a 1,200 square foot roof. The same rule can be used for circular PVC piping.

c) Proper Installation

Gutters are used to convey water from the roof to pipes to the storage tank or cistern. For both gutters and downspouts, proper installation is critical so that they function properly and will not be a safety concern. We recommend the following.

i. Rounded-bottom gutters because they limit debris buildup.

ii. Slope gutters at 1/16″ per foot of length to adequately drain them.

iii. Keep the front of the gutter 1/2 inch lower than the back to prevent water from splashing against the building.

iv. PVC pipe should be painted to reduce UV sunlight breakdown

v. If a straight run of gutter exceeds 60 feet, use an expansion joint.

vi. Down pipes should provide 1 square inch of opening for every 100 square feet of roof area.

vii. The maximum run of gutter for one down pipe is 50 feet.

viii. The conveyance piping from the gutter system to the cistern or filter should be preferably of PVC of appropriate diameter.

ix. Do not exceed 45-degree angle bends in horizontal pipe runs and at minimum provide 1/4-inch slope per foot.

3.1.3.3 Storage System

a) Tank Capacity

In general, the larger the tank, the greater the volume of rainwater that can be collected and stored during rainfall events (collection efficiency). However, this is true only up to a certain point–after which other factors, such as local rainfall patterns, roof catchment area and rainwater demand, will limit the amount of rainfall that can be collected and utilized by the system. Thus, for a RWH system with a given roof catchment area, rainwater demands and local rainfall patterns, the storage capacity of the tank can be described as follows;

Too small–Much of the collected rainwater overflows during rainfall events. Significant improvements in collection efficiency can be achieved from minor increments in storage volume.

Optimum range– Rainwater tanks in this range provide the best balance between collection efficiency of the RWH system and minimizing its size and cost.

Too large– Rainwater tanks in this range rarely fill to capacity. A smaller tank can be utilized without a significant drop in the collection efficiency of the RWH system. An over-sized rainwater storage tank, however, may be desirable if storm water management is a strong driver for installing a RWH system.

b) Tank sizing Method

In order to establish the volume of water several methods are applicable depending on the use of the stored water and catchment characteristics, material used for construction of the catchment area (roof area). The first method is demand driven approach and the second one is the combination of supply and demand approach.

i. Demand driven approach

The size of the catchment area and tank should be enough to supply sufficient water for the users during the dry period. Assuming a full tank at the beginning of the dry season (and knowing the average length of the dry season and the average water use), the volume of the tank can be calculated by the following formula:

$$\mathbf{V=txnxq} \qquad \mathbf{(3.2a)}$$

Whereby:

V = volume of tank, in liters; length of the dry season (days);
n = number of people using the tank; and
q = consumption in liters per capita per day.
t = Dry period in Days

If, for example, 20 lpd (q) is agreed upon and a dry period of 100 days (t) is normally not exceeded, a storage volume of $10m^3$ would be required for a family of 5 members (n).

$$\mathbf{V = 100\ (t) \times 5\ (n) \times 20\ (q) = 10\ 000\ liters\ or\ 10\ m^3} \qquad \mathbf{(3.2b)}$$

The required catchment area (that is the area of the roof) can be determined by dividing the volume of the tank by the accumulated average rainfall volume (in liters) per unit area (in m^2) over the preceding wet months and multiplying this with the runoff coefficient, which varies from 0.8 to 0.95 depending upon type of roof. *Note: This approach is applicable in abundant rainfall catchments areas.*

ii. Combination of supply and demand approach

The optimal tank sizes can be calculated using the following steps

i. Determine the local rain water precipitation volume this can be determined through rainfall data obtained in Basin Water Board and Tanzania Meteorological Agency (TMA) and establish yield of the catchment

ii. Calculate the rainwater catchment area of the roof including all projections (independence of the roof slope)

iii. Determine the approximate water demand (irrigation, domestic use, industrial, livestock etc.)

iv. Multiply with a reserve factor of one month per year so as to cater for seasonal variations

v. Calculate the average of Catchment yield and calculated demand and multiply by 30days over 365 days to obtain the required storage tank.

Annual Precipitation value (P)	X	Projected roof area (A)	X	Roof Type correction factor (R)	=	Rain yield per year (Y)
$0.4m^3/m^2$	X	$100m^2$	X	0.8		$32m^3$

Note: *this is given as representative example*

The final storage of the tank is calculated by using the following equation

$$V = \frac{(Y+D)}{2} x \frac{30}{365} \qquad \textbf{(3.2c)}$$

Whereby: V= Volume of water to be stored

Y= Rain yield per year

D=Annual Demand

30 =Thirty days (1 Month) as reserve factor for seasonal variations

iii. Modelling and Water balance application

In this approach, water balance equation taking into account the historical rainfall data, catchment size, demand, targeted population, can be utilized to estimate optimal storage size that would ensure high rainwater usage (minimal loss by overflow), and minimal no water days with respect to the available rainfall and catchment size. The user can assess performance of various storage size options, and select the size that meets his/her specification, and whose cost they can afford. This approach is possible even under excel environment, and will enable a designer/user to capture the variation of rainfall during the year/years hence estimate the respective overflow days as well as days of deficit. Daily and monthly data can be both utilized, with the former capturing and accommodating inter-annual variability. Figure 3-1 illustrates water balance scenario within a storage system.

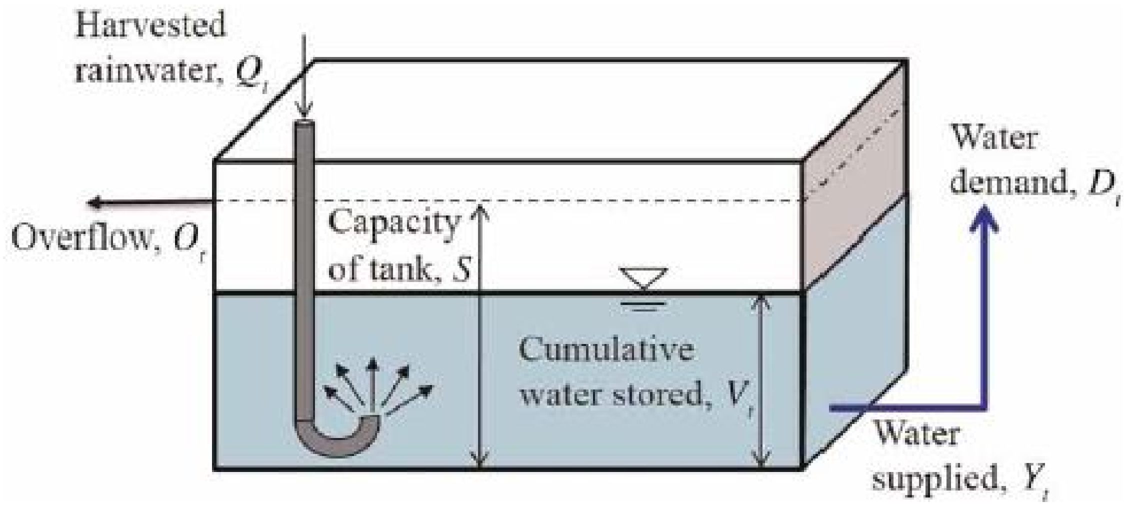

Figure 3-1: Schematic diagram of rainwater fluctuation in the tank

c) Materials of the tank

Various material can be utilized in constructing storage tanks for rainwater harvesting. Selection criteria may take into consideration potential implications of health, cost, and skills required. Table 3.1 below showcases considerations for tank material with respect to where it will be placed within a compound.

Table 3-1: Placement considerations for different storage tank material

Storage tank selection		
Placement	**Type**	**Considerations**
Above grade (Outside)	i. High-density Polyethylene(HDPE) ii. Metal iii. Concrete iv. Block/brick work v. Mortar jars vi. Ferro cement	i. Overflow discharge location. ii. Property right-of-way and setbacks. iii. No cost or very low site excavation costs. iv. Many different volumes and tank dimension. v. Location of outlet taps in order to avoid tapping of settled particles
Below grade (Outside)	i. High-density Polyethylene(HDPE) i. Concrete ii. Ferro cement	i. Overflow discharge location and method. ii. Location of buried service lines. i. Located at the lowest elevation from the conveyance pipe to

Storage tank selection		
Placement	**Type**	**Considerations**
		allow gravity inflow of rainwater ii. Mechanisms for safe water accessibility with minimal health implications iii. Site accessibility for excavation machinery. iv. Location of access hatch (man hole) for annual service. v. Property right-of-way and setbacks. vi. Structural loading if under a driveway or an area with added weight at surface. vii. Excavation increases overall system cost. viii. Many different volumes and tank dimension.
Building Integrated	i. In-situ cast Concrete	i. Overflow discharge location and method. ii. Mechanisms for safe water accessibility with minimal health implications iii. Interior must be sealed and waterproofed. iv. Tank included on the foundation plan of architectural drawing set. v. Property right-of-way and setbacks. vi. Tank size and dimensions can be designed to best fit each site. vii. Concrete costs allow for greater economies of scale – larger tanks can be created compared to the same cost for a smaller plastic

Storage tank selection		
Placement	**Type**	**Considerations**
		tank. viii. Potential for extra excavation increases overall cost of system. ix. Structural engineering is required. x. Volumes and tank dimensions can be adapted to each site.
Inside a Basement or heated Garage	i. High-density Polyethylene(HDPE) ii. Fiberglass iii. Concrete	i. Overflow discharge location and method. ii. Location of basement drain or sump pumps in close proximity to tank. iii. Mechanisms for safe water accessibility with minimal health implications iv. Tank size and dimensions must fit within allocated space. v. Engineered floor required – if not located on concrete floor. vi. Installation of tank before the floor plate is installed. vii. Venting of tank to exterior to release any noxious gas buildup. viii. No excavation costs. ix. Size of tank lessens usable floor space. x. Volumes and dimensions must be sized appropriately to fit within the chosen location.

d) Tank Location

The optimum location of a tank on a given site depends upon the required fall for the gravity flow conveyance network, as well as a broader range of issues, including:

i. Placement of tank –Storage tanks are commonly placed either above the ground or below the ground or Integrated within buildings. Table 3.3 summarizes the advantages and disadvantages of tank placement options.

ii. Desired/required rainwater storage tank capacity,

iii. Geological conditions,

iv. Site conditions – site grading, accessibility, and space availability,

v. Proximity to the following:

- Catchment area,
- Overflow discharge location,
- Control components of pump and pressure system,
- Other site services (i.e. gas, electricity, water, storm water, wastewater, phone, or cable lines).

Following consideration of each of these issues, it is likely that trade-offs must be made – for instance, the optimum tank storage capacity may be too large to be accommodated at the site, or the optimum location for the tank may be in an area that is difficult to access.

Table 3-2: Advantages and disadvantages of storage tank placement options

Tank Placement	**Advantages**	**Disadvantages**
Above Ground Storage	• No site excavation costs associated with below-ground storage • Water extraction can be by gravity and by taps • Inspection of leakages and cracks is simplified	• High cost due to increased investment in design and construction for addressing the challenge of water pressure distribution since it is exposed on the ground. • Takes up yard space.
Below Ground Storage	• Does not take up yard space • Surrounding ground gives support, hence reduced investment in wall thickness	• Location must be free of buried service lines and accessible by excavation machinery • Water extraction may require pump system, hence costly • Inspection/detection of

Tank Placement	Advantages	Disadvantages
		cracks and leakages maybe difficult • Excavation requires additional site work which increases cost of RWH system • Prone to contamination by infiltration from surrounding ground
Integrated Storage	• Storage tank capacity can be customized for each site • Permits year-round operation • Little or no excavation required	• Engineers must design storage reservoir such that it is structurally sound and does not leak into the building

e) Considerations during selection and installation of Tank or Cistern

i. The storage tank (cistern) must be sized properly to ensure that the rainwater potential is optimized. See the previous section regarding capacity for sizing information.

ii. Cisterns can be located above or below ground.

iii. The best materials for cisterns include concrete, steel, Ferro-cement, and fiberglass.

iv. When ordering a cistern, specify whether the cistern will be placed above or below ground and if the cistern will be used to store potable water. (Fiberglass cisterns are constructed differently to meet the various criteria.)

v. If using a manufactured tank designed to hold drinking water, the tank should conform to the published specifications

vi. A cistern should be durable and watertight.

vii. A smooth clean interior surface is needed.

viii. Joints must be sealed with non-toxic waterproof material.

ix. Manholes or risers should have a minimum opening of 24 inches and should extend at least 8 inches above grade with buried cisterns.

x. Fittings and couplings that extend through the cistern wall should be cast-in-place (Cavities facing upward) surrounding the base of the inlet pipe. The blocks can be 8"x 8"x16" blocks with the pipe exiting one inch above the bottom of the cistern. Baffles to accomplish the same result can be made as part of fiberglass cisterns. This is not a concern for cisterns that always have a large reserve.

xi. The use of two or more cisterns permits servicing one of the units without losing the operation of the system.

xii. Have a fill pipe on the cistern for adding purchased water as a backup.

xiii. Have a cover to prevent mosquito breeding and algae growth due to sunlight exposure.

xiv. Underground storage cisterns should be placed at least 15 m away from animal stables and/or toilets, waste water treatment systems e.g. septic and soak away pits

xv. In above ground tanks, the outlet tap should not be located very close to the bottom of the tank (at least 4 inches) in order to prevent mix up with deposited sediments/particles.

xvi. For above ground tanks the collection chamber should be properly designed to avoid water stagnation during operation.

3.1.3.4 Treatment system

The following are methods used to minimize or prevent water contaminations.

i. Dirt, debris, and other materials from the roof surface may contaminate the rainwater. The best strategy is to filter and/or flush out the contaminants before they enter the cistern.

ii. A coarse screen on the gutter, on or in the downspout and on storage is helpful.

iii. A primary strategy is to reject the first wash of water over the roof. The first rainfall will clean away any contaminants and is achieved by using a "roof washer.

iv. The main function of the roof washer is to isolate and reject the first water that has fallen on the roof after rain has begun and then direct the rest of the water to the cistern. Roof washers are commercially available and affordable, reliable, durable, and require minimal maintenance. Table 3-3 summarizes recommendations on depth of rainfall to be flushed out in order to achieve a certain targeted turbidity level.

v. Roof washing is not needed for water used for irrigation purposes. However, if used it will keep out debris and reduce sediment buildup. A sand filter can also be used.

vi. Removing the water from the cistern can be achieved through gravity, if the cistern is sufficiently high enough, or by pumping.

vii. Most cases will require pumping the water into a pressure vessel similar to the method used to withdraw and pressurize water from a well (except a smaller pump can be used to pump from a cistern).

viii. A screened 1.25-inch foot valve inside the tank connected to a 1.25-inch outlet from the cistern approximately one foot above the bottom (to avoid any settled particles) will help maintain the prime on the pump. A float switch should be used to turn off the pump if the water level is too low.

ix. Another alternative is the use of a floating filter inside the cistern connected to a flexible water line. This approach withdraws the water from approximately one foot below the surface, which is considered to be the clearest water in any body of water.

x. The water that will be used for potable purposes can pass through an inline purification system or point of use water purification system. Other uses for the water do not need additional purification. (Water purification options are not discussed in the Sourcebook). Additionally, the following maybe considered:

- If community or individual is against the ingestion of any kind of chemical disinfectors such as chlorine, one can select other disinfection treatment methods such as Boiling, UV light technologies, filtration (membrane, ceramic, granular media), solar disinfection for drinking.
- Boil water for 5 minutes or buy UV water disinfection information from nearest market. 1-micron filter slowly allow water to pass thus, good only for small amount of water.
- If you have doubt in your water, collect your water sample for faecal coliform test.

Table 3-3: Recommended first flush amount in mm of rainfall (Thomas & Martinson 2007)

Initial run-off turbidity (NTU)	**Target turbidity (NTU)**			
	50	**20**	**10**	**5**
50	0	1.5	2.5	3.5
100	1	2.5	3.5	4.5
200	2	3.5	4.5	5.5
500	3.5	4.5	5.5	6.5
1000	4.5	5.5	6.5	7.5

Initial run-off turbidity (NTU)	Target turbidity (NTU)			
	50	20	10	5
2000	5.5	6.5	7.5	8.5

3.1.3.5 Distribution

The harvested rainwater can be distributed through taps positioned within storage tanks or in specified domestic points. Hygienic management of collection points is essential. Collection chambers should not favour water/mud ponding to avoid creating mosquito breeding sites. Gravel packs or similar attempts may be useful to allow overflowing water and spill out to seep into the ground quickly, leaving the collection chamber dry.

3.1.4 General Considerations

To optimize the yield, ensure safe water quality and reduce maintenance of the system, the following should be considered:

i. Ensure the roof surface is suitable for collecting quality rainwater

ii. Install roof gutters and down pipes of appropriate size and standards

iii. Provide gutter mesh system to prevent leaves and debris from blocking gutters

iv. Keep the gutters inclined between 3-5 degree

v. Keep bushes and trees away from roof and tank.

vi. Use good filter/roof washer to disallow dirt and particles.

vii. Fit insect proof screens to all pipe openings

viii. Fit appropriate sized First flush water diverter

ix. Provide water storage tank of sufficient capacity

x. Obtain potential of rainwater storage from Annex 1A and Annex 1B

xi. Ensure proper maintenance of system

xii. Block off or remove any possible access to your roof and tank by animals.

3.2 PART B: RAIN WATER HARVESTING BY SMALL EARTHDAMS

Rainwater harvesting by small dam is very important in rural areas so as to harvest water flowing in the valleys and seasonal streams.

3.2.1 Purpose and scope

The purpose of this chapter is to provide a guide to communities, technicians, farmers and others who are considering RWH by small dams for agricultural, livestock watering or domestic purposes. Various options are discussed and the development of ponds and small earth dams covered in detail. Guidance is provided on site investigation, design, construction, maintenance and repair.

Since site investigations, design and construction of medium and large size earth dams require experienced engineers and should not be constructed by field Technicians and farmers, they are not included in this handbook. Guidelines of Such kind of dams are covered in Dam Safety Guidelines of the Ministry of Water, which are the part and parcel of Water Resources Management Act No. 11 of 2009 and its associate Regulations; GN 237 of 2013.

3.2.2 Types of small earth dams

Small earth dams with storage capacities up to about 10,000m^3 and having embankments up to a height of about 5m are the subject of These guidelines, which covers their design, construction, operation and maintenance. Small earth dams can be built manually, using animal draught, a farm tractor, a crawler or bulldozer.

The three types of small earth dams described in these guidelines area as follows:

i. **Charco dams:** For almost flat land.
ii. **Hillside dams:** For rolling and hilly land.
iii. **Valley dams:** For seasonal watercourses and valleys.

3.2.3 Considerations before building small earth dams

Before constructing a small earth dam, or any type of communal water source, it is vital to confirm that the project is viable. To determine this, it is helpful to ask a few key questions at the outset, such as:

i. Will the water be clean enough, and if not, can the quality be improved?
ii. How much water is needed?
iii. How much water will the new source provide?
iv. Is the project cost effective?
v. Is it desirable by the community targeted?
vi. Is the project manageable in terms of operation and maintenance upon

project completion?

vii. Are the relevant conditions for the dam establishment met?

3.2.4 Total water storage requirement

To determine the total water storage requirement needed to meet a demand of 200 m^3 for ¼ acre per year two other factors, evaporation and seepage causing natural losses from any open reservoir need to be taken into account.

i. Evaporation loss can remove up to 2.5m depth of water per year from an open dam reservoir in a hot climate, although for a good estimate of this loss the evaporation rate in the specific location and the surface area of water must be known. A useful rule of thumb is that about 50% of the water in a reservoir is lost each year to evaporation.

ii. Seepage loss is also difficult to estimate because dam reservoirs are built of various soil types, which result in varying degrees of seepage. Nevertheless, another common rule of thumb states that seepage may account for about half that of evaporation (or 25% of the water in a reservoir).

On the basis of the above rules of thumb, it can be concluded that if 200 m^3 of water is required, then the water reservoir should have a storage capacity of 800 m^3 to cater for an evaporation loss of 400 m^3 and seepage loss of 200 m^3 (Table 3-4).

Table 3-4: Demonstration of estimated water storage for the reservoir

Domestic, livestock and irrigation water usage	200 m^3
Estimated evaporation loss (50%)	400 m^3
Estimated seepage loss (25%)	200 m^3
Required storage capacity of water reservoir (100%)	**800 m^3**

3.2.5 Estimating the benefits of small dams

The main cost for a dam is paid at the time of construction, but the benefits can be calculated over the life of the reservoir of at least 10 years or more, assuming that it will eventually fill with silt.

Economic benefits will include the value of labor and time saved fetching water and watering livestock. Benefits may also result from improvements in the condition of livestock and small stock, cash from sale of irrigated farm produce and value of food grown for the household.

To estimate the economic feasibility of constructing a pond or dam it is helpful to estimate the value of the benefits, such as additional income, time and labour saved, and comparing these with the cost.

3.2.6 Other important considerations

If the answers to the questions listed in section 3.2.3suggest that the building of a dam may be technically and economically feasible, then the next questions are:

i. Will the project have any major impact on the environment?

ii. What will the impact of the project be on local people and how are they involved in its planning and management?

iii. Does the project address issues, which affect the roles and work of men and women in the community (gender issues)?

iv. Are there any laws, cultural or ownership issues associated with the project, which need to be addressed?

3.2.7 Legal requirements

It is always advisable to ask the authorities before starting any construction works in order to avoid disappointment and legal cases.

Generally, it is understood that farmers may construct ponds and small earth dams on their land without asking permission from anyone, provided they do not block water runoff to people living downstream.

Borrow pits along roads: can be turned into water reservoirs by digging a trench or two for diverting run-off from a road into a borrow pit. Whether this is allowed depends on the local authorities in that region. Therefore, it is better to ask before digging that trench, instead of being confronted by the authorities or fined afterwards.

Subsurface dams: weirs and sand dams built across small streams and dry riverbeds can easily be built using soil, sandbags or rubble stone masonry, thus damming and diverting water for various purposes. However, care should be taken as plans for building such structures require approvals by Ministry of Water through the Director of Water Resources and other relevant authorities, because Weirs may reduce the water supply for people living downstream.

3.2.8 Community involvement

Past experience has shown that many projects fail for social rather than technical reasons. Failure may be because projects were poorly managed and lacked proper maintenance. This often occurs when it is unclear who is responsible to ensure routine inspection and maintenance as well as when it is required. Local disputes over access or ownership of water systems are also a common problem.

To avoid this, the local community should be involved from the start of any project, both in planning and later in managing it. This ensures a sense of ownership by everyone involved. It also gives the community the opportunity to sort out any issues, which could threaten the future of the project. As well, operation and maintenance plan should be well prepared/designed beforehand.

3.2.9 Charco dams

Farmers and cattle owners in semi-arid parts of Tanzania build small earth dams known as Charco, or *Malambo* in *Kiswahili*. These dams are built in a way which triesto reduce evaporation losses by deepening the water reservoirs and minimizing their surface area. Trees and scrubs are grown on the windy site of the charco dams to function as windbreaks that also reduce evaporation.

3.2.9.1 Site selection for Charco dam

The best sites for constructing Charco dams are in natural depressions where rainwater either flows or accumulates during the rainy season. The soil should, preferably, be deep clay, silt or Black Cotton soil. Coarse textured sandy soils should be avoided as these are highly permeable and water will drain through them. If seepage is high in Charco dams, they can be plastered with clayey soil and compacted using compactors made of tree trunks.

Sites with underlying strata of sand, gravel, limestone or fractured rock at a shallow depth may also result in high seepage losses, unless they are sealed with clayey soil.

Ideally, a Charco dam should be located near to a gully or a natural waterway, which carries water during and after rainfalls, as this water can easily be diverted into the dam. Avoid building dams near or downstream from livestock enclosures to avoid organic and/or chemical pollution.

Individuals near their homesteads for usually excavate Charco dams manually for Watering livestock. The water may also be used for some domestic purposes, if it is boiled or treated by the sun’s UV rays in transparent bottles, a process known as SODIS.

Farmers dig their ponds during dry seasons and enlarge them every year, until the owner is satisfied with the capacity of the dam.

3.2.9.2 Design

The most economical and perfect shape for a Charco dam is that of a calabash cut in half and used for scooping water. The "handle" is used for the inflow channel and for giving access to people and livestock, while the “bowl” is the water reservoir.

The bested design of Charco dams area circular and oval designs, which are preferred, because:

i. They give maximum storage volume for a minimum of work.
ii. The internal and external pressures are evenly distributed and this prevents cave-in of the soil in the walls of the water reservoir.
iii. In sandy soils, they can be lined successfully with clayey soil, because the shapes do not have any corners.

The size of a Charco dam depends on the following factors:

i. A farmer’s financial capacity to hire laborers to assist him with excavation.
ii. The expected volume of run-off water from the catchment.
iii. The area available for constructing the pond.

iv. The soil type.

Marking out a Charco Dam

Before the excavation work of a Charco dam can be started, the outline of the various parts of the structure has to be marked with wooden pegs. The following components should be indicated in the layout:

i. The embankment wall should be clearly outlined on the ground prior to excavation commencement.

ii. The runoff inflow channel should be marked sloping from the catchment to the pond or reservoir.

iii. Reservoir or pond area should be clearly indicated.

iv. The overflow or spillway should be well measured and indicated on the site layout and properly marked with wooden pegs.

3.2.9.3 Construction

The construction site should be cleared of all vegetation, including the semi-circular area where the excavated soil will be placed as the dam wall on the lowest side of the water reservoir.

Then the outlines of the dam reservoir and the half-circular dam wall are drawn and pegged out using a long string tied to the center of the dam reservoir. A 2m wide space, called a berm, should be left untouched between the dam reservoir and the dam wall. Its purpose is to facilitate transportation of soil, while also preventing soil from the dam wall to slide back into the excavated reservoir. The excavated soil should form a semi-circular dam wall (embankment) all around the water reservoir, except at the inflow channel, to reduce wind speed and evaporation. The slopes of the dam wall should be flatter than 1:1 (45 degrees). The top of the dam wall, called the crest, must be highest opposite the inflow channel to prevent washout of the dam wall.

Rainwater must not be allowed to wash any soil back into the pond. Therefore, trees and grass should be planted on the dam wall to protect it from erosion and create a windbreak. More trees should be planted outside the embankment on the side towards the prevailing wind to form a windbreak, which will reduce evaporation losses and provide firewood, poles and timber.

Another way to reduce evaporation and conserve water towards the end of the dry season is to deepen one end of the dam reservoir. As the pond dries out, the remaining water will accumulate in the deeper section and minimize the area of water exposed to evaporation.

A spillway should be built at each end of the curved dam wall that reaches the inflow channel. These two spillways will facilitate excess water to spill over the water reservoir safely. Large stones should be placed along the lower side of the two spillways to prevent erosion of the dam wall.

A series of silt traps also need to be constructed to reduce the volume of sediment entering the dam reservoir. Excavating depressions in the flat land before the inflow channel can make these. Sediment trapped in the silt traps should be removed after rain showers, so the silt traps do not get filled up with silt. The removed silt is rich in nutrient and therefore an excellent fertilizer for a vegetable garden.

3.2.10 Hill side small dams

Small earth dams with curved walls built on hillsides and sloping land are the simple stand cheapest earth dams to locate, design, construct and maintain. It is therefore surprising that these dams, known as hillside dams, are not promoted more widely.

3.2.10.1 Site Selection

Suitable sites for hillside dams can be found on almost any sloping land that produces rainwater runoff. The catchment can include roads, compounds, roofs, agricultural land and rock outcrops. To avoid contamination of the water, there should not be any pollution sources, such as drainage from villages, slaughter houses, latrines, rubbish pits, cattle dips etc., in the catchment area.

Naturally, the best soil type for constructing a water reservoir should have a high content of clay. However, soil types other than the clayey type can also be used, although some seepage may occur downstream.

Despite seepage being considered as wasted water, the water can still be utilized constructively if it was extracted from a hand-dug well, thereby providing safe and clean water for e.g. domestic use, watering livestock, garden irrigation, making burnt bricks, a wood lot, etc.

3.2.10.2 Design

The design of hillside dams consists of a semi-circular dam wall, shaped like a new moon. The curved dam wall is made of compacted earth, which must be higher at the middle than at both ends to prevent any water spilling over the middle of the dam wall.

Each of the two ends of the curved dam wall function as spillways and should therefore be at the same level. The lower sides of the two spillways are strengthened with rocks to prevent the water from spilling over and eroding the ends of the dam wall.

3.2.10.3 Equipment used for leveling

Leveling is one of the common method for obtaining the site elevations and establishment of contours. Before establishing the dam layout and sections, leveling determines the dimensions of the dam body as well as the construction materials, Full Supply Level and the freeboard of the embankment. The common equipment to be used is the optical leveling machine.

3.2.10.4 Construction

a) Setting out

The outline of a hillside dam is done by hammering a peg into the run-off line of the rainwater. Preferably, the peg should be placed in a depression in the run-offline, because that will provide free storage capacity.

b) Excavation work

The excavation and soil works for a small earth dam on a hillside site can be done manually, with oxen, a plough mounted on a farm tractor, or a crawler. The construction work involves excavating soil from the central pit and placing it in a semi-circular line along the downstream side of the excavation.

The crest (top of dam wall) must always be at least one meter higher at the middle than at the ends to prevent a washout of the middle section by a heavy thunderstorm. In addition, height must be increased by 10% if the soil is compacted by a tractor. This must be increased by 20% if compacted by oxen and by 30% if the dam wall is not compacted at all. These increased heights are called the settlement allowance; because when the reservoir of a newly built dam gets filled with water, the soil in the dam wall will settle and lower the middle of the dam wall, which endangers the safety of the dam.

c) Spillways

The two ends of the curved wall of hillside dams function as spillways to allow surplus water from the reservoir to flow safely out of the dam. Heavy rain-showers on large catchments produce huge volumes of run-off water that must pass over the spillways without eroding the ends of the dam wall otherwise water might destroy the whole dam wall.

Spillways should therefore be reinforced by placing large stones against the ends of the dam walls. Long-rooted grass with runners should be planted between the stones to prevent overflowing water from eroding the stones. The floor of the spillways should also be covered with stones interpolated with grass to prevent erosion. If the floor of the spillways is steep a concreted stone-masonry structure may be needed.

d) Enlarging a catchment

Should the volume of run-off water not be sufficient to fill a pond, then a catchment can be enlarged by diverting run-off water from another catchment into the pond by means of soil bunds as explained in the former chapter.

e) Enlarging a water reservoir

Dams having catchments with sufficient run-off can be enlarged to hold much more water by deepening the reservoir and using the excavated soil to increase the height of the dam wall. Labor for enlargement of dams might be obtained by:

i. Allowing neighbors to collect water free of charge, if they will excavate and transport one wheelbarrow of soil for every 20 liters of water they fetch.

ii. Charging people a fixed amount for every 20 liters of water they fetch and using the money rose to hire people for further excavation work.

3.2.11 Valley dams

An earth dams built in a valley is the cheapest way to create water storage, because the excavation work is less than for Charco dams and hillside dams. However, the gain in cost per volume can be lost overnight by flooding from one heavy thunderstorm or shower, which, unfortunately seem to be bigger every year. The washout of a dam wall can be very serious and endanger both lives and property. For this reason, experienced technical help should always be sought for the design and construction of valley dams which might present a possible threat to downstream households.

3.2.11.1 Estimation of the reservoir capacity

The rainwater runoff from the catchment area must therefore be sufficient to fill the proposed water reservoir during a rainy season. On the other hand, if the catchment is too large, the volume of run-off water might be so voluminous that the dam risks being washed away, even if spillways are extra-large. Since it is very difficult to obtain precise rainfall data, a simple and reliable method on estimating the volume of run-off can be applied as shown below.

Long-time residents' knowledge about the biggest flood ever experienced can be used as the basis for calculating the size of spillways, as follows: Multiply the width of the flood (Example 10m) with its depth and divide by 2. In this example: 10 x 1 m /2 = 5 square meters of flood. If the flood moves with a velocity of 1 meter per second, and if the valley is flooded for an average of 3 hours, the volume of rainwater run-off will be: 5 m^2. x1 m x 60 seconds x 60 minutes x 3 hours = 9,000m^3.

Now the question is: What are the approximate dimensions of a water reservoir for a valley dam that should be able to store 9,000m^3?

The question can be answered by the formula for estimating the volume of a reservoir for a valley dam, which is:

Volume = Maximum width x maximum depth x maximum throw-back (length) /6 (3.3)

3.2.11.2 Site criteria

i. The wall of the earth dam should be situated in a narrow part of the valley that widens just upstream to give additional free storage capacity for water.

ii. The dam wall needs to be built in a part of the valley, which provides an impervious (water tight) valley floor of clayey soil.

iii. The valley floor should be flat, because it will give free storage volume.

iv. The dam wall should be situated at least 100 m from any bends in the valley to prevent currents causing erosion when heavy runoff occurs.

v. Suitable clayey soils for building the dam wall should be available from a borrow pit in the reservoir and from excavating the spillways.

vi. Reservoirs should not contain boulders or rock outcrops because they might cause leakages; this can be prevented if covered with clayey soil.

vii. Natural depressions in the banks of a reservoir, when present, should be used for spillways in order to reduce construction costs.

3.2.11.3 Design

i. Spillways

For instance; the maximum flood level (MAX. FL) is 15 m wide and 2 m at its deepest. That gives a cross-section of: 15 m x 2 m / 2 = 15 square meters. The size of the spillways should be the double of that, namely 30 m wide and 1 m deep = 30 square meters.

ii. Soil for dam walls

Before the cross section of a dam wall can be designed and drawn, it is necessary to analyze some soil samples taken on the site, because the type of soil available on the site determines the type of the dam wall to be constructed. A permeability characteristic of the fill materials is a governing factor, which determines the water tightness of the embankment wall. In presence of the construction material with sufficient coefficient of permeability would lead to opt for homogeneous embankment. In absence of enough impervious materials within the vicinity of dam site should call for zoning of embankment cross section. Therefore, the following are the common way of making a watertight embankment cross-section:

Homogeneous dam walls: can be built of the soil types classified as GC, SC, CL and CH, and if the soil has a clay content of 20% to 30%.

Zoned dam walls: consist of a core of clayey soil whose sides are supported with sandy soil. It is a more stable and economic design than a homogenous dam wall because it can be built with steeper slopes, thereby reducing the cost of earth works.

Diaphragm dam walls: are used where there are plenty of rocks and/or stones or gravel on a site. These pervious materials are covered on the upstream side with an impervious blanket (diaphragm) of soil with clay content of 12% to 40%. The blanket must start below the front toe to prevent seepage under the dam wall.

Gradients of dam walls: The upstream and downstream gradients (slope) of dam walls depend on the type of soil to be used for the construction works. Unstable sandy soils require more gradient than stable clay soil. This property of the soil can be tested in the laboratory by conducting shear test of the soil sample so as to determine the angle of repose and cohesion of the materials.

iii. Estimation of the volume of the fill materials

The following is a simplified formula used to compute the volume of fill materials to be used for construction of the earth embankment.

$$V = 0.216xHLx\ (2C + HS) \quad (3.4)$$

Whereby:

V = the volume of soil in cubic meters.

H = the maximum height of the dam wall in meters - before settling

L = the length of the crest in meters

C = the width of the crest in meters

S = the sum of the upstream and downstream slope (Upstream slope 3:1 + Downstream slope 2.5:1)

3.3 PART C: RAINWATER COLLECTION FROM ROADS

3.3.1 Introduction

The challenge of road construction once constructed is changing surface hydrology and impacting on runoff resulting in local flooding, water logging and erosion. But its potential can be realized through adoption of techniques to harvest the water from the roads. This is very important in rolling or mountain terrains. The harvested water after acquiring proper treatment as stated in chapter 5, can be used for different purposes including groundwater recharge, soil moisture maintenance, firefighting, horticulture, domestic water supply and livestock keeping. The runoff water can be harvested from culverts, side drains and depressions. The main challenges when applying this technique are evaporation and infiltration. However, the environment favoring evaporations and infiltration can be modified so as to maximize the quantity of stored water. Therefore, to reduce the infiltration in the ground, the pond base and walls should be plastered by using clay materials. Since evaporation depends on the footprint area of the water surface, hence, increasing the water quantity through increase of the water depth can reduce water loss through evaporation.

3.3.2 Water collection and Storage Methods

The methods used in road runoff water collection are; Murram pits, Small Pans and Large Pans, Charco Dams, Hillside dams, Valley dams. Since methods for design and construction of earth dams, Charco Dams, Hillside dams and Valley dams have been discussed in the previous chapter, therefore this chapter will focus on the infrastructures, which are not yet covered. The storage facilities that will be explained are Murram pits and small and large pans.

3.3.2.1 Murram pits

Murram pits, also called borrow pits, are always situated along roads and are easy to convert into water reservoirs, because only excavation of one or two trenches is required. However, before digging the trenches, it is advisable to discuss the issue with the local authorities.

Murram pits are found along most roads, because the material (murram) excavated from them is used for building the roads. Whenever a road is re-carpeted with murram, the existing pits are either widened, or new murram pits are excavated. *Note that when the murram pit found to be pervious the base and the wall of the pit should be plastered by using about 30cm thick clay materials so as to reduce seepage.*

Diversion channel to the Murram pits: *The run-off water from a road is diverted into a murram pit through a trench excavated upstream of the pit and collecting water from ditches running along the road. To prevent sedimentation of the water reservoir in the murram pit, the trench should have a gradient of about 3: 100 cm.*

3.3.2.2 Small and large pans

Pans are natural depressions without any dam walls around their water reservoirs. Pans were scooped out by elephants long time ago whereas murrain pits are man-made. Rainwater running off roads can be diverted into pans by excavated trenches, or along stone bunds, having a gradient of about 3:100.

3.3.3 Benefits from rainwater running off roads

It is estimated that 1,300m^3 run-off water from 1 km of road can water more than 150 local cows every day in a year, while taking into account that 30% of the water may be lost due to evaporation or seepage. Besides watering livestock, the water could also be used for other purposes, such as:

i. Tree nurseries, woodlots, orchards and vegetative fencing of fields and homesteads, which provide income from sale of tree seedlings, timber, firewood, fruits, etc.

ii. Manufacturing of burnt bricks, concrete blocks, culverts and other building materials that can be sold.

iii. Sale of water to neighbors for watering their livestock, construction works, etc.

iv. Raising ducks, geese, fish and bees in or near open water reservoirs.

v. Sale of sand harvested from weirs and sand dams in gullies and riverbeds.

vi. Recharge of hand-dug wells near subsurface dams, weirs and sand dams in riverbeds from where domestic water can be drawn.

vii. Increased agricultural production from fields irrigated by road run-off water.

Note: *Using run-off water from roads for domestic use is not advisable due to the risk of contamination by tar and other contaminants.*

3.4 PART D: RAINWATER COLLECTION BY USING SAND DAMS

3.4.1 Introduction

A sand storage dam (or sand dam) is a small dam build on and into the riverbed of seasonal Sand River. The functioning of a sand dam is based on sedimentation of coarse sand upstream of the structure, by which the natural storage capacity of the riverbed aquifer is enlarged.

3.4.2 Functions of a sand dam

i. **Water Storage:** The purpose of sand dam is increasing water availability by storing water in the riverbed and banks. Water is stored in the spaces (voids) in the sand, which can hold up to 35 percent of the volume of sand. Sand dams obstruct groundwater flow through the riverbed, resulting in a (continuous replenishment of the) enlarged groundwater reservoir upstream of the dam

ii. **Regional groundwater recharge:** A cascade of sand dams in a will cause a general rise in groundwater levels in a larger area. This positively affects the environment in the surrounding area of the dam, due to more water availability for people and vegetation.

iii. **Sand harvesting and rehabilitating of gullies:** Sand dams can rehabilitate erosion gullies, while the sand sediments behind the dam can be harvested for sale. If a sand storage dam is built for this purpose, the dam doesn't have to be impermeable. Usage of plastic bags filled with soil is more profitable for this purpose).

3.4.3 Types of sand dams

i. **Stone-masonry dam:** A dam built of concrete blocks or stones,

ii. **Reinforced concrete dam:** A dam consisting of a thin wall made of reinforced concrete,

iii. **Earth dam:** A dam consisting of impermeable soil material (mostly clay or clayey soils, or black soils).

3.4.4 Useful design guidelines (for drinking purpose only)

Average minimum household (HH) daily consumption

$$\mathbf{QHH = 10 + (n \times 5) \text{ litres } (n = \text{number of people in HH})} \qquad (3.5)$$

Average sufficient HH daily consumption

$$\textbf{QHH = 30 + (n x 7) litres (n = number of people in HH)} \quad (3.6)$$

It is recommended to utilize minimum QHH in areas with only one rain season and a dry period between 6-8 months and sufficient QHH in areas with two or more rain seasons and a dry period between 3-5 months.

i. Annual consumption (QA)

$$\mathbf{QA = 365 \times QHH} \quad \mathbf{(3.7)}$$

ii. Storage volume of sand dam (V)

$$\mathbf{V = H/2 \times (100 \times H/S\ (\%)) \times W \times P\ (0,\ 3)} \quad \mathbf{(3.8)}$$

Whereby:

H = Height of dam

S = slope of river

W = river width

P = porosity

3.4.5 Designing

After determining the water demand and estimating the water yield at the selected sand dam location, the design can be made. There are different approaches in designing a sand dam.

A sand dam can be defined in four main parts namely:

i. The dam;

ii. Spillway;

iii. The wing walls;

iv. Stilling basin.

3.4.5.1 Dam height

This is the maximum height as referred from the lowest point of the dam axis to the top crest elevation. To determine the dam and spillway height at a specific location, it is very important that the water level and the maximum flood level will remain below the riverbanks after construction of the dam. If the flood level is higher than the riverbanks (Bh), construction of a dam is not advisable. The dam and spillway height are therefore determined by the maximum discharge and maximum flood height.

Maximum discharge can be calculated in 2 different ways:

i. Calculating the maximum discharge by the highest flood level (known by flood marks on the banks or information from local communities);

ii. Calculating the discharge at the selected location by using a certain return period (for example rain event with a return period of 50 years) by using a rainfall-runoff model or a mathematical formula for rainfall runoff.

3.4.5.2 Spillway

This is the dam component which is used to safely convey excess water from the reservoir and thus avoid overtopping. The maximum discharge (as determined using the equation3.9) is used to determine the spillway dimensions, for which the formula is given below.

Using maximum discharge to calculate spillway dimensions

$$\mathbf{Q = c\ x L s x H^{3/2}} \tag{3.9}$$

Where: Q = maximum discharge in riverbed section (m^3/s)

Ls = length of spillway (m)

c = 1, 9 (constant depending on spillway shape, here: broad crested weir)

H = height of spillway (m)

Figure 3-1, illustrates cross-sectional width dimensions for a typical sand dam construction. Where,Gf is gross freeboard (m), L_w is length wing wall (m), H_f is height freeboard (m), Lw_e is length wing wall extension (m), H_d is total height of dam (m), L_s is length spillway (m).

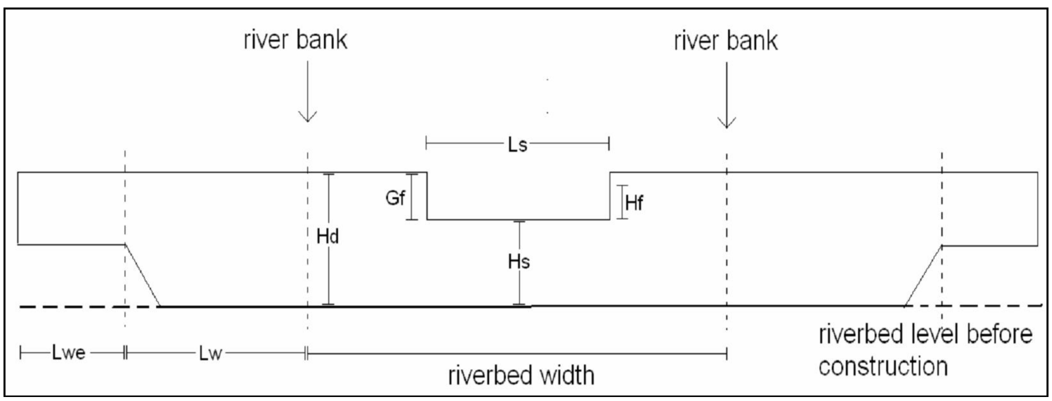

Figure 3-2: Cross-sectional width dimensions for a typical sand dam construction

3.4.5.3 Wing walls

When determining the distance, the wing walls go into the banks, bank characteristics have to be taken into account.

i. In loose riverbanks: approximately 7 metres into the riverbanks;

ii. In hard soils: approximately 5 metres into the riverbanks;

iii. In hard and impermeable soil: approximately 0 – 1 metre into riverbanks;

iv. In rock formation: no need of constructing in riverbanks.

The length of the wing wall (Lw) should be approximately 2 metres into the riverbanks. The length of the wing wall extension (Lwe) should be approximately 5 metres. Figure no. 3-1shows an example of wing wall dimensions in loose riverbanks.

3.4.5.4 Stilling basin

These are hydraulic structures established for the purpose of dissipating energy of water exiting through a spillway. Hence, preventing scouring. The following equation 3.10 is useful in estimating its dimensions.

$$\mathbf{SL = c \times L^{1/3} \times H_2^{1/2}} \qquad \mathbf{3.10}$$

Where: SL = length of stilling basin (m)

c = 0, 96 (constant)

H_2 = height of freefall (m): height of water level upstream –height of water level downstream

3.4.6 Application

Sand dams maybe applied in the following conditions and for the following purposes:

i. In places with limited water resources for water supply – e.g. no perennial water sources and groundwater potential are low (low yield) or problematic (quality unacceptable).

ii. Most suitable in sandy, seasonal rivers prone to sedimentation.

iii. Supplementing unreliable water supply caused by seasonal variation to normal water availability.

iv. In remote and inaccessible areas.

3.4.7 Environment benefits

Reduction of erosion, management of silt deposition within river basins, and increased moisture infiltration within the soil profile and into the groundwater are environmental benefits associated with sub-surface dams

3.4.8 Advantages

Sand dams maybe advantageous in several ways as mentioned below:

i. Evaporation of stored water decreases.

ii. Siltation does not create a problem as topsoil particles and decries are cleared during flash floods.

iii. Contamination of water by insects, birds and animals cannot take place as water is not exposed.

iv. Downstream users not deprived as water only fills up behind the created dam in the sand reservoirs with floods when water is plentiful anyway.

3.4.9 Limitation:

Nevertheless, there are limitations when practicing water harvesting by sand dams, which are summarized below:

i. Limited to areas with seasonal riverbeds with floods event during the wet season

ii. Rivers with less coarse sand will not have sufficient water storage capacity.

iii. River slope between 1 and 5 %.

iv. River bed should be solid rock without fractures

v. Construction material should be local available

3.5 RAINWATER HARVESTING INTO LINED/UNLINED OPEN WATER PONDS OR BODIES

3.5.1 Introduction

Rainwater runoff water harvesting into open water bodies (mostly pond like structures) is a common practice in most rural parts of the country. The catchments are not limited to flat surface, and rock outcrops. The runoff water is tapped for domestic purposes. Seepage and evaporation are challenges on maintaining potential quantity harvested. However, in some cases the ponds are usually lined with clay or even cement mortar. The quantity and quality potential of the targeted catchment maybe enhanced through catchment cementing, fencing, and raising awareness on catchment management.

Moreover, for the area that is susceptible to seepage (high porosity geology) one of the easiest ways of reducing the seepage in the water bodies is to provide an impervious lining material. A large number of factors have to be considered before designing a perfect system for appropriate lining of the system. The important geographical factors are topography, rainfall and type of soil in the area. The engineering factors are design, alignment, transmission losses, capacity and structures of the water bodies. The various types of linings can be grouped into two main categories.

i. **Exposed and hard surface lining:** Such linings are constructed of cement concrete and mortar, asphaltic materials, bricks, stones etc. Exposed and hard surface lining is subject to wear, erosion and deterioration effect of the flowing water, operation and maintenance equipment and other hazards.

ii. **Buried membrane lining:** Buried membrane lining consists of an impervious and relatively thin material covered by a protective layer. The protective layer saves the membrane from direct exposure, turbulent water, weeds, maintenance equipment and animal traffic. Generally, earth gravel and tiles are used as protective material, however, some other materials like shotcrete and asphalt macadam have also been used successfully. The commonly used buried membranes are

a. Sprayed-in-place asphalt membrane lining
b. Pre-fabricated asphaltic membrane lining
c. Bentonite and clay membrane lining
d. Plastic film lining

Among the commonly used lining materials, plastic lining is considered to be the best option due to the factor that it is cheap, available in the market and is not highly affected by weather factors as compared to other lining options. However, care should be taken during installation in order to avoid leakages as a result of puncturing.

3.5.2 Plastic film as lining material

The use of plastic films as a lining material has offered tremendous scope as lining material which provide an impervious lining thus prevent water losses due to seepage. The performance of these films as lining material has been found very satisfactory. These linings using Polyvinyl Chloride (PVC) and Low Density Polyethylene (LDPE) film have been tried experimentally. Out of all the types tested so far, LDPE film appears to be the best, whereas PVC lining has several limitations. It cannot be manufactured in wide width and, further, the stability of this film is hampered by the migration of plasticizers, which are essential for ex-truding flexible PVC film. Therefore, the most recommended material for lining in Tanzania is LDPE, which is discussed in subsequent sections of this document.

3.5.3 Precautions for laying the film

i. Before laying the black LDPE film and the protective earth cover, the subgrade should be dressed true to level so as to form a firm and even bed for laying of the LDPE film. If pebbles or other sharp edged materials or voids are present in the subgrade, a sand cushion of suitable thickness should be provided before laying the LDPE film.

ii. Before placing the earth cover, the black LDPE film should be minutely inspected to ensure that there are no perforations present in the film. Any such perforations should be heat sealed with at least 100 mm patch all around it.

iii. A protective earth cover of 45 cm should be provided over the black LDPE film. The protective earth cover should be laid uncompacted. It should be ensured that the protective earth cover does not contain any pebbles or other sharp-edged materials, which may damage the film.

iv. The black LDPE film should be laid with 5% slack in both directions, distributed evenly along the length and breadth of the film.

v. The LDPE film should be spread loosely on the subgrade. It is very much essential that the laid film should be covered with earth cover at the end of the day.

3.5.4 Do's and don'ts of Agri-film for lining

i. Do keep the Agri-film rolls in original packing in shaded and covered area prior to laying of film.

ii. Don't keep the Agri-film exposed to sunlight for longer period while joining and laying in the pond. After laying, it should be covered/buried within the manufacturer's specified minimum period, to protect it from strength deterioration.

iii. Don't rough-handle or drag Agri-film rolls, as the film may get damaged in the process.

iv. Don't let workers walk on the Agri-film while the lining operation is in progress to avoid puncturing of the film. In case this is unavoidable, they should walk barefoot.

v. Don't slide the cover material like bricks etc., on Agri-film to avoid damage and displacement of flexible membrane lining.

vi. Don't use hooks for lifting Agri-film rolls.

vii. Do use good quality LDPE film as per IS: 2508/1984. Re-cycled or re-processed polythene may not be impervious and enduring, which will reduce the efficiency of the lining.

3.5.5 Requirement of Agri-film material

Before joining of the Agri-film, estimate the size (length and Width) of the Agri-film, with the help of formulae given below (Figure no. 3-2):

Length of Agri-film (L): Length of bottom (m) + 2 x length of side (m) + 1 m (for 50 cmlength for burying in soil) + 1 m for shrinkage of the film.If bottom length of reservoir is 'b' meter, slope is 3:1 and depth is 'h' meter, then, length of Agri-film L = $b + 2\,(9h^2 + h^2)^{0.5} + 2$ m

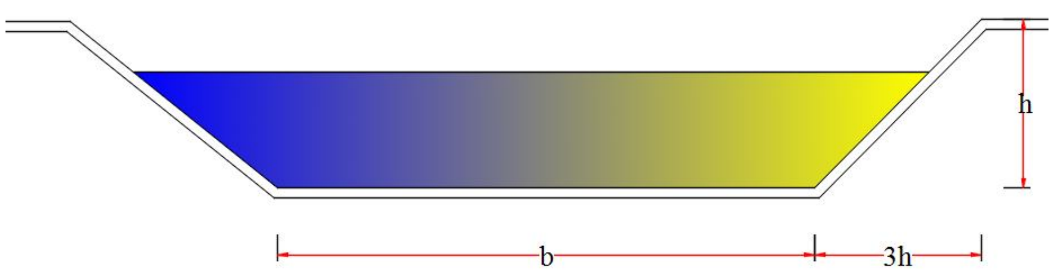

Figure 3-3: Determination of length of Agri-film

Width of Agri-film (W): If service reservoir is of rectangular shape and bottom width of reservoir is c' meter, slope is 3:1 and depth is 'h' meter,

Then, width of Agri-film W = c + 2 $(9h^2 + h^2)^{0.5}$ + 2 m

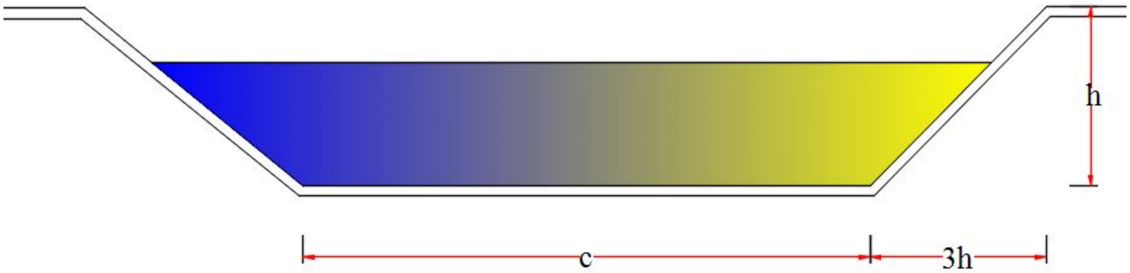

Figure 3-4: Determination of width of Agri-film

Size of the Agri-film= (L x W) m^2

3.5.6 Joining of Agri-film

Normally the film of required width should be procured to avoid jointing. However, if the film of desired width is not available, the required width can be achieved by jointing the film pieces together. There are various methods of jointing adjacent length of the film to make it completely waterproof.

3.5.6.1 Thermal welding (heat sealing)

Pressure is applied to the film for a pre-determined period through one or two heated jaws or blades, the temperature of which can be adjusted and maintained at a constant level. After welding the joints should be tested so as to detect the leakage of the joints

3.5.6.2 Jointing by hot bitumen

A coat of bitumen can also joint films. Bitumen grade 85/25 and 80/100 in the ratio of 2:1 should be heated at a temperature around 100ºC. Heated bitumen can be crudely tested on a small piece of film so that overheated bitumen may not damage the film. After ascertaining the appropriateness of the temperature, apply a thick coat of tested bitumen on 10 cm area along the width of both the sheets and fold them so as to enhance watertight.

3.5.7 Earth cover

The film on the bed should be covered with the excavated soil. To avoid any damage to the film a 5 cm layer of sieved earth should first be laid and compacted over the film. Rest of the earth cover should be spread over it in 15 cm layers, watered and rammed to avoid bleaching effect at the water line. After finishing the profile with well compacted earth, the position of the slope above full supply level may be turfed with grass as per the availability.

CHAPTER FOUR: OPERATION AND MAINTENANCE OF RAINWATER HARVESTING SYSTEMS

4.1 ROOF RAINWATER HARVESTING SYSTEMS

4.1.1 Introduction

Roof rainwater harvesting system will require regular maintenance. The maintenance of the system's components must be carried out by the owner, unless there is an alternative maintenance agreement with the builder or contractor who installed the system.

4.1.2 General Operation and Maintenance Considerations

The suggested operation and maintenance frequency and requirements of the roof rainwater harvesting system's components are highlighted in tables 4-1 to 4-5 below:

Table 4-1: Maintenance of roof rainwater collection and conveyance system

Inspection item	Inspection frequency	Maintenance requirement
Roof surface	Prior a heavy rain season.	i. Hose down or sweep the roof surface to remove dirt and debris, making sure not to allow dirt and debris to enter the conveyance pipe. ii. Trim overhanging trees and foliage.
Conveyance network i. Eaves troughs ii. Down spouts iii. Down spout to conveyance pipe connection	Every six months.	i. Remove accumulated dirt, debris, leaves, etc. ii. Install eaves trough screens to reduce debris entering eaves. iii. Inspect downspout to conveyance pipe connections to make sure they are secure. iv. Repair damaged sections as needed.
Pre-storage treatment component i. Gutter guard ii. First-flush device iii. Leaf beater iv. In-ground filters v. Settling chamber	After several rainfall events, or as outlined by manufacturer.	i. Clean out the first-flush chamber and other pre-storage devices to guarantee that they are free of accumulated debris. ii. Certain devices are designed to be self-cleaning. iii. Investigate impact of traffic or pets on in-ground filters.

Table 4-2: Maintenance of rainwater storage system

Inspection item	Inspection frequency	Maintenance requirement
Storage tanks: above and below ground	Once annually: inspect inside of tank.	i. **Leakage:** Repair cracks and connections as needed, following manufacturer's specifications and all safety precautions regarding confined spaces. ii. **Sediment and debris buildup:** Pump out accumulated sediment and debris using an appropriately sized effluent or sump pump. iii. **Pest control:** Ensure any screens on pipes exiting the storage tank (i.e. overflow pipe) are in place and in good repair.

Table 4-3: Maintenance of rainwater distribution system

Inspection item	Inspection frequency	Maintenance requirement
Pump and pressurized distribution system	Once annually	i. Check that the pump and pressure system are functioning properly. ii. Inspect for pump wear and overheating. iii. Ensure there are no leaks in the distribution plumbing lines. iv. Check the pressure system when no demands are placed on it. If the pump continually cycles on and off, there may be a leak in the distribution plumbing lines, or an issue with a foot or check valve.
Non-potable warning labels	Once annually	Ensure they are present, and replace as necessary.
Post-storage filtration and treatment devices. Filters, disinfection units and other devices.	Every three months or as outlined by manufacturer	i. Replace filters or filter media. ii. Maintain disinfection units by replacing UV Lamps or chlorine, iii. Clean or replace other components.

Table 4-4: Maintenance of roof rainwater Top-up system and backflow prevention

Inspection item	Inspection frequency	Maintenance requirement
Top-up system: i. float switches, ii. solenoid valves, iii. top-up drainage piping	Every six months, even if functioning properly, or as needed when issues arise.	i. Ensure the appropriate control equipment was chosen and installed properly. ii. Visually inspect the amount of water in the storage tank to see if top-up systems functioning. iii. Verify that electricity is supplied to all necessary equipment (pump, solenoid valves, water level sensor, float switches, etc.). iv. Ensure that a closed valve is not restricting the potable water supply. v. Verify top-up tank area in mechanical room is dry; exhaust humid rooms with fan.
Backflow preventer and air gap	Once annually	Refer to appropriate manufacturer's manual and procedures

Table 4-5: Maintenance of roof rainwater over flow and storm water management systems

Inspection item	Inspection frequency	Maintenance requirement
Discharge pipe: above ground	Once annually	i. Examine discharge location for erosion. If there are signs of erosion, install a "splash pad" or section of rock or gravel. ii. Inspect the screen of the lockable cover at the end of the discharge pipe and remove any dirt and debris buildup. iii. Inspect drainage pipe for dirt and debris buildup, and remove as needed to prevent clogging.

Discharge pipe: below grade	As needed: when the overflow system is blocked or performing poorly.	i. Check for signs of water damage to the rainwater tank, access hatch, and internal components located above the maximum water level. ii. Check for signs of water leakage from the access hatch. iii. Check for signs of water leakage from the downspout to conveyance pipe connection and the top-up system air gap.

4.1.3 Owner's / Operator's checklist and maintenance log

This checklist ensures that adequate information is collected during the installation phase of the rainwater harvesting system. It can be used as a diagnostic tool in the event of a problem within the system, and should be passed on to a new owner/operator after a home sale. This checklist also serves as a maintenance log for the ongoing upkeep of the rainwater harvesting system

1. What type of roofing material is used? Asphalt .... Metal ...... Other ....
2. Do trees or foliage overhang the catchment surface? Yes .... No ....

   How will it be managed? ....
3. Are downspouts located close to the storage tank? Yes .... No ....

   Explain ....
4. What pre-storage treatment devices are installed? Eavestrough screen .... Downspout filter .... First-flush device .... In-ground filter .... Settling chamber .... Other .... N/A ....Explain..
5. What type of conveyance pipe is used? PVC Standard Dimension Ratio (SDR) 35 .... PVC system 15 .... (Schedule 40) ABS .... Other ....
6. What is the conveyance pipe's slope? 0.5%–2% .... 2% .... >2% ....
7. At what depth is the conveyance pipe buried? .... metres (or .... feet)
8. Is insulation installed above the conveyance pipe? Yes .... No .... Explain ....
9. What is the insulation type and thickness? .... mm (or .... inches) Type: .... N/A ....
10. Is tracer wire (for locating buried non-metallic pipe) installed above the conveyance pipe? Yes .... No ...... Explain ....

11. What is the storage tank type? HDPE .... Fiberglass .... Cast-in-place .... Precast concrete .... Crate and bag .... Other ....

12. What is the storage tank size? .... liters (or .... US gallons)

13. Where is the storage tank located? Above ground .... Where? .... Below ground .... How deep?............... Building integrated .... Where? ....

14. What type of post-storage treatment is used? Particle filter .... Micron............. Other filter............. UV disinfection............... Chlorination.................. Ozonation............... Other disinfection...............

15. Is the required purple pipe (or purple marking) installed on the suction and distribution pipe? Yes .... No .... Explain ....

16. Is the required “Warning: Non-potable Water — Do Not Drink” signage installed at each non-potable outlet point? Yes .... No .... Explain...

17. Is the pump appropriately rated for the number of fixtures and pump head? Yes .... No .... Explain ....

18. Is the pressure tank appropriately sized for the installed pump? Yes .... No .... Explain ....

19. How is the top-up system installed? Automated .... Manual............... Internal top-up tank .... Gravity feed into main storage tank ....

20. Is the control equipment of the top-up system functioning properly? Yes .... No............. Explain..

21. What type of backflow and cross-connection prevention methods is used? Air.............. Devices............ Explain ....

22. What method of overflow control is installed? Gravity fed to surface.............. Pump to surface.............. Pump to storm sewer.......................... Explain...

23. Has the rainwater system and all of its components been thoroughly explained to the homeowner or operation and maintenance manual referred to? Yes......... No........ Explain.......................

24. How will the rainwater harvesting system be maintained? Homeowner............. Rainwater system installer .... Both.............. Explain...

4.2 OPERATION AND MAINTENANCE OF SAND OR SUB SURFACE DAMS

4.2.1 Introduction

This section focuses on the operation and maintenance of sand dams or sub-surface dams related infrastructures. The reader is advised to visit section 4.1above for operation and maintenance of other related infrastructures such as storage facilities, water conveyance, treatment and distribution system.

Sand dams require careful maintenance, and immediate repair, if necessary, as flooding causes hundreds of tons of water to fall over the dam wall and onto the spill-over *apron*. Floodwater may also spill over and erode the wing walls and, perhaps, even over the riverbanks during heavy rains.

In contrast to *sand dams*, subsurface dams are not exposed to forces of floods, since the dam is below ground.

4.2.2 Management

4.2.2.1 Training of local community

For community sand dam projects, facilitating community trainings on implementation, operation, management and maintenance is important. Community trainings have the following objectives for the community:

i. Full participation in the process of the project planning and implementation;

ii. Enhanced awareness on project management;

iii. Ensured technical and management skills after project completion; and

iv. Enhanced awareness on management of the water quality and risks involved.

Community trainings can be divided into three categories:

i. Sessions on the project planning, implementation and management of activities.

ii. Educational sessions on natural resources management, sanitation and hygiene; and

iii. Technical trainings on operation, management and maintenance for the water committee.

4.2.2.2 Management of a sand dam

For community based sand dam project, the responsibility of the sand dam will be fully assigned to the water committee and care takers – who have attended the fore mentioned training – after completion of the construction of the sand dam. The water committee will be responsible for the management of the sand dam as well as the payment scheme and the caretakers will be responsible for the daily monitoring, operation and maintenance of the sand dam, wells and surrounding area.

The water committee, with support and assistance of the concerned Local Government Departments and the implementing partner, will monitor all activities to ensure sustainability of the project.

The dam owner shall take responsibilities explained above for private owned sand dams. The owner may engage qualified personnel for sand dam management.

4.2.3 Maintenance

Maintenance of a sand dam can be assured if the following issues have been properly addressed during the project:

i. Good workmanship during the construction of the sand dam;

ii. Full involvement of the community to ensure operation, management and maintenance once construction of the sand dams has been completed;

iii. Presence of a trained mason near to the sand dam project to ensure adequate repairs if there should be any serious damage to the structure, which is beyond the capacity of the trained caretakers;

iv. Proper linkage between the local community, local administration and governmental sector to ensure technical and advisory assistances for the community;

4.2.3.1 Considerations for immediate maintenance

i. Dam wall curing

For the first 21 days after the sand dam is completed, the owner need to keep a close watch on the dam wall. The concrete must be kept damp to cure it properly to avoid cracks and leakages along the dam wall. Heavy rainfall during this time of curing will hinder this process. It is not advised to build sand dams during the rainy season.

ii. Protecting the banks and catchment area around the sand dam

a. Terracing: Terracing will prevent excessive soil deposits upstream from the dam, by controlling fast, high volume run-off of water that causes soil erosion. It keeps silt out of the dam. Terraces will also conserve water in the embankments and trenches. It is important to stress that terraces are built and maintained so silt is kept out of the sand dam. Silt does not store water well. If silt fills the dam, there is little space for water in the voids.

Napier or other grass and/or legumes must be planted on the terrace ridges to provide good fodder and serves as an anchor for the terrace, further preventing erosion. (Consider trying vetiver grass if free-range livestock might destroy the edible grasses).

b. **Plantings downstream:** the planting of Napier grass or other grasses or trees is important on the sides of both banks downstream to stabilize the site and prevent erosion. This planting needs to be done immediately after construction.

c. **Fencing:** The owner may want to build a fence around the water points in the river bed upstream to protect the area from animals fouling the sand and reducing the dam's water storing capacity.

d. **Potential erosion spots:** Small rills or gullies near the site should be blocked to prevent soil erosion. These may be blocked by sand sacks or grasses. These rills and gullies are also used for additional water harvesting.

4.2.3.2 Considerations for long term maintenance

The following are the most important things to check for long term maintenance:

i. Immediately after a heavy rain, inspect the sand dam for damage.
   a. Check to make sure no water is going around the wings. If it is, extend the wings. If this is not done, the dam will wash out on that side and the work is lost.
   b. Check to see that tree trunks, branches and other materials that have been carried down the river are removed.

ii. Check for erosion downstream and renew plantings of Napier grass. Sometimes the length of the wings can be extended to prevent this erosion.

iii. Check that erosion is not occurring at the apron (i.e. the area directly under the primary and secondary spillways), along the bottom of the spillway and along the bottom of the wings downstream. If it is, reinforce the apron with cement and/or stones to avoid dam failure.

iv. Check for leaks and/or cracks in the masonry of the dam wall and wings and repair immediately to avoid dam failure.

v. Check the banks upstream and downstream and renew any plantings to control erosion.

vi. Check the terraces and replant any embankments that are damaged.

vii. Consider fencing if you see damage from animals on the terraces (or use vetiver grass).

viii. Think seriously of making more sand dams above and/or below the first one. A series of sand dams creates much more water storage, raises the water table, and increases the vegetation in the area. In the long term, this change will significantly improve the ecology of the area and the lives of the people.

Sand dams can be placed every 1 to 2 kilometers along a stream, and allows water to be stored rather than running to the ocean.

4.2.4 Monitoring & Evaluation

The amount of water abstracted from sand dam should be monitored on a daily basis. This will help in future water use management.

Water stored in sand dam is of safe quality when it is protected against pollution. To confirm the reference water quality, the dam owner should take a water sample from an observation well 50 meter upstream of the dam in the center of the river bed. A first sample has to be taken upon completion of the dam and sampling should be repeated on annual basis. The sample should be analyzed for all physical, chemical and bacteriological drinking water quality parameters. If any changes are observed the dam owner should call in the advice of water quality expert.

The dam owner should take the following protection measures to avoid pollution of the riverbed:

i. Livestock will be kept away from the river bed (100-200 meters upstream of the dam;

ii. No other garbage is dumped in the river bed especially during the dry period; and

iii. Organize a cleaning action just before the expected onset of the rains.

4.3 OPERATION AND MAINTENANCE OF CHARCO DAMS/SMALL EARTH DAMS

4.3.1 Introduction

This section focuses on the operation and maintenance of charco dams related infrastructures. The reader is advised to visit parts Aand B above for operation and maintenance of other related infrastructures such as management of catchment area, storage facilities, water conveyance, treatment and distribution system.

4.3.2 General Operation and Maintenance recommendations

i. Conduct periodic water quality analysis as shown under **section 4.2.4**above;

ii. Carryout visual inspection of all charco dam sections to ensure its safety by observing the following after each major rainy season:

   a. Check for any embankment movement/dislocation and report to your contractor or a nearby BWO in case of any anomaly,

   b. Check for any leakage along the embankment, spillway and outlet structure,

c. Check for erosion on both sides of the embankment and on the spillway,

d. Check for grass plantation on the downstream and replace where necessary, and

e. Remove trees and unwanted material along the dam for the case of valley type of the small dam.

iii. Avoid any human activities upstream of the dam for about 200 meters to reduce pollution and siltation. The same, a buffer zone of about 50 meters should be provided on both sides and on downstream of the dam,

iv. Siltation is probably the greatest risk of failure with ponds and dams. The idea is to keep silt out in order to reduce the need for subsequent de-silting,

a. Keep a good cover of indigenous grasses in the run-off area to prevent silt build-up. The owner should also consider provision of contour lines with trees or grasses in the runoff area.

b. If the inflow channel is defined, silt traps can be tried out to reduce silt load. In this case, stones laid across the channel form mini dams and perennial vegetation can be grown between these mini dams to reduce flow velocity of water, thereby encouraging silt deposition.

c. De-silting will most probably need to be carried out at some stage.

v. High evaporation rates are common with open water in certain areas, depending on the climate. Evaporation estimates may be higher than the real situation so, water lost to evaporation can be considerable. Some ways to reduce this might include:

a. Digging deeper to have a larger volume to surface area ratio.

b. Planting trees around the dam will act as a windbreak, thereby reducing evaporation.

vi. Construct the dam during the dry season,

vii. Fish can be introduced to eat mosquito larvae, while at the same time providing a source of nutrition. Mudfish are a good option as they can survive dry periods in the silt at the base of pond.

CHAPTER FIVE: WATER QUALITY

5.1 Introduction

Rain water harvesting is a valuable solution to water shortage and will lead to an improvement in livelihood, health and social economic growth. This can only be achieved if water for drinking and for other uses is of an acceptable quality.

Rainwater is generally safe for domestic use provided certain precautions are taken as part of water collection, storage, distribution and use. The cleanest water is water that falls directly from the sky. Water that has not come into contact with soil has no contaminants such as harmful bacteria, dissolved minerals or heavy metals. However, rainwater in heavily industrialized areas where atmospheric pollution is high may contain certain chemicals above the standards, like Sulphur oxides or nitrogen oxides causing acid rain.

Rainwater that touches the earth acquires other substances from process of leaching, weathering and dissolution. Living organism may also enter the water depending on the condition of the catchment surface and surrounding area. Poor design, installation and management of collection, conveyance and storage systems can also be blamed for the cases of poor rainwater quality e.g. bad odour, greenish as a result of algae growth.

This chapter provides knowledge and formalized measures to protect rain water from contamination during planning, harvesting, storage, distribution and use.It provides guidelines for risk assessment and quality control, testing and analyzing rain water, rain water quality criteria, survey, data base and, the recommended treatment methods. The chapter will provide rain water quality guideline to all parties involved in planning, construction, operation maintenance, inspection, monitoring and management of rain water harvesting schemes in the social economic and geographical context of Tanzania.

5.2 Factors Determining Water Quality of Harvested Rainwater

Water quality is determined by the composition of water as affected by natural processes and human activities. Water quality depends on the constituents dissolved or contained within thewater. It is often presumed that the chemical composition of water is the only factor involved. However, especially (micro) biological factors are of main importance when considering water quality. Next to this there are also physical factors. This is illustrated in figure 5-1.

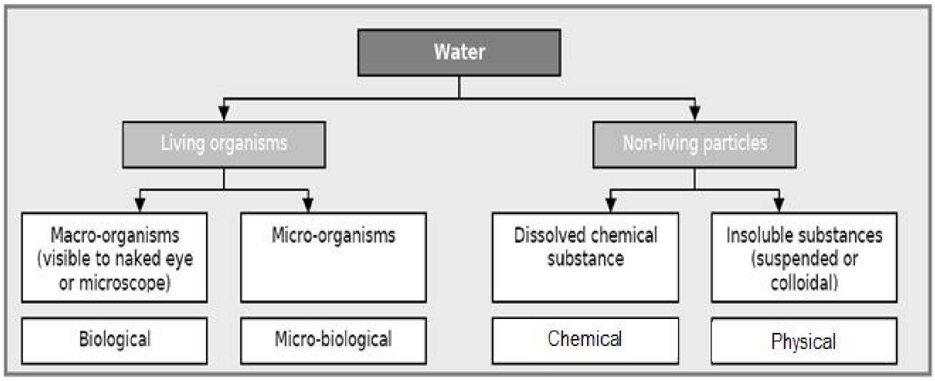

Figure 5-1: Factors determining water quality

Depending on the circumstances and exposure, contamination in rainwater harvested can be distinguished as follows:

i. (Micro) biological contamination:

The most common hazard in water sources obtained from roof or surface catchments is microbial (biological and microbiological) contamination, especially enteric pathogens. Enteric pathogens are micro-organisms (bacteria, viruses, and protozoa) that cause gastrointestinal illness. These organisms are introduced into drinking water supplies by contamination with fecal material (from human or animal origin) or dead animals and insects. The most relied indicator is E-Coli.

ii. Chemical contamination

Chemical contamination results from air pollution (industrial and traffic emissions), runoff and leaching of chemical substances (agricultural and human activities) and toxic material use. All these factors can pose serious health threat.

iii. Physical contamination.

Physical contamination includes inorganic and organic sediments like sand, silt, clay or plant material. Physical contamination affects the colour, odour or taste of the water, but it poses no direct health risk. Users can however object to water if its colour, odour and taste are found less attractive. The breeding of mosquitoes in or near RWH systems is another health hazard of rain water contamination.

5.3 Risk Assessment and Control

5.3.1 Water Safety Plan (WSP)

A Drinking Water Safety Plan is a documented plan that identifies health risks from catchment to consumer of a water supply system. The plan prioritizes those risks and puts in place controls to mitigate them. As shown in figure 5-2, three key stages can be defined in a Water Safety Plan: system assessment, monitoring and management.

These are defined by health-based targets and the desired outcomes, these are verified using a surveillance system.

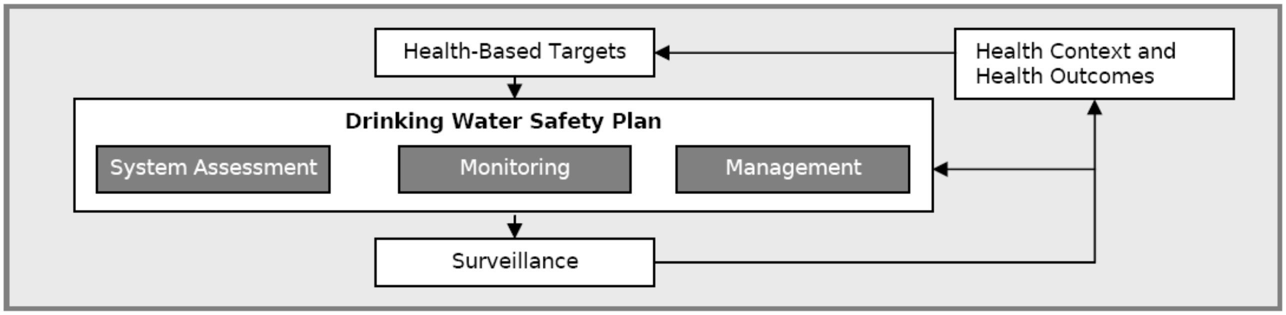

Figure 5-2: Framework for safe drinking water

5.3.2 Health-based targets

A direct measurable target is the quality of the water provided. Improving the livelihoods of people by providing a reliable, safe and nearby source of water can be measured in different ways, like the annual number of diarrhea episodes or the time spent on the collection of water. However, most health-based targets are difficult to measure since they are not only influenced by the source of water, but also depend on the living circumstances and customs of people.

5.3.2.1 System assessment

The RWH system as a whole has to be assessed to verify if the water delivered is of a quality that meets the targets specified. Mapping the risks of contamination and taking proper measures to limit these risks as much as possible, should be the main objective.

5.3.2.2 Operational monitoring

By monitoring the control measures which influence the water quality as identified in the system assessment, safe drinking-water can be more ensured. Check lists has been prepared which are shown in annexes 2a, b and c.

5.3.2.3 Management plans

By documenting the system assessment outcomes and describing actions to be taken in normal operation and incident conditions, management of the RWH system can be optimized. Checklists has been developed and actions plans given, these are shown in annexes 3a, b, c

5.3.3 System assessment: mapping the risks of contamination.

Generally treating and filtering of water seems the obvious method for obtaining a certain water quality. This, however, is an end-of-pipe solution. If contamination resulted from for example use of toxic materials or by poor maintenance, recontamination will certainly occur. By following a top-down method of preventing contamination, a more cost-effective approach can be reached (figure 5-3).

Area	Industrial, agricultural or human activities influencing water quality by air, water or soil		Filtration		
Catchment Surface	Roof paved or unpaved surface, dry river bed, maintenance	Prevention	Filtration		
Conveyance	Gutter, inlet constructions or riverbed maintenance		Filtration		
Storage	RWH systems maintenance			Treatment	
Delivery	Taps, hand pump, operation and management				Filtration

Figure 5-3: Mapping risk of contamination in RWH systems

The number of people using a RWH system also influences the impact of a health hazard if contamination would occur. It is therefore important to link the impact of a health risk with the number of people. For household RWH systems the health hazard due to poor water quality is relatively small, since few people are using the water. For community managed systems, for example school systems, the risk increases since more people can get sick from the water, but also spread the disease to family members in their homes.

5.3.3.1 Area

The area can be described as the external factors influencing the background or reference water quality in a RWH system and can be divided into physical and social factors:

i. **Physical factors:**The air, water and soil pollution present within the area, resulting from industrial and agricultural activities and geology directly influences the water quality of the RWH system. Mostly these factors are difficult to influence, but should be taken into account when starting a RWH project. In rural areas their influence is relatively small and can often be excluded, but can reflect unexpected outcomes in water quality tests.

ii. **Social factors:**Human conduct and level of education, reflected in the level of awareness of the relation between water and health, hygiene and sanitation, management and maintenance skills of RWH systems are social factors controlling water quality of a RWH system.

5.3.3.2 Catchment Surface

Depending on the type of RWH system, several catchment surfaces can be defined, i.e. roofs, paved or unpaved surfaces, dry sandy river beds. Contamination can be prevented by:

i. Using non-toxic materials for roofing, like cement, corrugated and galvanised iron. Metal roofs subjected to atmospheric corrosion can act as a source of heavy metals;

ii. Frequently cleaning and clearing of the catchment surface (from human, animal andorganic matter), removing overhanging branches and fencing off of the catchmentarea in the case of surface runoff.

Faecal contamination of water from rooftops can result from animal droppings on the roofsurface. Water harvested from ground surfaces or underground catchment is vulnerable to contamination by animal or human faeces and may also contain dissolved minerals above the standards. The larger the catchment surface, the bigger the chance for contamination due to more complex management of the catchment.

5.3.3.3 Conveyance

Depending on the type of RWH systems, several conveyances can be defined: gutters, inlet pipes, and collection and inlet canals. Contamination can be prevented by:

i. Using non-toxic materials**;**

ii. Frequently cleaning of the conveyances. Debris and pools should not remain in the gutters, since they can become pools of contamination.

Filters should be installed at the entrace or end of the gutter or inlet canals to prevent small animals, organic matterand debris from entering the RWH system. A first flush device should be installed to divert the first rainfallwhich contains higher contaminant load.

5.3.3.4 Storage

Three different types of RWH storage systems can be defined: above groundtanks, below ground tanks and sand dams. Contamination can be prevented by:

i. Using non-toxic construction materials;

ii. Using adequate covering to prevent influence from direct sunlight, animals,insects and organic matter from entering the storage system .Tanks that permits light to enter stimulates algae growth.Opaque tanks maintain high water quality than translucent tank.

Contamination might have occurred in the previous levels. Treatment of the water can be applied when found necessary (see table 5-1 and annexes 3 a, b and c). Residence in the storage system itself provides opportunities for water purifying processes such as sedimentation, biofilm growth adsorbing heavy metals, organics and pathogens, bacterial die-off and filtration (for sand dams), increasing the water quality over time.

Cleaning of the storage system should only be done if the previous water was found to becontaminated. Surface runoff storage systems will contain a lot of soil material which has to be removed every year when the tank is empty (before the rainy season) since it does not only affect the water quality, but also decreases the tank capacity. Sand dams have no closed storage system which makes it even more important to limit contamination risks as much as possible in the previous levels.

Other possible risks of contamination at the storage level are:

i. Frequent opening of the manhole.

ii. Mixing of tank water or filling of a tank with water from other sources.

5.3.3.5 Delivery

Contamination in the delivery system can be prevented by:

i. Proper management of the water distribution;

ii. Creating awareness on hygiene issues (hygiene education). People can contaminate the water by non-hygienic use of the taps or pumps, as well as use of unclean containers in or after extraction.

iii. Closing/Fencing the area around the delivery point for animals,because they can infect the water by drinking from the (leaking) taps or pumps;

iv. Preventing water pools around the RWH systems which could enhance mosquito breeding for example by increasing the infiltration capacity of the soil at the delivery point (gravel pack).

If the quality of the water is still questionable, treatment at a household level can be applied (see table 5-1).

5.4 Recommended Methods and Measures for Ensuring and Improving Water Quality

5.4.1 Hygienic practices

These are performed for purposes of preserving one's health. If adopted and adhered to, a health family and community would result.

5.4.1.1 The importance of hygiene in water supply projects

Hygiene education and monitoring of the operation and maintenance of the RWH system, along with sanitary practices, are essential in providing safe and clean water. Creating awareness on personal and system hygiene issues related to water is crucial.

5.4.1.2 Treatment and filtering

The main desired impact of water supply projects is to improve health, and therefore treatment of water should be applied if health is at risk.

5.4.2 Recommended treatment and filtering methods

Water treatment only makes sense if it is done properly, and if hygienic collection, storage and use of water ensure prevention of recontamination. The most applied practices are boiling and chlorination.Table 5-1belowsummarises recommended treatment and filtering methods for RWH systems. A summary of potential health hazards and preventive measures with roof water harvesting is given in annex I. Annex II provides a checklist for rainwater storage.

Table 5-1:The recommended treatment and filtering methods for RWH systems

Solution or substances to be added		Roof run off	Surface run off	Sand dam
	Chlorination	Tank	House hold	
	Aluminium sulphate	Not applicble	House hold/tank	Not applicable
	Silver coated ceramic balls	Tank	House hold/tank	House hold
Filters	Ceramic pot filter	House hold	House hold	House hold
	Bio sand filter	House Hold	House hold	House hold
Heat and UV radiation	Boiling	House hold	House hold	House hold
	SODIS	House hold	House hold	House hold

5.5 Recommended Methodology for Water Quality Sampling and Testing

5.5.1 Sampling and testing

The recommended methods for sampling and testing for RWH are as prescribed in the standard methods for examination of water and waste water.

5.5.2 Water quality criteria

The rain water quality standards should always be tested next to national standards. Based on the WHO Guidelines for Drinking Water Quality (2004/2011), rain water quality analyses criteria for potable water is as listed in the table 5-2 above. Parameters may be omitted or added depending on the criteria for other uses of water or susceptibility of catchment to certain contaminants other than listed in table 5-2. Table 5-2 explains Criteria for water quality based on WHO guidelines.

Table 5-2: Criteria for water quality based on WHO guidelines

	Roof Harvesting	**Surface runoff**	**Sand dams**
E.coli	<10cfu/100ml	<10cfu/100ml	<10cfu/100ml
Ammonia	<1.5mg/l	<1.5mg/l	<1.5mg/l
Aluminum	<0.2mg/l	<0.2mg/l	<0.2mg/l
pH	6.5-8.5	6.5-8.5	6.5-8.5
Turbidity	Not relevant	<15NTU	<5NTU
Nitrate/nitrate	Not relevant	<50mg/l	<50mg/l
Lead	<0.01mg/l	0.01mg/l	0.01mg/l
Zinc	<15mg/l	15mg/l	15mg/l
Total petroleum Hydrocarbon	Not relevant	300microgram/l	300microgram/l
Total Suspended solids	70mg/l	70mg/l	70mg/l
Total dissolved solids	500mg/l	500mg/l	500mg/l

5.5.3 Baseline and long-term water quality survey

The first rainy season after completion of a RWH system, a water quality survey should be done. This survey will also give a general idea of the performance of each system, the skills of construction of the implementing partner and the community operation and management. The results of this first survey will lead to fine-tuning of RWH system; identifying construction flaws, identifying operational, maintenance and management flaws and selecting most optimal treatment measures (see annexes 2a, b and c

Table 5-3: Methodology for baseline and long- term water quality surveys.

	Baseline survey	Long-term survey	
Period	After 1st rainy season after construction	After rainy season	
	All RWH systems constructed that year	Random selection of 30% of all tanks(>1 year old)	
Parameters	All parameters listed in table 5-2	Roof water harvesting • E,Coli • Chlorine if chlorination has been applied	Surface run off and sand dams. • E.Coli • Turbidity • Chlorine if chlorination has been applied • Aluminum if it has been applied

For the long-term survey a random selection of 30% of all RWH systems older than 1 year will be made. This survey should also be executed after the rainy season and the outcomes can be compared to the outcomes of the baseline survey in order to detect effects of improvements made, treatment measures applied or different operation and management of the RWH system. Table 5-3 guides on methodology for water quality surveys.

5.5.4 Rain water quality database

Water quality data base of each project should be developed in which analysis results of each sample tested can be added, edited, and analyzed statistically. The database should be a living document which will grow in time and can be updated to new insights. The data can be used to optimize RWH systems operations and management and provide data for policy, advocacy and promotion.

CHAPTER SIX: AWARENESS CREATION AND TECHNOLOGY TRANSFER TO THE COMMUNITY

6.1 Awareness Creation

Awareness creation is the first step towards making any intervention successful. When people become involved with their own water supply projects it creates a sense of ownership and assures sustainability. Therefore, raising awareness will be the catalyst for people to change their attitudes towards rainwater harvesting so as to supplement the existing water supply sources in the country. A successive awareness creation and technology transfer will enhance reduction of operation and maintenance cost due to involvement of the community in the whole process.

This chapter will provide guidance on how to conduct awareness creation and define the responsibilities of key role players.

6.1.1 Objectives of Awareness Creation

Public awareness brings certain issues to the attention of the intended group of people by informing, sensitizing and drawing attention. It strengthens networking, collaboration, participation and sustainability. The following objectives are aimed for in RWH:

i. To increase public awareness of the need for water conservation and the benefits of Rainwater Harvesting (RWH);

ii. To promote safe and hygienic rain water collection/ harvesting practices; and

iii. To build climate resilience into the water sector in Tanzania

6.1.2 Awareness creation in RWH

Awareness creation can be done by using different strategies. The educational level of the community members plays an important role. In these guidelines, two types of awareness creation can be used

However, awareness can be created among general public, Potential or actual beneficiaries and partners

i. **Informative:** Awareness Creation can be done by using either of these information media to help people understand what is Rain Water Harvesting, TVs, Radios, News Papers, Pamphlets, Fliers, brochures, Posters, Websites and other internet-based tools.

ii. **Participative:** In this type, the audience is involved and has an opportunity to discuss, share their views and ask questions. Methods used under this approach are presentation, study tour, workshop, meetings, group discussions, exhibition, awareness creation events and training.

6.1.2.1 Presentation

This is commonly used and it does not require extensive preparation. The presenters need to have skills in talking to participants without boring them, be able to answer questions correctly, and guide the group discussion. More developed options include dialogue, debate and round table.

i. The presenters explain on the issues decided upon beforehand, in some cases using slides, videos or printed material. A session should last for a reasonable time depending on the issue and the audience;

ii. Facilitate discussion among participants, and prepare means of obtaining feedback on what they have learnt.

iii. Prepare requirements for the presentation (Projector, speakers, etc.)

6.1.2.2 Study Tour

Direct observation creates a greater learning impact for participants. The success of a tour depends greatly on the time and opportunity of the visit. It requires good preparation and coordination, and the safety of the participants. The following should be considered

i. The coordinators prepare the itinerary and coordinate the logistics.

ii. The facilitators or the people of the place visited offer technical explanations.

iii. Close the event with a questionnaire to be filled out by participants on what they have learned

6.1.2.3 Workshop

Working with the hands on tangible products helps to motivate the participants. The facilitators guide the implementation of an art project (drawing, crafts, map, etc.). Depending on the issue chosen, a workshop could last around 6 hours or more. The following should be done:

i. Present the results to all the participants and evaluate them. Close the session with questions and answers to test their understanding.

ii. Transfer of the central message and a questionnaire to fill out on what they learned.

6.1.2.4 Meeting

This is another method which is less expensive and not time consuming. Here the facilitator and audience have time to discuss, ask questions. Arrange a two to three hours meeting with the audience and sell the idea to them. Be ready and patient to answer questions because some may be provocative. This depends on the type of the group.

6.1.2.5 Group discussions

Group discussion is done by grouping five to ten members who shall discuss a certain topic and come up with their observations. Similar or different topics can be discussed among different groups after which a joint session is conducted and presentations are done by individual groups.

6.1.2.6 Exhibitions and awareness creation events

These are usually done by demonstrating certain technology or material in public gatherings. You can make a use of SabaSaba, Nane Nane, Maji Week and other celebrations to create awareness on Rain Water Harvesting.

6.1.2.7 Trainings

This can be done through both short and long term sessions in which participants are given knowledge through presentations and hands on sessions. The Facilitator has to develop training objectives, topics, demonstration materials and contents for the sessions. One or more facilitators can be engaged during the training.

6.1.3 Steps to be followed before engaging in awareness creation

i. Identify your target group

ii. Understand the social economic characteristics of the audience group

iii. Choose the appropriate method of awareness creation according to the social economic characteristics of the group

iv. Identify resources needed in awareness creation

v. Build rapport (Good and harmonious environment for you to work)

vi. Don't totally ignore traditional ways of RWH they have but build on what they already have (embrace existing indigenous knowledge and figure out ways to develop on them, merging with current technology and advancements)

vii. Create awareness

viii. Give room for the audience to ask, discuss, criticize and comment

ix. Asses the outcome of the activity

x. Write report

6.2 Technology Transfer

The guidelines provide some clues on how to transfer knowledge of RWH and its systems to the community. It involves imparting knowledge to the targeted group of people.

6.2.1 Rationale of Technology Transfer

In considering promotion of RWH adoption, technology transfer is imperative for the following reasons:

i. To train a cadre of skilled persons to install, operate and maintain service of RWH systems,
ii. To ensure availability of supply chain and technical assistance
iii. To ensure sustainability

6.2.2 Approaches for technology transfer

In transferring RWH knowledge, similar approaches as for awareness creation are used except that more time is spent to provide detailed practicality of the technology concerned. This involves practical training and site visits. The following methods are generally applied depending on the social, economic and education level of participants:

i. Training courses
ii. Workshops
iii. Demonstration events
iv. Exhibitions

6.2.3 Steps for technology transfer

The following steps are used to identify suitable approach for technology transfer:

i. Identify your targeted group
ii. Understand the social economic characteristics of the audience group
iii. Choose the appropriate method according to the social economic characteristics.
iv. Identify resources needed in training
v. Conduct training/ Seminar/ workshop
vi. Give room for the audience to ask, discuss and comment
vii. Assess the outcome of the activity
viii. Write report

6.2.4 Modules for technology transfer

The following modules are to be used in technology transfer:

i. Introduction to Water Management
ii. Concept of Rain Water Harvesting
iii. Importance of Rainwater harvesting and status of current available/relied water supply sources
iv. Rain water collection and Community Participation
v. Water use quality, Quantity and Pollution
vi. Relief and Drainage
vii. RWH systems and techniques
viii. Sustainability of RWH systems
ix. Monitoring and Evaluation of RWH systems

6.3 Main Actors in Awareness creation and Technology Transfer

Actors of Awareness Creation and Technology Transfer are divided into National, Regional, District and Community levels. The responsibilities of these actors are shown in table 6-1 below:

Table 6-1: Responsibilities of actors at National level

Level	Actor	Responsibility
National	Ministry of Water	i. Prepare and disseminate the guidelines for RWH ii. Monitor the implementation of the guideline iii. Provide technical and financial support iv. Orient users on the guidelines v. Ensure quality assurance of rain water
	Ministry of Education	i. Prepare syllabus for RWH trainings

Level	Actor	Responsibility
		ii. Installation of RWH systems demonstrations in schools iii. Monitor the implementation of RWH in schools
	PO-RALG	Supervise, facilitate and oversee implementation of RWH demonstration projects and bylaws in LGAs
	Ministry of Health	Handle the hygiene and sanitation aspect relative to RWH practices Provide relevant guideline
Regional	Regional Secretariats (Water),	i. Monitor awareness creation ii. Monitor Technology transfer iii. Monitoring, Evaluation and Follow ups iv. Ensure quality of Rain Water harvested v. Prepare Reports and submit to the appropriate authority
	Regional health Officers	i. Monitor awareness creation i. Monitor Technology transfer ii. Monitoring, Evaluation and Follow ups iii. Ensure quality of Rain Water harvested iv. Prepare reports and submit to the appropriate authority
	Regional Education Officers	i. Monitor implementation of syllabus for RWH trainings ii. Monitor installation of RWH systems during demonstrations in schools iii. Monitor the implementation of RWH in schools

Level	Actor	Responsibility
District	District Community Development Officers	i. Disseminate guidelines ii. Facilitate awareness creation activities iii. Monitoring, Evaluation and follow Ups
	District Water Engineers	i. Facilitate awareness creation activities ii. Monitoring, Evaluation and follow Ups iii. Provide technical and financial support
	District Health Officers	i. Disseminate guidelines ii. Facilitate awareness creation activities iii. Monitoring, Evaluation and follow Ups iv. Provide technical and financial support
	District Education Officers/Teachers	i. Disseminate guidelines ii. Facilitate awareness creation activities iii. Monitoring, Evaluation and follow Ups iv. Provide technical and financial support
Community	Community Based Organizations (CBOs)	i. Mobilize community members ii. Conduct Awareness Creation iii. Facilitate Technology transfer through workshops and teachings
	Non-Governmental Organizations	i. Conduct Awareness Creation ii. Facilitate Technology transfer through workshops and teachings

CHAPTER EIGHT: FINANCIAL ARRANGEMENTS/REQUIREMENTS FOR ADOPTION RWH

It is essential to address the financial aspect of owning and practicing RWH at individual and community level. System cost is usually the main challenge in considering adoption at individual level, hence proper strategies should be put in place. Several self-financing initiatives exist and have been practicable in other sectors including agricultural, mining and these should be considered in empowering individuals and communities to improve their own water supply with RWH.

Self-supply has been explained as a low cost approach to service delivery, initiated by individual families or groups. Self-supply initiatives can serve as a motivator to external support from the public sector and the private sector as well, upon seeing internal efforts to improve the standard of living. Systems financed under self-supply initiatives have the potential for better maintenance and management. These may include, co-financing, cash/in-kind contributions, labor contributions, and microfinancing.

In community RWH projects, the involvement and cooperation of the public sector, the community and the private sector is essential. Each entity involvement has a beneficial impact on the project implementation and sustainability. Alternatively, companies can support such projects in communities as a corporate social responsibility (CSR) activity. As a way forward to attain financial support and stability the following needs arises:

- Exposure and increased awareness to self-supply initiatives such as micro financing institutions and models e.g. SACCOS, VICOBA, and UPATU

- Company or private sector involvement e.g. co-financing with communities (communities contributing in kind or cash or through labour input), or donation as a corporate social responsibility

- Government involvement through provision of incentives, subsidies and or tax exemptions.

- Customer survey to establish financial support criteria/scenario.

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