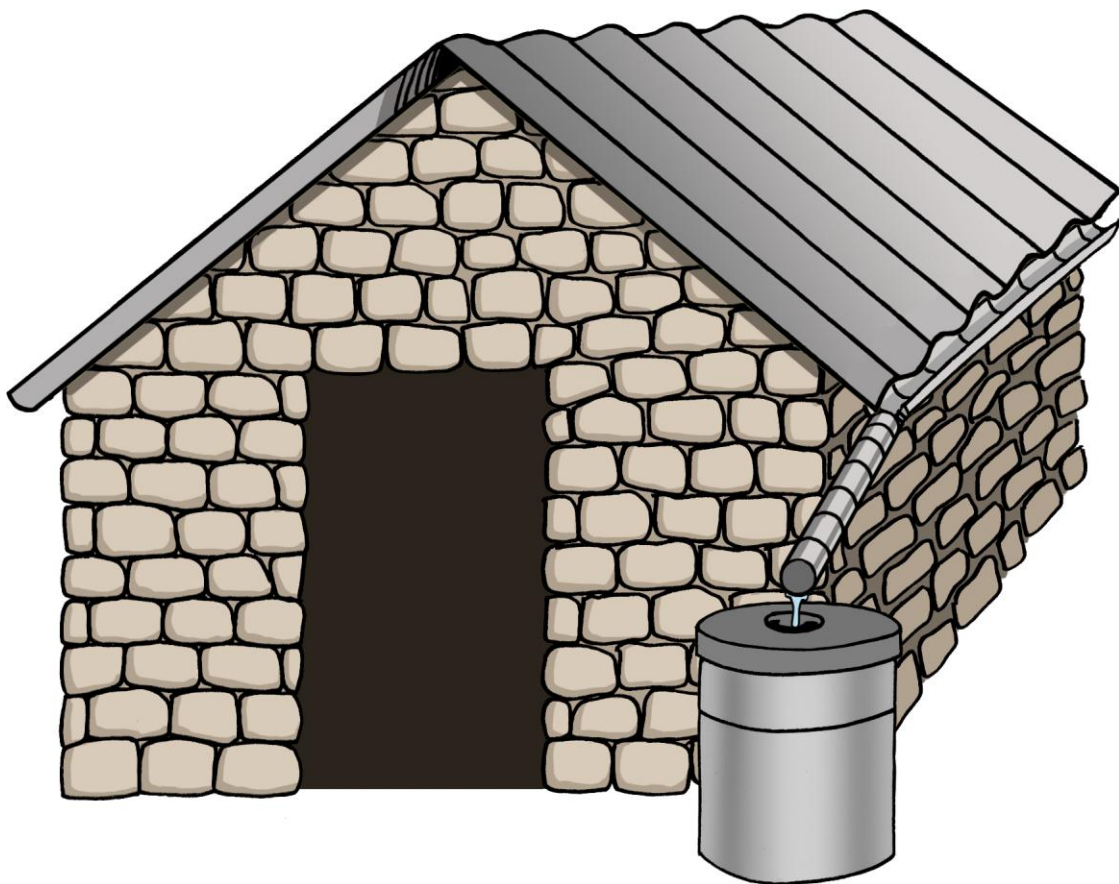


Introduction to Household Rainwater Harvesting





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CAWST transfers knowledge and skills to organizations and individuals in developing countries through education, training and consulting services. This ever expanding network can motivate individual households to take action to meet their own water and sanitation needs.

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Glossary

Abanbar (Persian)

Traditional, communal, excavated rainwater reservoirs housed in distinctive roofed buildings and still used in modern day Iran.

Aggregate

Crushed stones normally between 8 mm and 32 mm

Barrios (Spanish)

Marginal informal squatter areas in Central American cities.

Brick masonry

The technique of using mortar to build with burnt bricks.

Bund

Low earth wall, ridge or dyke used to divert or retain rainwater runoff.

Catchment

Any discrete area draining into a common system; e.g. a river catchment is all drained by one river.

Check Dam

Can be large or small, but is used to store rainwater

Chultun

Excavated underground rainwater tank lined with stucco (cement/lime) found in the limestone area of Yucatan Peninsular, Mexico.

Cistern

Tank for water storage.

Community based organization (CBO)

Small, local, non-profit organization that addresses community needs. Typically they have first hand knowledge of the problems they are addressing and a personal stake in the success of their solutions.

Concrete

Mixture of cement, coarse sand, crushed stones (aggregate) and water.

Corrugated iron

Usually galvanized sheet iron or sheet steel shaped into straight parallel ridges and hollows.

Curing

The process of assisting mortar and concrete to harden by keeping it moist for a period of weeks.

Developing country

A loose term used to identify poor nations based on per capita income. Developing countries may also be termed underdeveloped, low-income, majority world, the South or the Third World.

Drain

Can be large or small, but it is used to receive heavy rainfalls on the land

Fascia

Boards nailed to the edge of a roof; often where a rain gutter is attached.

Favelas

Large, squatter slum areas typical of large South American cities.

Ferrocement

Construction method involving the reinforcement of cement mortar using weld-mesh, British Reinforcement (BRC) mesh, chicken mesh, G.I. wires or barbed wire.

First (foul) flush

Any system or device designed to discard the initial roof runoff at the start of any rainfall.

Galvanized iron

Usually a sheet of iron that is coated with zinc to prevent it from rust.

Glide

Stone or tile ridge constructed at an angle on the roof to divert rainwater into a tank and to avoid the need for gutters.

Guttersnipe

A special type of self-cleaning foul flush device which can be attached to the downpipe just beneath the gutter.

Hafir (Arabic)

Excavated water reservoir filled by storm runoff for livestock and domestic water supply.

Hygiene

Practices, such as frequent hand washing, that help ensure cleanliness and good health.

Impermeable

Material or soil that does not allow, or allows only with great difficulty, the movement or passage of water through it.

Inselberg / Monadnock / Koppie

A hard rock structure that rises above the grounds

Kundis

Large, traditional, saucer-shaped ground catchment systems with central covered systems found in Rajasthan, India.

Loess

Fine windblown deposits common in central and north-west China.

Mortar

Mixture of cement, sand and water without crushed stones.

Murram

Clay containing soft pebbles and sometimes used for road construction.

Nil

A cement slurry made from mixing cement and water which can be used as a substitute for waterproof cement.

Non-government organization (NGO)

Any local, national, or international organization, profit or non-profit, whose members are not employed by a government. Most are charitable, research or educational in nature. They are concerned with a wide range of social, economic and environmental issues. (See also civil society organization and non profit organization).

Oorani

Village tanks or ponds found in India which are used for harvesting and storing rainwater for community use.

Pila (Spanish)

Small, open cement water tank holding up to about 500 litres common in squatter areas in Honduras.

Pointing

Process of finishing joints in brickwork or masonry with mortar and concrete.

Polyvinyl chloride (PVC)

A tough, weather resistant plastic often used to make pipes.

Precipitation

A general term for water which falls from the atmosphere as rain, sleet, snow and hail. Note: Fog, dew and frost and not generally considered as forms of precipitation as they condense or are deposited on to surfaces by impaction.

Rainwater catchment

Collection and storage of runoff primarily for domestic use and water supply.

Rainwater harvesting

A general term for most types of rainwater catchment (but excluding floodwater harvesting) for both agriculture and domestic supply.

Reinforced concrete

Concrete that is reinforced with steel bars, weld-mesh or British Reinforcement (BRC).

Risk analysis

The technique used to determine the likelihood or chance of hazardous events occurring.

Rubble stone masonry

The technique of using mortar with uncut, or undressed, rubble stones and rocks.

Runoff

The water that flows away from a catchment after falling on its surface in the form of rain.

Runoff coefficient

The ratio of the volume of water which runs off a surface to the volume of rain which falls on the surface.

Sand dam

A ridge that slows or traps water as it flows downstream

Sand river

A dry river bed, seasonal (ephemeral) river

Safe water

Water that is safe for drinking and bathing including treated surface water and untreated but uncontaminated water.

Sanitation

Maintaining clean, hygienic conditions that help prevent disease through services such as garbage collection, wastewater disposal, and latrines.

Sedimentation

Particles that settle out of the water

Shuijiao (Chinese)

Chinese underground bottle-shaped water cellar, up to 30 m³ in volume, especially common in the loess plateau region of central China.

Stone masonry

The technique of using mortar to build with regular dressed stones and blocks.

Tankas

Local name for rainwater tanks in parts of Northern India.

Thai jar

1-2 m³ ferrocement rainwater jar, modelled on traditional clay jars, used to store water with volumes typically less than 250 litres.

Threshing floor

A specially constructed mud and dung-plastered floor, surrounded by a low wall, used as a surface for threshing grain and, more recently, for collecting rainwater runoff.

Turbidity

Cloudiness caused by particles suspended in the water

SOURCES

[Gould, J. and Nissen-Petersen, E. \(1999\). Rainwater Catchment Systems for Domestic Supply: Design, Construction and Implementation. ITDG Publishing, Rugby, UK.](#)

The World Bank Group, Development Education Program, DEPweb (2005)

[Available at: www.worldbank.org/depweb/english/modules/glossary.html](http://www.worldbank.org/depweb/english/modules/glossary.html)

Acronyms

ALDEP	Arable Lands Development Programme
CBC	Canadian Broadcasting Corporation
CIDA	Canadian International Development Agency
CRI	China Radio International
DHAN	Development of Human Action Foundation
DTU	Development Technology Unit
EIA	Environmental Impact Assessment
GI	Galvanized iron
IDRC	International Development Research Centre
IRCSA	International Rainwater Catchment Systems Association
JMP	Joint Monitoring Program
NGO	Non-governmental organization
PVC	Polyvinyl chloride
SOPAC	South Pacific Applied Geoscience Commission
UNEP	United Nations Environment Program
UNESCO	United Nations Educational Scientific and Cultural Organization
UNHABITAT	United Nations Human Settlements Programme
UNICEF	United Nations Children's Fund
US AID	United States Agency for International Development
WHO	World Health Organization
WOCAT	World Overview of Conservation Approaches and Technologies

Units:

1 m = 1 metre = 100 cm = 1,000 mm

1 m = 3.28 feet = 39.37 inches

1 m³ = 1 cubic metre = 1,000 litres

1" = 1 inch = 2.54 cm = 0.0254 m

1 hectare = 100 m x 100 m = 2.47 acres

1 British imperial gallon = 0.83 US gallons = 4.55 litres

1 US gallon = 3.8 litres

Unit Conversion Website: www.onlineconversion.com

Formulas:

Where: r = radius

h = height

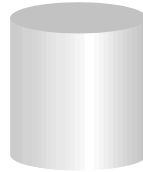
$\pi = 3.14$

Circumference of a circle = $2\pi r$

Area of a circle = πr^2

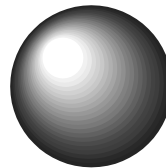
Volume of a cylinder = $\pi r^2 h$

Surface area of a cylinder = $2\pi r^2 + 2\pi r h$



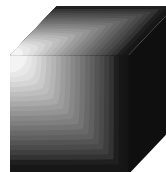
Volume of a sphere = $\frac{4}{3} \pi r^3$

Surface area of a sphere = $4\pi r^2$



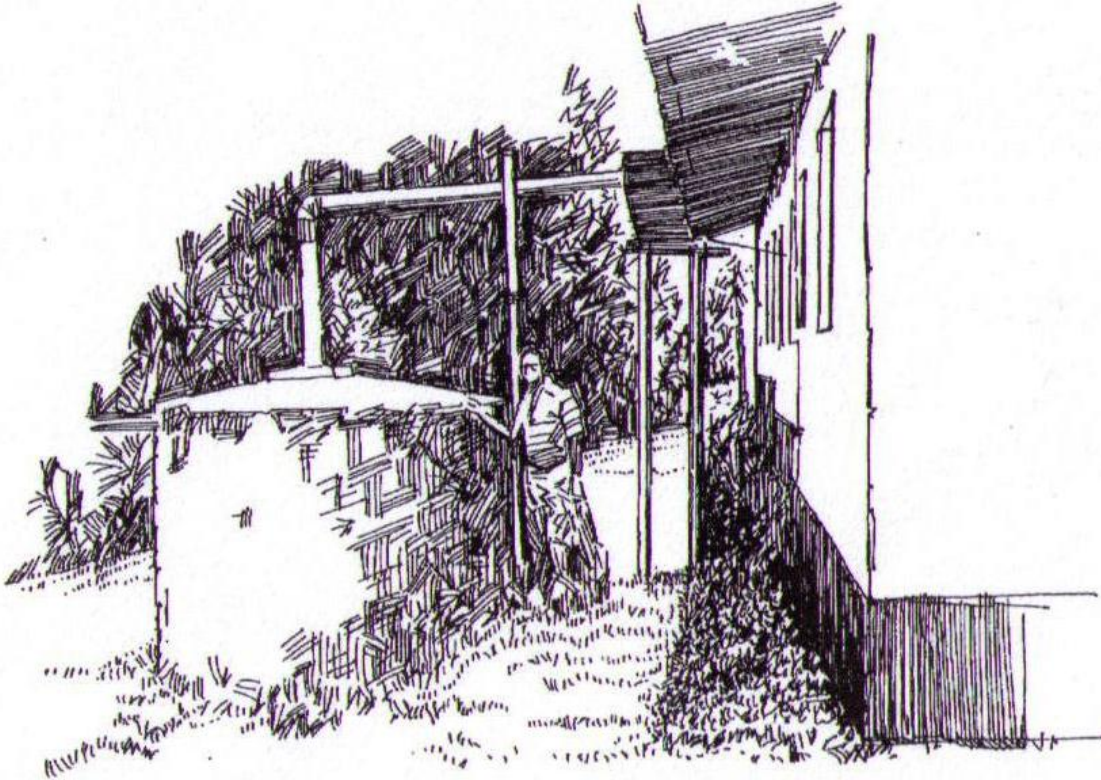
Volume of a cube = side x side x side

Surface area of a cube = 6 x side x side



1 Introduction to Rainwater Harvesting

“God must think we’re crazy. We let the rain fall off our roofs onto our soil; it washes the soil away and flows to the bottom of the hill. We then climb down the hill and carry it back up to drink.”



(Shaw, 2005)

~ Ugandan project worker (IRCSA, n.d.)

Learning Expectations

In this chapter you will learn about:

- Various uses for rainwater harvesting.
- The role of rainwater harvesting for domestic use in both rural and urban areas of developing countries.
- Benefits of rainwater harvesting for households in developing countries.

1.1 Introduction

At least 1.1 billion people in the world lack access to safe drinking water. The majority of these people live in Asia and Africa. One of the goals of the first United Nations Decade of Drinking Water and Sanitation (1981-1990) was to achieve universal access to safe drinking water. There were some positive developments with an estimated 620 million more people gaining access to a safe water supply and 435 million to sanitation facilities.

However, because of rapid population growth during the same time period, almost one-third of the world's population still lacks access to safe drinking water.

There remains a tremendous backlog in terms of billions of unserved people, mostly poor and marginalized citizens living in squalid, unhealthy environments in developing countries.

In the last 20 years, there has been a renewed and growing interest in the ancient practice of rainwater harvesting as a potential water source. In simple terms, rainwater harvesting is a technology used for collecting and storing rainwater for human use from rooftops, land surfaces or rock catchments. The collected rainwater can be used for a variety of purposes, including household drinking water, agriculture, flood control, back-up supply during dry spells or breakdowns, and emergency water supply in the case of disasters.

Large scale water projects using wells or dams have been built in the past few decades which have displaced rain water as an option for a water source. It has recently been recognized that traditional rainwater harvesting can be used as an important tool in managing water resources. Countries like China and India have made great strides in using traditional methods to ensure that limited water resources are being well managed.

It is worth noting however that rainwater harvesting is not the answer for all household water problems. There is a complex set of interrelated circumstances which have to be considered when selecting an appropriate water source. Cost, climate, technology, hydrology, social, and political elements all factor in the eventual selection of a water supply for a given situation (DTU, 1999).

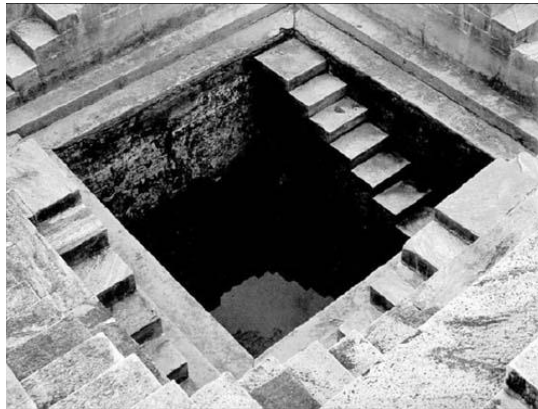
While rainwater harvesting may not always be the ideal solution for all situations, it can play a particular niche role and offer an alternative source of water supply that complements others.

1.2 Historical Development

Rainwater harvesting has been practiced by a variety of ancient civilizations around the world and appears to have originated in Asia and the Middle East several thousand years ago. Examples of traditional water collection for both domestic and agricultural use dating back more than 4,000 years have been documented all over India, from the Himalayan mountains to the eastern coastal plains. Rainwater utilization also has a long history in Sri Lanka, Nepal and Bangladesh where use of harvesting systems are still common today.

In the Negev desert in Israel, cisterns for storing runoff from hillsides, for both domestic and agricultural purposes, have allowed habitation and cultivation in areas with as little as 100 mm of rain per year since 2,000 BC or earlier (Evenari et al., 1961). Conical

dome shaped structures, known as *abanbars*, designed to house communal sub-surface rainwater cisterns have been used in Iran for many centuries and are still being constructed today (Hassanizadeh, 1984).



Traditional rainwater catchment in India (Global Rainwater Harvesting Collective, n.d.)

Traditional Technology Still Used in India

Tankas are underground tanks, found traditionally in most Bikaner houses in India. They are built in the main house or in the courtyard. They were circular holes made in the ground, lined with fine polished lime, in which rainwater was collected. Tankas were often beautifully decorated with tiles, which helped to keep the water cool. The water was used only for drinking. If in any year there was less than normal rainfall and the tankas did not get filled, water from nearby wells and tanks would be obtained to fill the household tankas. In this way, the people of Bikaner were able to meet their water requirements. The tanka system continues to be used in residential areas, temples, dharamshalas and hotels.

(Centre for Science and Environment, n.d.)

In China, there have been bottle-shaped underground tanks, known locally as *shuijiao*, which are up to 30 m³ in volume, used for several centuries to store water for many households.

The earliest known use of rainwater technology in Africa comes from Northern Egypt, where sub-surface cisterns with volumes ranging from 200 to 2,000 m³ have been used for at least 2,000 years – some are still in use today (Shata, 1982). In sub-Saharan Africa, the small-scale collection of rainwater into traditional jars and pots has been practiced for millennia. Rainwater has been traditionally collected in Uganda from trees using banana leaves or stems as temporary gutters; up to 200 litres may be collected from a large tree in a single storm (ITDG, n.d.).

Although there is limited historical evidence of rainwater harvesting in the Americas, archaeological remains in Mexico show that ground catchment systems, known as

chultuns, were being used in the Yucatan Peninsula as early as 300 AD (Gordillo et al., 1982). Evidence of roof catchment systems in Bermuda date back to 1628 and current regulations require tanks by law (McCallan, 1948). The Portuguese also introduced hand-dug cisterns in north-east Brazil and were commonly used until about 40 years ago (Gnadlinger, 1995).



Traditional Chinese shuijiao in current use (CRI, 2004)

See pages 7 – 10 in Gould and Nissen-Petersen, 1999 for more references to historical water catchments technologies.

1.3 Current Applications in Developing Countries

There was a decline in rainwater utilization in many parts of the world in the middle of the twentieth century when there was a great focus placed on large-scale water supply and distribution projects, such as dams and piped systems. However since the 1980s, there has been a renewed and growing interest in the traditional practice of collecting rainwater for domestic use in both rural and urban areas of developing countries, particularly in Africa and Asia.

The adoption and expansion of rainwater harvesting systems can be attributed to a variety of factors, including:

- Severe ground and surface water shortages in some regions.
- Increasing pressure on limited water resources.
- Poor ground and surface water quality (e.g. arsenic contamination, salination).
- Failure of conventional water supply systems.
- Growing use of impervious roofing materials, like tiles and corrugated iron, replacing traditional grass and thatch.
- Development of effective, low-cost tank designs (e.g. Thai ferrocement jars).

1.4 Rainwater Collection in Rural Areas

The number of rainwater tanks with volumes greater than 1 m³ is estimated to be many tens of millions worldwide. Most of these have been constructed since 1980, primarily in

the rural areas of developing countries. This is not surprising considering that in 2002 only 72 percent of rural residents have access to any improved water supply; this figure is only about 45 percent in sub-Saharan Africa (WHO/UNICEF JMP, 2005).

In Asia, several tens of millions of people are dependent on rainwater supplies, most significantly in north-east Thailand, central China and India. These countries in particular have seen an increasing willingness by some national and many local government authorities to invest in the promotion and implementation of rainwater harvesting technology. In Thailand alone, more than 10 million ferrocement rainwater tanks have been built since 1983.

Other countries such as Indonesia, Bangladesh, the Philippines, Nepal and Sri Lanka are also beginning to use rainwater technology, although to a lesser extent.

Domestic Rainwater Harvesting in Rural India

The very simple method of catching rainwater with a saree is practiced in the heavy rainfall areas of Kerala and Karnataka. The traditional technique is used for three months during the monsoon season and where the available water supply is not potable.

There is hardly any hesitation to drink rainwater in these areas. Although, families using the saree system typically boil the water before drinking. Some households keep the water in small storage vessels for their weekly drinking needs. Each household usually has one saree harvesting system and it is generally sufficient to supply enough drinking water for the family (Padree, 2004).



During the three monsoon months, drinking water needs of each house in this Karnataka village's 35-house colony are met by a simple saree based rainwater harvesting system. (Padre, 2004)

Although rapid expansion of rainwater catchment systems in rural areas has recently occurred in some parts of Africa, progress has been slower than South-east Asia. This is due in part to the following factors:

- Lower rainfall and its seasonal nature.

- Smaller number and size of impervious roofs.
- Higher construction costs in relation to typical household incomes.

Nevertheless, rainwater collection is becoming more widespread in Africa with Kenya leading the way and other projects currently in Botswana, Togo, Mali, Malawi, South Africa, Namibia, Zimbabwe, Mozambique, Sierra Leone and Tanzania (UNEP, 2002).

1.5 Rainwater Collection in Urban Areas

Since the 1990s, there has been a growing interest in the use of rainwater harvesting systems in urban areas. There are several benefits of collecting and storing rainwater in towns and cities, including providing:

- Supplementary supplies for households with limited access to water for domestic use.
- Backup supplies in case of dry spells, droughts or breakdowns in the main water distribution network.
- Emergency, safe water in case of disasters.
- Flood control during periods of heavy rainfall.

However, there are some constraints to collecting rainwater for domestic use in urban settings, such as poorer water quality due to air pollution, shortage of space, and the high cost of land.

Although 95% of those living in urban areas worldwide are served by improved water supply (WHO/UNICEF JMP, 2005), there are still a great number of people who live in informal, overcrowded peri-urban settlements where access to water is low. As a result, there are many cases where rainwater collection provides an important supplementary source of domestic water. The favelas in Rio Janeriro, Brazil and the barrios of Tegucigalpa, Honduras provide good examples of this phenomenon (see Case Study 2.1-3)



People wade through flood water in Dudhgaon, 570 km southwest of Bombay, India.

Many urban centres in Asia face the ironic situation of having a water scarcity problem, while at the same time their streets flood during the rainy season. This is the case in India where the annual rainfall is about 1,170 mm; higher than the global average of 800

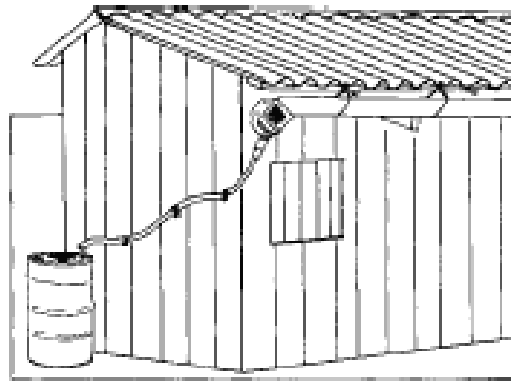
mm. However, most of the rain occurs during short spells of high intensity where it falls on the ground and tends to flow away rapidly. One of the potential solutions to the urban water crisis is to capture and store the rainfall runoff for future use (UN-HABITAT, 2004).

Rainwater Collection in the Barrios of Tegucigalpa

The barrios on the outskirts of Tegucigalpa are inhabited by low-income settlers who have moved to the city during the rapid urbanization of Honduras. They are poorly served by water and other amenities and local people are susceptible to water related diseases. The domestic rainwater harvesting systems found in the barrios are based on local ingenuity to address their desperate water situation. Even though there is relatively low rainfall in the area (788 mm per year) and the roof catchments are small (about 45 m²), the collection systems provide about 80% of the households with half of their water supply (Brand and Bradford, 1991).

The roofs are usually constructed from galvanized iron (GI) sheets, but other materials are also used, such as asbestos, tarpaper and various plastic sheets. The gutters are usually fitted to only half of the roof and are made from bent GI sheets from reused oil drums or from PVC pipes cut in half. The gutters are held by wire from the roof or by brackets made from reinforcing bar. Some prefabricated gutters were used on higher-income homes. Most of the households do not use a downpipe; water simply spills from the edge of the gutter directly into the storage tank. In some cases, downpipes are made from a hose attached by half a bottle. The collected rainwater is usually stored in old 200 litre oil drums, although some households use larger cement tanks known as *pila*.

Brand and Bradford's surveys found that more effective rainwater catchment systems are both feasible and desirable. The provision of loans for fully outfitting roofs with gutters and constructing *pila* up to 2,000 litres in capacity could be repaid over a relatively short time by using money saved from not having to purchase water from vendors.



Typical rainwater harvesting system in Tegucigalpa
(Brand and Bradford, 1991)

(DTU, 2002a; Gould and Nissen-Petersen, 1999)

1.6 Benefits of Rainwater Harvesting

Rainwater catchment systems have been successfully utilized by people all over the world throughout history. It is a technology that is flexible and adaptable to a wide variety of conditions, being used by the richest and poorest societies in the world, and in the wettest and driest regions of the world. While rainwater harvesting may not be the definitive answer to all household water problems, there are several benefits of the technology that make it an option to be considered for domestic use in developing countries:

- Rainwater harvesting is convenient in the sense that it can provide water at or near the point where water is needed or used, resulting in time savings for women who need to fetch water from other distant sources and eliminating the need for complex and costly distribution systems.
- Rainwater harvesting can complement other water sources and utility systems, thus relieving pressure on limited water supplies.
- Rainwater harvesting provides a buffer for use in times of emergency or breakdown of the public water supply systems, particularly during natural disasters.
- People have full control of their own catchment systems, which greatly improves household water security and water conservation, while at the same time reducing operation and maintenance problems.
- Technology is based on traditional methods and relatively simple to construct, install and operate.
- Rainwater harvesting technologies are flexible and can be built to meet almost any requirements. It is relatively easy to reconfigure, expand, or in some cases, relocate systems.
- Local people can be trained to construct and install rainwater harvesting technologies, and construction materials are also readily available.
- Rainwater is a free resource. While there are capital costs to construct and install a catchment system, households can save money over the long run since they don't have to purchase water from private vendors or pay public utilities.
- Operation and maintenance costs are also almost negligible.
- The physical and chemical properties of rainwater are usually superior to sources of surface and groundwater that may have been subjected to contamination.
- Water collected from roof catchments is generally of acceptable quality for domestic use and consumption.
- Constructing a rainwater harvesting system in conjunction with household water treatment allows people to enjoy improved water supply and quality which are linked to better health.
- Since rainwater is collected using existing structures (e.g. rooftops, parking lots, playgrounds, parks) not specially constructed for the purpose, rainwater harvesting has few negative environmental impacts compared to other water supply developments, such as dams and piped systems.
- Rainwater harvesting for domestic use emphasizes small-scale, community-based, self-help development.

The main disadvantages of rainwater harvesting technologies include:

- Seasonal nature and uncertainty of rainwater supply depending on the region in the world.
- Capital costs required to construct and install a rainwater harvesting system may still be high for the end users.
- Regular maintenance and cleaning is essential for successful operation.
- Potential breeding grounds for mosquitoes if storage tanks are not properly covered and maintained.
- Requires a "bottom up" rather than the traditional "top down" approach often used by government and international organizations in other water resource development projects. (This may also be considered as an advantage)

Other limitations which constrain the development of rainwater harvesting include:

- Lack of awareness about the merits and potential of rainwater harvesting technology among policy makers from government and institutional organizations.
- Lack of government policy about the role of rainwater harvesting within an integrated water resources management plan.
- Lack of financial support mechanisms to assist households in installing rainwater harvesting systems.
- Concern that installing rainwater harvesting systems would preclude households from qualifying for future water supply options with higher service levels (DTU, 2002b).

Summary of Key Points

- Rainwater can be used for a variety of purposes, including household drinking water, agriculture, flood control, back-up supply during dry spells or breakdowns, and emergency water supply in the case of disasters.
- Rainwater harvesting is a traditional practice that has been used for thousands of years by ancient civilizations around the world.
- In the last 20 years, there has been a renewed and growing interest in collecting rainwater for domestic use in rural areas of developing countries, particularly in Africa and Asia.
- Urban areas are also beginning to use more rainwater harvesting technologies, especially in low-income, peri-urban areas as an alternative water source.
- There are several benefits to rainwater harvesting for domestic use in developing countries, including:
 - Rainwater is a free resource.
 - Complements other water sources and utility systems.
 - Improves household water security and water conservation.
 - Relatively simple to construct, install and operate.
 - Flexible and adaptable to a variety of local and environmental conditions.
 - Allows households to enjoy improved water supply and quality.
 - Emphasizes small-scale, community-based, self-help development.

Activity - Self Assessment Solutions

1. At least 1.1 billion of the world's people lack access to safe drinking water.
2. False. While rainwater harvesting is one available option for water supply, it may not be the ideal solution for all situations. There is a complex set of interrelated circumstances which have to be considered when selecting an appropriate water source. Cost, climate, technology, hydrology, social and political elements all factor in the eventual selection of a water supply for a given situation.
3. Rainwater can be used for a variety of purposes, including household drinking water, agriculture, flood control, back-up supply during dry spells or breakdowns, and emergency water supply in the case of disasters.
4. The adoption and expansion of rainwater harvesting systems in rural areas of developing countries is due to a variety of factors, including:
 - Only 72 percent of rural residents have access to any improved water supply; this figure is only about 45 percent in sub-Saharan Africa
 - Severe water shortages are being suffered by many regions.
 - There is increasing pressure on limited water resources.
 - There are issues with poor ground and surface water quality (e.g. arsenic contamination, salination).
 - Conventional water supply systems have failed to meet people's needs.
 - There is growing use of impervious roofing materials, like tiles and corrugated iron, replacing traditional grass and thatch.
 - The development of effective, low-cost tank designs (e.g. Thai ferrocement jars).
5. False. There are still a great number of people who live in informal, overcrowded peri-urban settlements where access to water is low. As a result, there are many cases where rainwater collection can provide an important supplementary source of domestic water.
6. There are several benefits to rainwater harvesting for domestic use in developing countries, including:
 - Rainwater is a free resource.
 - Complements other water sources and utility systems.
 - Improves household water security and water conservation.
 - Relatively simple to construct, install and operate.
 - Flexible and adaptable to a variety of local and environmental conditions.
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1.7 Additional Resources

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This site contains numerous publications from two projects recently undertaken: Rainwater Harvesting in the Humid Tropics and Roofwater Harvesting for Poorer Households in the Tropics.

Available at: www.eng.warwick.ac.uk/DTU/rwh/index.html

Intermediate Technology Development Group (Renamed Practical Action)

Expertise in rainwater harvesting projects in Sri Lanka and parts of Africa. Case studies in Sri Lanka and an overview technical brief are provided.

Available at: www.itdg.org/?id=rainwater_harvesting

Rainwater E-Learning Toolkit

On-line learning course designed for people working in NGOs and government. Intended for self instruction and you do not have to enrol as a participant. Content is kept at a level that development workers as well as engineers can understand. External sources are given for those interested in more details.

Available at: www.rainwater-toolkit.net/index.php?id=75

UNEP Rainwater Harvesting and Utilisation, an Environmentally Sound Approach for Sustainable Urban Water Management: An Introductory Guide for Decision-Makers.

A good resource about the basics of rainwater harvesting and utilization, water quality and health issues, and considerations for program implementation. Global contacts, examples from around the world, and country profiles are provided.

Available at: www.unep.or.jp/ietc/Publications/Urban/UrbanEnv-2/index.asp

UNEP IETC Sourcebook of Alternative Technologies for Freshwater Augmentation

Information on rainwater harvesting projects around the world, organized by description, cost, community involvement, suitability, advantages, disadvantages, references etc. Also has a list of contacts for each region.

Africa: www.unep.or.jp/ietc/Publications/TechPublications/TechPub-8a/index.asp

Asia: www.unep.or.jp/ietc/Publications/TechPublications/TechPub-8e/index.asp

Latin America and the Caribbean:

www.unep.or.jp/ietc/Publications/TechPublications/TechPub-8c/index.asp

Small Island Developing States:

www.unep.or.jp/ietc/Publications/TechPublications/TechPub-8d/index.asp

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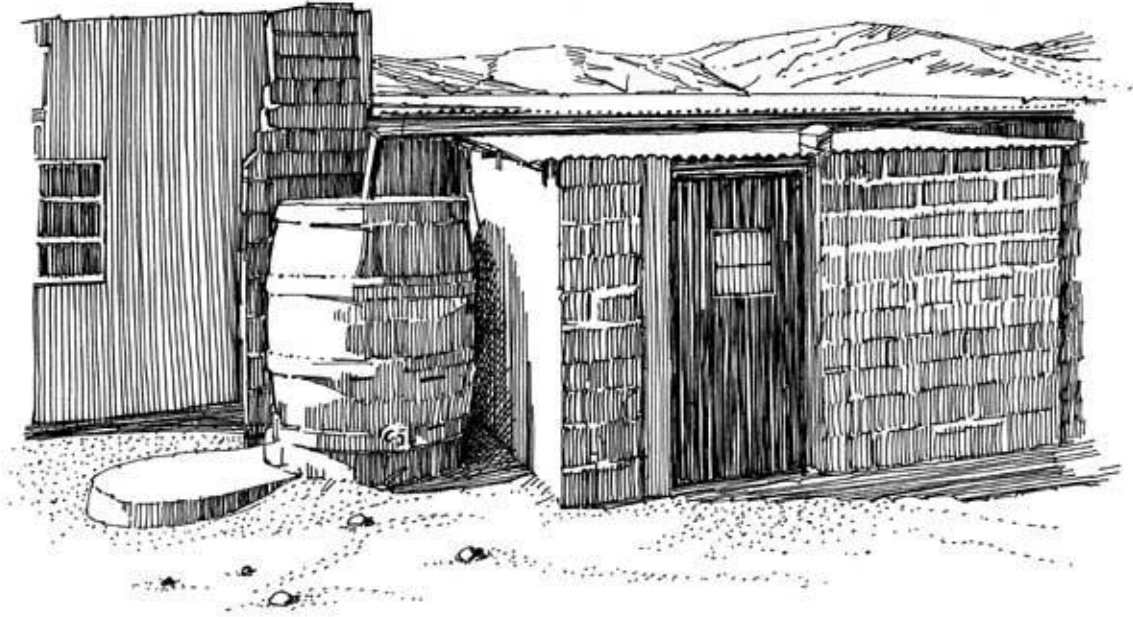
Latin America and the Caribbean:

www.unep.or.jp/ietc/Publications/TechPublications/TechPub-8c/index.asp

Small Island Developing States:

www.unep.or.jp/ietc/Publications/TechPublications/TechPub-8d/index.asp

2 Rainwater Harvesting Technology



Shaw (2005)

Learning Expectations

In this chapter you will learn about the basics of rainwater harvesting technology, including:

- Different scopes and sizes for rainwater harvesting projects.
- Common types of catchment systems for domestic use.
- Three main components of any rainwater catchment system.

2.1 Scope and Size of Rainwater Harvesting Systems

Rainwater harvesting systems can generally be subdivided into small, medium and large-scale, as shown in Figure 2.2-1.

Large-scale systems:

- Flood waters are diverted using bunds, diversion structures and small dams for spate irrigation, groundwater recharge and flood control.
- Runoff farming where water is harvested for crops.

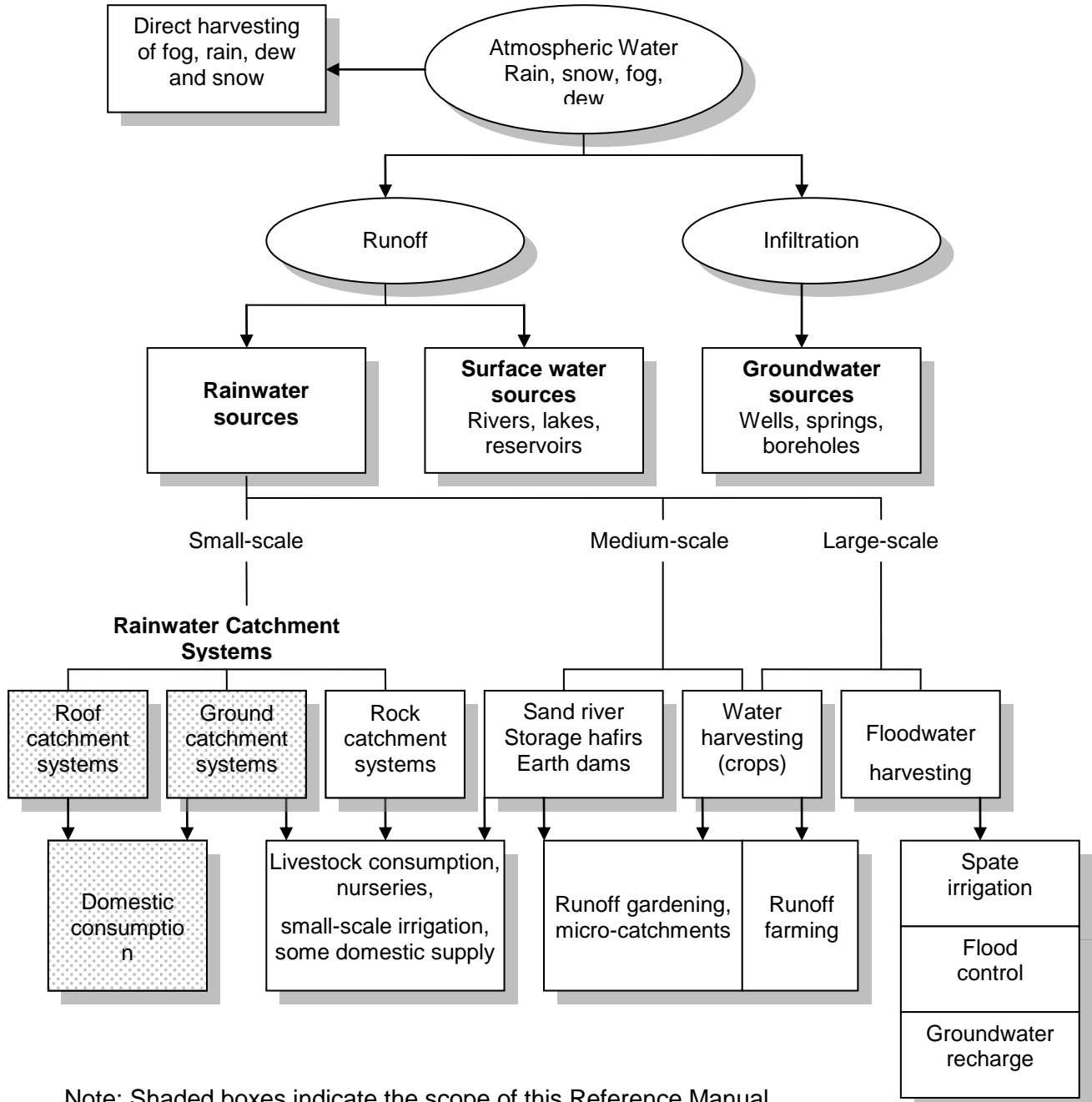
Medium-scale systems:

- Micro-catchments and smaller water harvesting structures designed for runoff gardening, household subsistence farming, domestic gardening and individual trees.

Small-scale systems:

- Direct collection of rainwater from roofs and other purpose-built catchments, small constructed or natural surface catchments, and rock catchments.

The scope of this Reference Manual covers only small-scale roof and ground surface catchment systems for domestic use, indicated by the shaded boxes in Figure 2.2-1.



Note: Shaded boxes indicate the scope of this Reference Manual.

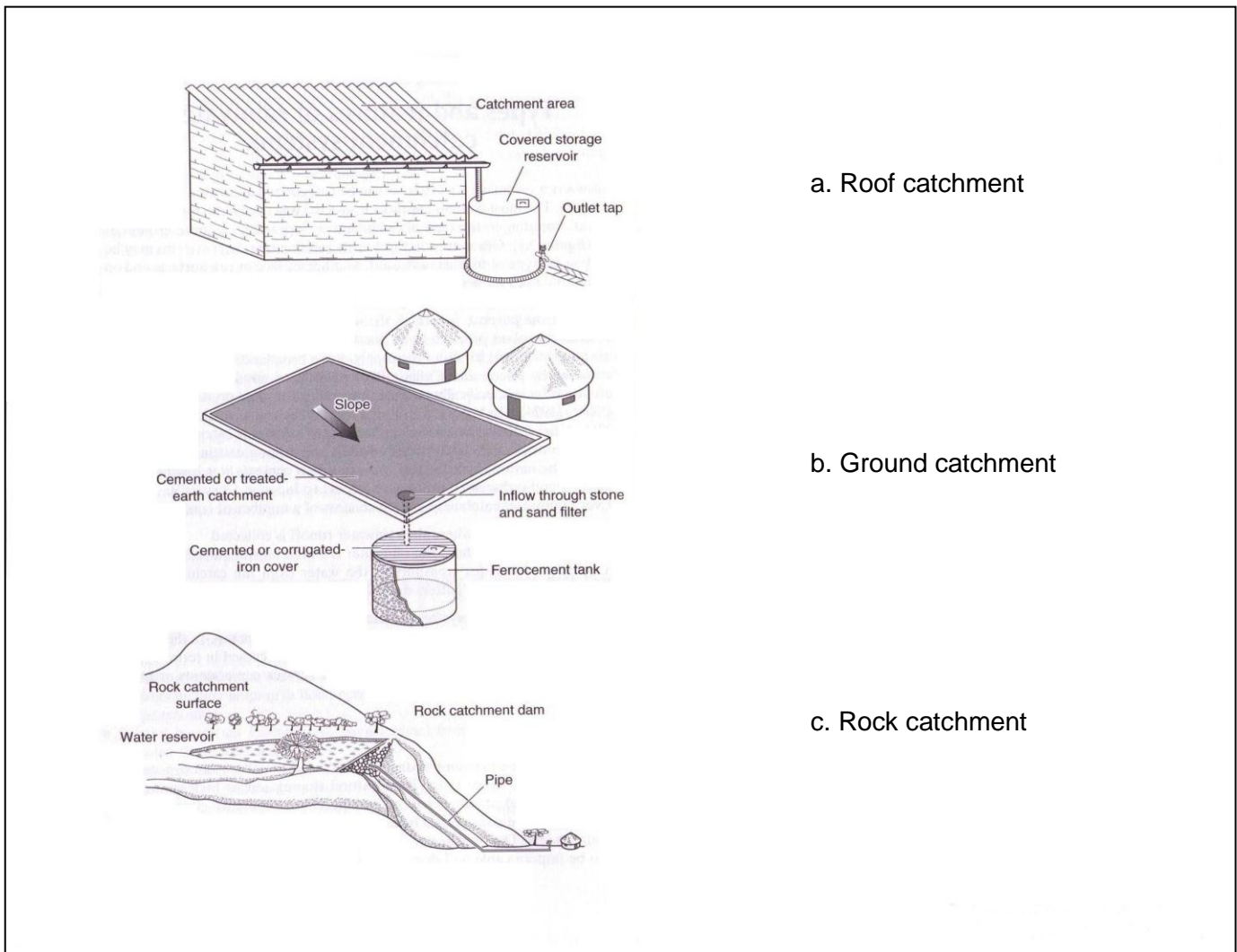
(Adapted from Gould and Nissen-Petersen, 1999)

Sources of water and the context of rainwater catchment systems

2.2 Systems for Rainwater Catchment

There are different ways to categorize rainwater catchment systems, for example, by the materials used for tank construction (e.g. ferrocement, concrete, plastic) or the purpose for which water is being collected (e.g. domestic use, livestock, flood control).

The most common approach, and the one used in this reference manual, is to subdivide rainwater catchment systems by the type of surface used (e.g. rooftop, ground surface, rock). We will only focus on rainwater catchment systems using roof tops and the ground surface.



(Gould and Nissen-Petersen, 1999)

Figure: Examples of roof, ground and rock catchments

Roof Catchments	Ground Catchments
Best suited for providing water to individual households.	Best suited for providing water to several households or a community.
Provides a direct water supply.	People still need to fetch water.
Can use an existing structure (e.g. house or building).	Can use an existing catchment (e.g. threshing floor, playground).
Efficient in collecting rainwater due to high runoff coefficient.	Not as efficient as roofs for collecting rainwater, but the larger area yields a higher overall quantity of runoff.
Provides relatively good quality water.	Water is usually of poor quality and requires treatment before consumption.

2.3 Components of Rainwater Catchment Systems

All rainwater catchment systems can be divided into three main components:

1. Catchment surface where the rainwater runoff is collected;
2. Delivery system for transporting the rainwater from the catchment to the storage reservoir; and
3. Storage reservoir where the rainwater is kept until it is needed.

2.3.1 Catchment Surfaces

There are many different types of catchment surfaces that can be used to collect runoff. They can range from natural surfaces to constructed catchments built from a variety of materials including cement, tiles, or metal sheets.

Many already built structures such as roofs, roads, children's playgrounds and threshing floors make excellent rainwater catchments. An advantage of using an existing structure is that the cost of construction has generally already been covered. This can be an important savings within the total cost of putting together a system.

2.3.2 Roof Catchments

For domestic rainwater harvesting the most common catchment surface is the roof of a house or building. The roof style, construction and material affect its suitability for rainwater collection. Typical roofing materials that are most

appropriate for rainwater harvesting include corrugated galvanized iron (GI) sheets, tiles, and asbestos sheets (DTU, 2002).



Cambodian household with a sheet metal roof used for rainwater harvesting (*Resource Development International Cambodia, n.d.*)

2.3.3 Ground Catchments

Ground catchment systems use natural, treated or covered land surfaces to collect rainwater. The catchment can be specifically built or it may already exist for another purpose, e.g. threshing floor, playground or road. Ground catchments are normally used when a suitable roof surface is not available.

Collected rainwater is usually of poor quality since it can become easily contaminated by pollutants and excrement. It is recommended that rainwater collected from the ground surface only be used for secondary purposes like watering livestock or gardening. The water should be treated if it is intended for drinking and domestic use. Refer to Module 1.8 for further information about household water treatment technologies.

2.3.4 Delivery Systems

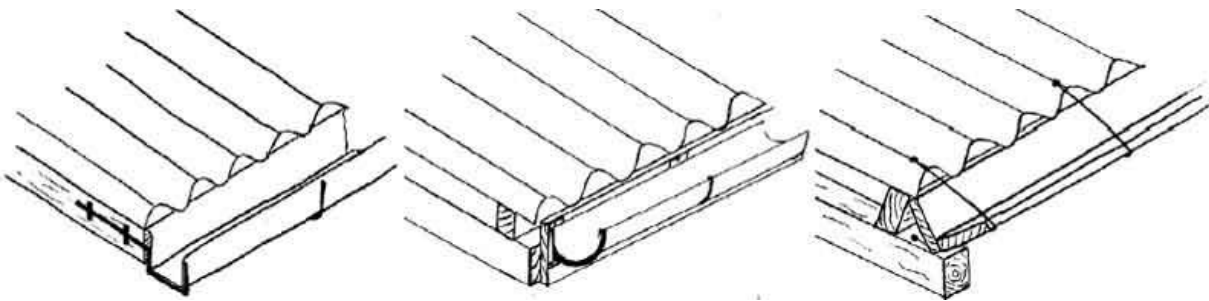
A delivery system is needed to transfer rainwater runoff from the rooftop or ground surface to the storage reservoir.

Roof Catchments

There are different ways to convey runoff from the roof to the storage tanks using:

- Gutters
- Roof glides
- Surface drains or channels

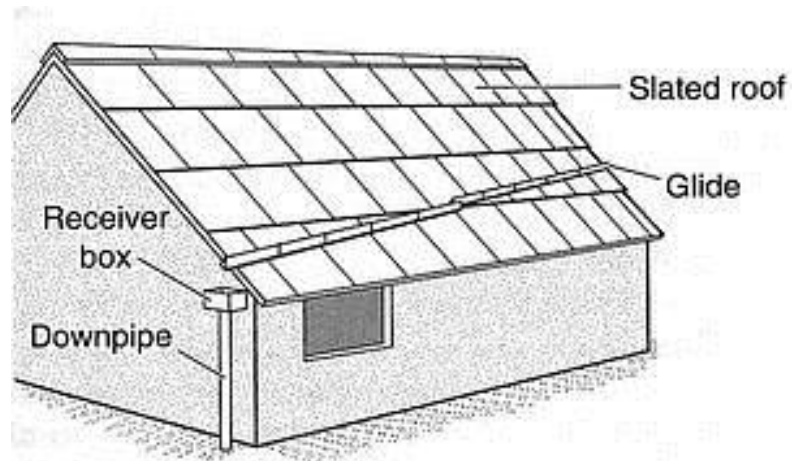
Gutters are most common and come in a wide variety of shapes and forms, ranging from factory made polyvinyl chloride (PVC) pipes to locally made bamboo or folded sheet metal gutters. Guttering is usually fixed to the building just below the edge of the roof and catches water as it falls. In developing countries, gutters are often the weakest link in the rainwater harvesting system (Rainwater Toolkit, 2005).



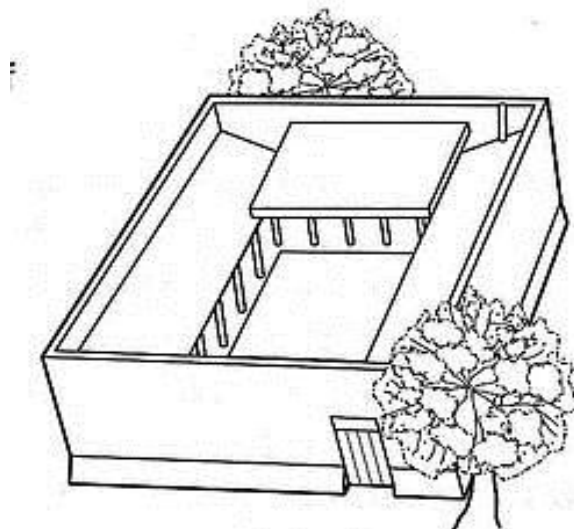
Typical gutter Shapes (Rainwater Toolkit, 2005)

Glides are slanting ridges made of metal, brick, stone or wood constructed on the roof to direct runoff towards the storage tank. They tend to only be used on roofs in Bermuda.

Surface drains are used in rural China where people cannot afford metal gutters. They construct cement channels on the surface of their courtyards to divert the roof runoff into sub-surface tanks (Zhu and Wu, 1995).

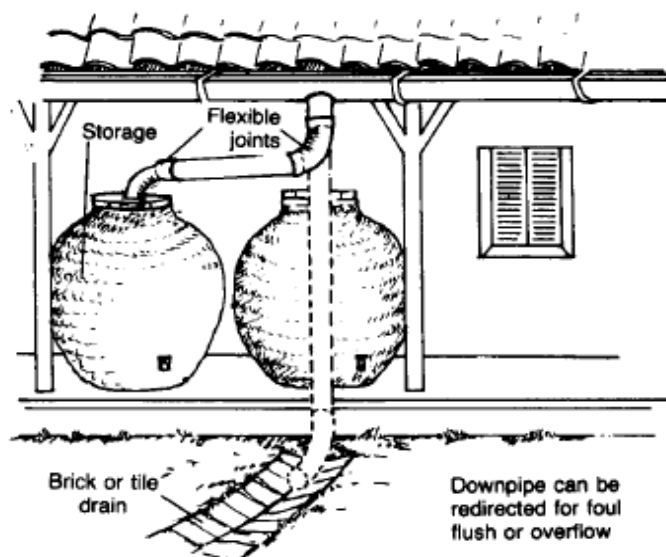


Bermuda roof glides (Gould and Nissen-Petersen, 1999)



Chinese courtyard system (Gould and Nissen-Petersen, 1999)

Debris, dirt and dust will collect on the roof catchment area and when the first rainfall arrives this unwanted material will be washed into the storage tank. Rainwater harvesting systems can incorporate a system for diverting this “first flush” water so that it doesn’t enter the tank and affect the water quality.



Flexible downpipe to redirect the first flush (US AID, n.d.)

There are a number of simple first flush devices which are commonly used, and there are also more complex systems. The simple ideas manually move the downpipe away from the tank inlet and then replace it once the initial flush has been diverted (see Figure 2.2-6). More sophisticated methods use mechanical systems to reject the first flush water. Practitioners often recommend that very simple, easily maintained systems be used since they are more likely to be repaired if failure occurs.

Roof catchments may also use filtration systems and settling tanks to help remove debris and sediment at the inlet and outlet of the storage tank. Similar to the first flush devices, the level of sophistication for filters varies from rudimentary to complex technology.

2.3.5 Surface Catchments

The delivery system for a surface catchment usually consists of a channel or trench to direct the water into an underground tank. A trap or filtering device can be used to reduce the amount of silt or dirt that enters the tank.

2.3.6 Storage Reservoirs

The collected rainwater is ultimately stored in some sort of reservoir, usually a tank. The storage tank usually represents the largest capital cost of a domestic rainwater harvesting system. Careful design and construction are essential to provide optimal storage capacity while keeping the cost as low as possible (Rainwater Toolkit, 2005).



Corrugated steel tank in Uganda
(DTU, 2002)



Plastic tank in India
(Bangalore Rainwater Club)



Mortar tank in Bangladesh
(Rainwater Toolkit, 2005)

Key features of any storage tank are that it should be:

- Watertight
- Durable
- Affordable
- Designed to not contaminate the water in any way

There are two types of tanks that can be used to store water:

1. Surface tanks made of ferrocement, bricks, reinforced concrete, metal, plastic, fibreglass or wood.

Sub-surface tanks made using ferrocement, concrete, brick and traditional clay linings.

Roof catchments

Surface tanks are most commonly used to store rainwater captured from rooftops. However, there are situations where sub-surface tanks are employed by households.

Ground catchments

Sub-surface tanks are generally used to store rainwater runoff collected by ground catchments.

Summary of Key Points

- Rainwater harvesting systems can generally be subdivided into small, medium and large-scale
- There are three types of rainwater catchment systems: roof, ground surface and rock. The scope of this reference manual covers only roof and ground surface catchment systems that are commonly used by households.
- All rainwater catchment systems can be divided into three main components: catchment surface, delivery system and storage reservoir
- Catchment areas can be natural (e.g. ground surface) or constructed (e.g. roof)
- Two key requirements for a catchment surface are that it has to be impermeable and does not seriously contaminate the rainwater
- There are different ways to convey runoff from the roof to the storage tanks including gutters, roof glides and surface drains or channels. Gutters are the most common
- Many roof catchment systems incorporate a “first flush” device for diverting the initial rainwater so that debris from the roof doesn’t enter the storage tank and affect the water quality
- Filters and sedimentation tanks are sometimes used to further remove debris and sediment from the storage tank
- Ground catchments use either a sloped surface or a network of drains or channels to convey runoff from the area to the storage tanks
- Two types of tanks commonly used for rainwater water storage are surface and sub-surface tanks.
- Key features of any storage tank are that it should be watertight, durable, affordable, and not contaminate the water in any way

Self-Assessment

1. The two types of rainwater catchment systems commonly used by households are _____ and _____.
2. True or False. The key components of any rainwater harvesting system are the catchment area, delivery system and storage tank. _____
3. Identify the two key requirements for a catchment surface.

4. The most common way to convey rainfall runoff from the roof to the storage tank is by using:
 - a. Roof glides
 - b. Gutters
 - c. Surface drains
5. In developing countries, the weakest link of rainwater systems is often the:
 - a. Catchment area
 - b. Gutters
 - c. Storage tank.
6. Explain what a “first flush” device is.

7. Identify the two types of tanks commonly used for household rainwater water storage.

8. List some of the key features for any storage tank.

Activity - Self-Assessment Solutions

1. The two types of rainwater catchment systems commonly used by households are roof and ground surface catchments.
 2. True. The key components of any rainwater harvesting system are the catchment area, delivery system and storage tank.
 3. Two key requirements for a catchment surface are that it has to be impermeable and does not seriously contaminate the rainwater.
 4. Gutters are the most common delivery system and come in a wide variety of shapes and forms, ranging from factory made PVC pipes to locally made bamboo or folded sheet metal gutters.
 5. In developing countries, gutters are often the weakest link in the rainwater harvesting system.
 6. First flush is any system or device designed to divert the initial roof runoff at the start of any rainfall to prevent debris from entering the storage tank.
 7. The two types of tanks commonly used for household rainwater water storage are surface and sub-surface tanks.
 8. Key features of any storage tank are that it should be watertight, durable, affordable, and not contaminate the water in any way.
- Rainwater is a free resource.
 - Complements other water sources and utility systems.
 - Improves household water security and water conservation.
 - Relatively simple to construct, install and operate.
 - Flexible and adaptable to a variety of local and environmental conditions.
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2.4 Additional Resources**Domestic Roofwater Harvesting Research Programme, Development Technology Unit, School of Engineering, University of Warwick, UK.**

This site contains numerous publications from two projects recently undertaken: Rainwater Harvesting in the Humid Tropics and Roofwater Harvesting for Poorer Households in the Tropics.

Available at: www.eng.warwick.ac.uk/DTU/rwh/index.html

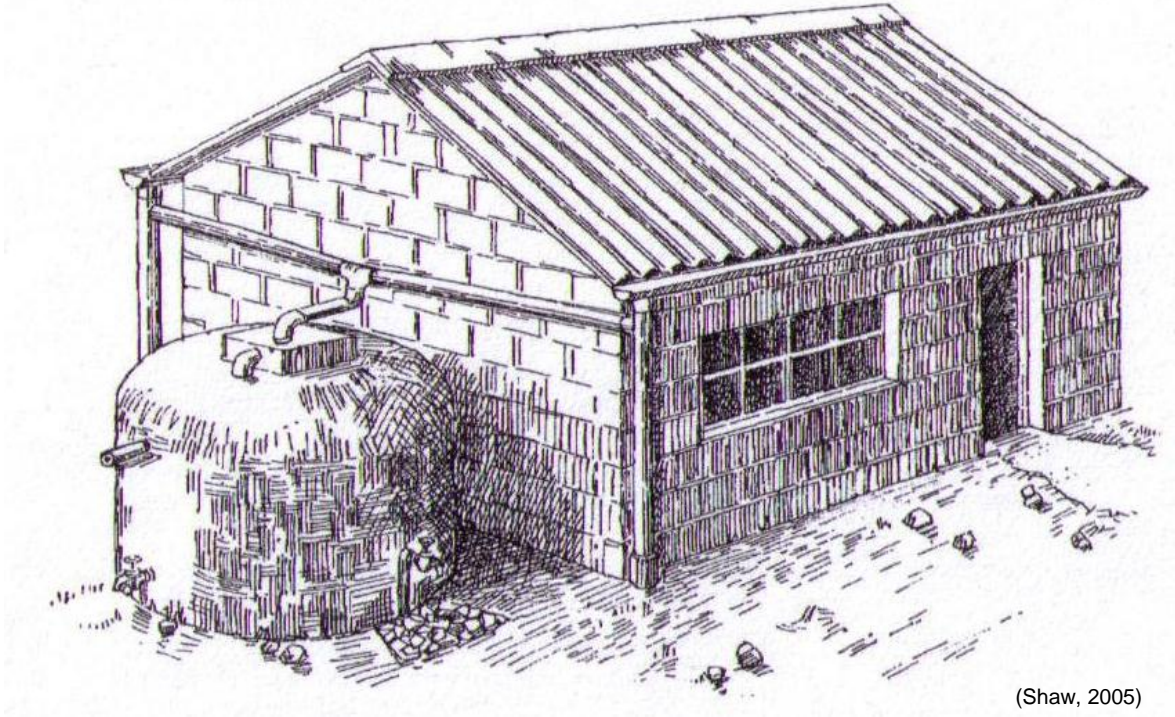
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level that development workers as well as engineers can understand. External sources are given for those interested in more details.

Available at: www.rainwater-toolkit.net/index.php?id=75

3 Rainwater Supply and Demand



Learning Expectations

In this module you will learn how to:

- Obtain historical rainfall data.
- Estimate household water demand.
- Estimate the amount of rainwater that can be supplied by a particular catchment area.
- Determine the storage tank size using different methods.

3.1 Introduction

One of the first steps in deciding if rainwater harvesting is an appropriate technology is to estimate the potential rainfall supply to make sure that it meets the household needs. Water supply and demand are based on a number of interrelated factors, including:

- Local rainfall data and weather patterns
- Catchment area
- Runoff coefficient
- Number of domestic users and consumption rates

This information is also needed to calculate the size of the water tank needed to give adequate storage capacity for a household.

3.2 Rainfall Data

Rainfall is variable and unpredictable, especially in dry climates that are susceptible to droughts. Since rainfall may vary greatly from year to year, it is important to use historical data, preferably for a period of at least 10 years to increase the probability of a successful design. If available, rainfall data from 20 to 30 years is ideal, especially in drought prone areas.

There are various places where you can find rainfall data, including:

- National meteorological departments
- Airports
- Universities
- Research stations
- Internet
- Local knowledge within the community

Care should be taken when selecting an appropriate data source since the average rainfall may vary considerably over short distances and it may be misleading when applied to the site of the rainwater catchment system, especially in mountainous areas. If rainfall data is not available for your region, you can use records from the nearest weather station with comparable local conditions (e.g. aspect, altitude).

Unfortunately, rainfall data can be expensive to purchase and it is often hard to locate even where it exists, especially in remote rural regions. There will be situations where rainfall data is simply not available and there are no comparable weather stations. In this case, it is worthwhile speaking with local people who probably know quite well the seasonality of precipitation. Traditional rainwater harvesting may have also been practiced in the area for long enough that people have a feel for what is an adequate tank size.

3.3 Water Demand

Residents in developed countries use significantly more water on a daily basis than those living in developing countries. Per capita domestic water consumption in North America (about 350 litres per day) and Europe (about 200 litres per day) are high compared to 50-150 litres per day in developing countries in Asia, Africa and Latin

America. In regions with insufficient water resources, this figure may be as low as 20-60 litres per day (Environment Canada, n.d.; UNESCO, 2000).

The minimum target set by the United Nations during the International Drinking Water Supply and Sanitation Decade was 20 litres per day for rural residents in developing countries.

Domestic water demand includes all water used by the household for the following essential purposes:

- Drinking
- Food preparation and cooking
- Washing dishes
- Personal hygiene (e.g. hand washing, bathing, brushing teeth)
- Toilet flushing
- Washing clothes
- Cleaning (e.g. floors, bathroom)

Other non-essential domestic uses for water include:

- Watering gardens (e.g. trees, flowers, vegetables)
- Water for animals (e.g. pets, chickens, small livestock)
- Washing vehicles
- Water for construction (e.g. repairing mud walls)
- Recreational uses
- Income generating activities (e.g. food sales, beer making)

In most areas, properly designed household roof catchment systems can normally meet the domestic demand for essential purposes. Only in situations where the rainfall is low or the roof and tank are sized too small will rainwater catchment systems fail to meet basic water needs.

A survey should be the starting point to estimate the household water demand. There are several variables that affect domestic water consumption, such as the:

- Number of adults and children (i.e. adults use more water than children)
- Family members staying at home (i.e. absentee members working or studying away from home for part of the year)
- Time of year (i.e. more water is used during the hottest and driest seasons)

When water supplies become more consistent and there is a great volume of water available to users, the amount that is used tends to increase. The survey may indicate how much water is currently being used but when a rainwater system is introduced, you may find that the amount of water used may increase substantially.

(see page 47 – 50 in Gould and Nissen-Petersen, 1999).

Households located in regions with low and very seasonal precipitation may require large storage tanks which can be expensive to build. In these situations, it is worth investigating ways to reduce the storage capacity by modifying the household water

demand according to the time of year. Rationing and using alternative water sources during the dry season and drought conditions can lead to a significant reduction in the storage tank size and cost of the system (see page 55 - 56 in Gould and Nissen-Petersen, 1999).

Example of Estimating Household Water Demand

To calculate the basic amount of water used by a household per year, multiply the average daily water use per person by the number of people living in the house by 365 days. For example, a household survey reveals that the essential daily water use is averaged to be 40 litres per person throughout the year and there are 6 members in the household.

$$\begin{aligned} \text{Demand} &= 40 \text{ L/person/day} \times 6 \text{ people} \times 365 \text{ days/year} \\ &= 87,600 \text{ L/year or } 87.6 \text{ m}^3/\text{year} \end{aligned}$$

The total annual household consumption is 87,600 litres or 87.6 m³.

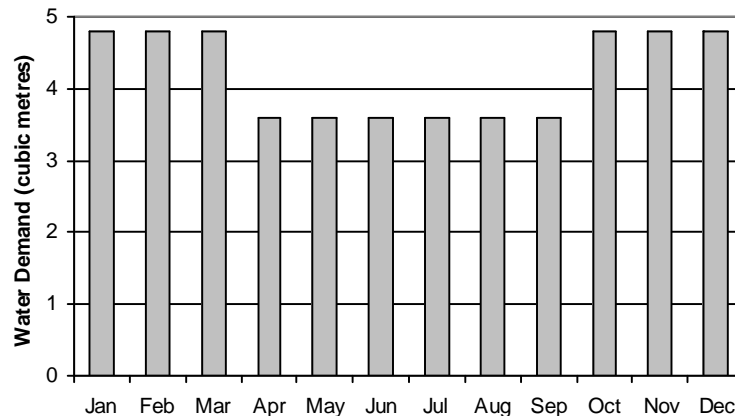
However, the survey also shows that four of the family members are children and their personal daily water use is estimated to be about 20 litres. The demand calculation can then be revised to the following:

$$\begin{aligned} \text{Demand} &= (40 \text{ L/p/day} \times 2 \text{ people} + 20 \text{ L/p/day} \times 4 \text{ people}) \times 365 \text{ days/year} \\ &= 58,400 \text{ L/year or } 58.4 \text{ m}^3/\text{year} \end{aligned}$$

So the total annual household consumption is reduced to 58,400 litres or 58.4 m³.

It was also discovered that the father works away from home for half of the year. The demand calculation can be further refined to the following:

$$\begin{aligned} \text{Demand} &= (40 \text{ L/p/day} \times 1.5 \text{ people} + 20 \text{ L/p/day} \times 4 \text{ people}) \times 365 \text{ days/year} \\ &= 51,100 \text{ L/year or } 51.1 \text{ m}^3/\text{year} \end{aligned}$$



Monthly household water demand

By taking these factors into consideration, the annual household water demand is reduced by almost 40 percent. Figure 2.3-1 illustrates how the monthly water demand varies throughout the year when the father is away from home.

Exercise 1: Calculating Household Water Demand

You are working with a local NGO in Peru to design rainwater catchment systems for domestic use. Your first task is to conduct a household survey to determine the water demand for a particular family.

Work with a partner to create some survey questions that will help you to assess the household's water needs. The class will then come together to ask their questions of the Workshop Facilitator to identify the appropriate data needed to calculate the *essential* water demand for the household.

Use the following space to list your questions, record the survey responses, and calculate the household water demand.

Solutions at end of chapter

3.4 Water Supply

The quantity of available rainwater supply depends on the:

- Amount of rainfall
- Catchment area
- Runoff coefficient

The following equation is used to calculate of the maximum amount of water that can be supplied by a particular catchment area:

$$\text{Supply (m}^3\text{/year)} = \text{Rainfall (m/year)} \times \text{Catchment Area (m}^2\text{)} \times \text{Runoff Coefficient}$$

What is the Runoff Coefficient?

The rainfall runoff coefficient is the ratio of the volume of water that runs off the catchment surface to the volume of rainfall that falls on the surface. It is represented by a number between 0 and 1.

$$\text{Runoff coefficient} = \frac{\text{Volume of runoff}}{\text{Volume of rainwater}}$$

The runoff coefficient helps you to figure out how much rainwater will actually enter the storage reservoir by accounting for loss due to spillage, leakage, infiltration and evaporation.

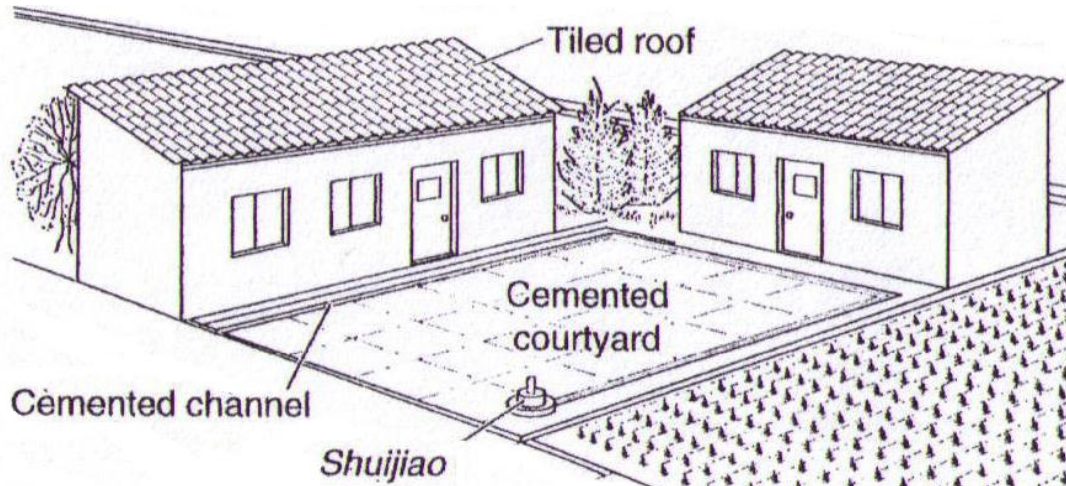
By calculating the runoff coefficient, you can also compare the efficiency of different catchment materials when designing your rainwater harvesting system. The higher the runoff coefficient, the higher the collection efficiency of the surface.

The runoff coefficient for a well-constructed roof catchment system with properly installed gutters is generally assumed to be about 0.8.

Module 2.4 Ground Catchment Systems and Module 2.5 Roof Catchment Systems provide runoff coefficients for various catchment surfaces.

Exercise 2: Calculating Water Supply

Arid Gansu province in Central China receives an average of just 12 inches of rain per year. Since 1992, tiled roof catchments, concrete-lined courtyards, cement channels and cement-lined *shuijiao* water cellars have been widely replicated throughout rural areas in the province to capture and store rainwater. A typical combined roof and courtyard catchment area ranges between 80 and 200 m².



(Adapted from Gould and Nissen-Petersen, 1999)

As shown in the above illustration, assume that two households share a combined catchment area with the following features:

- One house has a roof with an effective plan area that is 3.5 m wide by 9 m long and the other is 3.5 m wide by 7.5 m long.
- Both roofs are constructed of machine-made clay tiles.
- The concrete lined courtyard shared by the two houses is 11 m by 9 m.

Use the following space to calculate the total annual amount of rainwater supply that can potentially be collected by the households.

Hint: The runoff coefficients for the different catchment surfaces can be found in Gould and Nissen-Petersen (page 53) or in Modules 2.4 and 2.5.

Calculating Water Supply Continued

Solutions at end of chapter

3.5 Sizing the Storage Tank

For a rainwater system to provide a year-round supply of water, the following two conditions must be met:

1. Total water supply must be greater than the total demand.
2. There must be sufficient storage capacity to allow enough water collected in the wetter seasons to be carried over to meet the demand in the drier seasons

Usually, the main calculation when designing a rainwater catchment system will be to size the water tank correctly to give adequate storage capacity. Often the only variable that a designer can influence is the tank size since existing roofs are used as catchments and the amount of rainfall cannot be changed (DTU, n.d.).

When sizing the system, it is important to consider whether it is going to be used in conjunction with other water sources as a supplementary, partial or backup supply. For example, rainwater may only provide drinking water while other sources are used for cleaning, toilet flushing and washing. The water demand in these situations will be very different than if it is the primary source of water supply. If rainwater is intended to be the main or only source of water supply, then the reliability of the system becomes critically important.

As a general rule of thumb, it is appropriate to over design a rainwater catchment system to provide at least 20 percent more than the estimated demand. While this may cost more, it is preferable to under designing the system and risking an empty tank. This safety margin is especially important if the rainwater system is the main or only source of water supply.

There are a number of different sizing methods which vary in complexity and sophistication. Some are readily carried out by relatively inexperienced first-time practitioners, while others require computer software and trained users who understand how to use the models.

The selection of the most appropriate method will depend largely on the following factors:

- Size and complexity of the rainwater catchment system.
- Availability of tools and data required for using a particular method (e.g. computers, historical rainfall data)
- Skill level required for using a particular method (e.g. computer training)

The following sections describe three methods commonly used for determining the storage tank size. The different methods all rely on certain assumptions and good quality input data. It is worth remembering that, while these methods can be useful tools for predicting system performance, they are often subject to a significant margin of error. Assumptions regarding human behaviour (i.e. water use and demand) are especially vulnerable to miscalculation. The tank dimensions that are calculated using these sizing methods should be treated only as a guide.

Method 1: Dry Season Demand

This is a very simple method is to estimate the largest storage capacity needed to meet the household water demand throughout the dry season (i.e. period during which there is no significant rainfall).

Advantages:

- Simple and easy to calculate.
- Does not require historical rainfall data.

Disadvantages:

- Only provides a rough estimate of tank size.
- Only suitable in areas where a distinct dry season exists.
- Does not consider rainfall availability and variations between different years.
- Does not consider capacity of the catchment area.

Example of Using the Dry Season Demand Method

Assume the following:

Water demand = 20 litres per person per day

Number of household members = 6 people

Longest average dry period = 25 days

Dry season demand = 20 L/person/day x 6 people x 25 days

$$= 3,000 \text{ L or } 3 \text{ m}^3$$

Therefore, this household requires a storage tank with a minimum capacity of 3,000 litres to meet their water needs during the dry season.

Exercise 3: Sizing the Storage Tank Using Dry Season Demand

In Kenya, a family of four uses an average of 35 litres of water per person per day. The hot season lasts from mid-December to mid-March and this particular household goes without water for a 90 day period on average.

Use the space below to calculate the minimum capacity of the storage tank needed to supply water to this household throughout the dry period.

Solution at end of chapter

Method 2: Graphing

Graphing the catchment runoff and daily water demand is another simple method that will give a more reasonable estimation of the storage requirements. This is important in areas with low or uneven rainfall, where more care has to be taken to size the storage tank properly. During some months of the year, there may be an excess of water, while at other times there may be a deficit. If there is enough total rainfall throughout the year to meet the demand, then sufficient storage will be required to bridge the periods of water scarcity (DTU, n.d.).

Advantages:

- Relatively simple to calculate.
- More accurate method that gives a reasonable estimation of storage requirements.
- Considers rainfall availability and variations between different years if at least 10 years of rainfall data is used.
- Considers the runoff capacity of the catchment area.

Disadvantages:

- Requires historical rainfall data.

The basic steps that have to be followed under this method are:

3. Plot a bar graph of the average monthly water supply (i.e. runoff) and add a line showing the average monthly water demand.
4. Use a table to calculate the cumulative water supply and demand.
5. Plot a bar graph of the cumulative water supply. Add a line showing the cumulative water demand. The difference between these values indicates the minimum storage requirement.

The following real life example provides a more detailed explanation on how to use the graphing method.

Daily or weekly rainfall data can be used for more accuracy, especially for regions with year-round rainfall. The graphical method is most effective if at least 10 years of rainfall data are plotted to take into account any variations between years. For drought-prone regions, it is advisable to use 20 years of rainfall data (Gould and Nissen-Petersen, 1999).

Example of Using the Graphing Method

This example is taken from a rainwater system built for a medical dispensary in the village of Ruganzu, Biharamula District, Kagera, Tanzania in 1997. The rainfall data was supplied by a nurse had been keeping records for the previous 12 years. Average monthly figures for the rainfall data were used to simplify the calculation (As indicated in the figure).

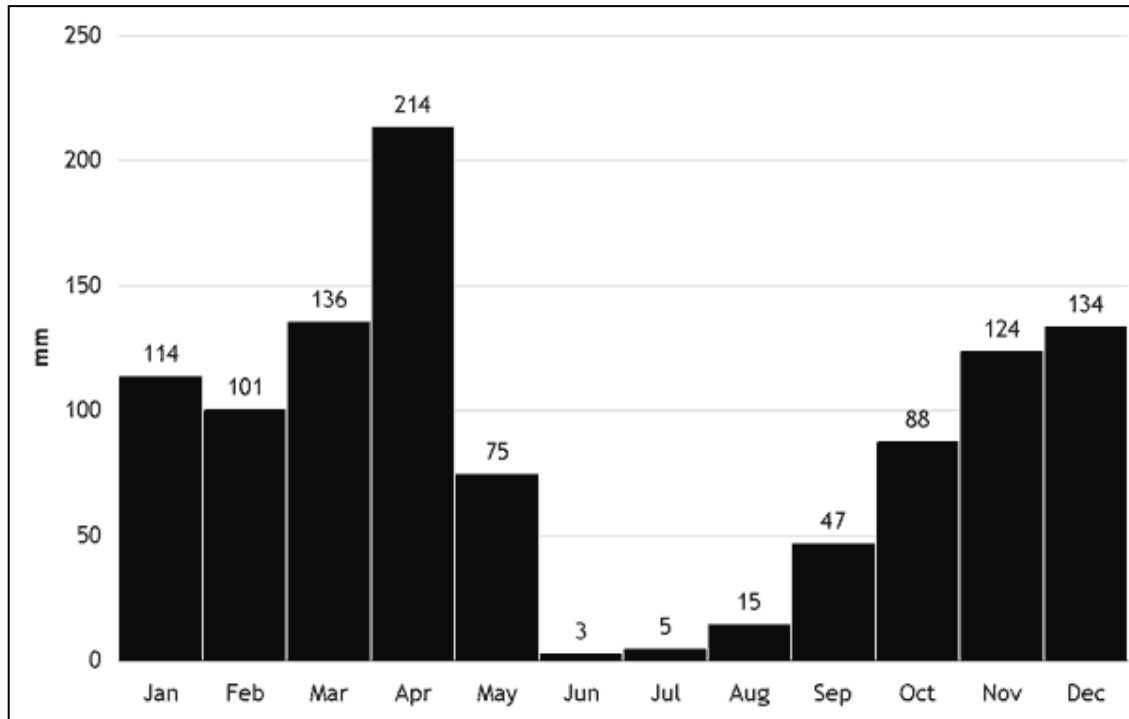


Figure: Average rainfall data for Biharamulo District

Water Demand:

Number of staff = 7

Staff water use: 45 L/person/day x 7 people = 315 L/day

Number of patients = 40

Patient water use = 10 L/person/day x 40 people = 400 L/day

Total water demand = 315 L/day + 400 L/day

= 715 L/day or 0.715 m³/day

= 21,450 L/month or 21.45 m³/month

Water Supply:

Roof area = 190 m²

Runoff coefficient = 0.9 (new corrugated GI roof)

Average annual rainfall: 1056 mm/year

Total water supply = 1.056 m/year x 190 m² x 0.9

= 180.58 m³/year

= 15.05 m³/month

= 0.49 m³/day

The monthly water supply can also be calculated using the monthly rainfall data.

In this particular situation, the hospital's estimated water needs ($21.45 \text{ m}^3/\text{month}$) cannot be met by the available rainwater supply ($15.05 \text{ m}^3/\text{month}$). This means that the hospital will need to reconsider its water demand and either reduce its consumption or find an additional source if water is to be supplied year round.

Figure 2.3-2 is a bar graph that shows the monthly water supply and water demand. In this graph, the hospital's water demand was lowered to be $15.05 \text{ m}^3/\text{month}$ since that is the maximum amount of rainwater supply available.

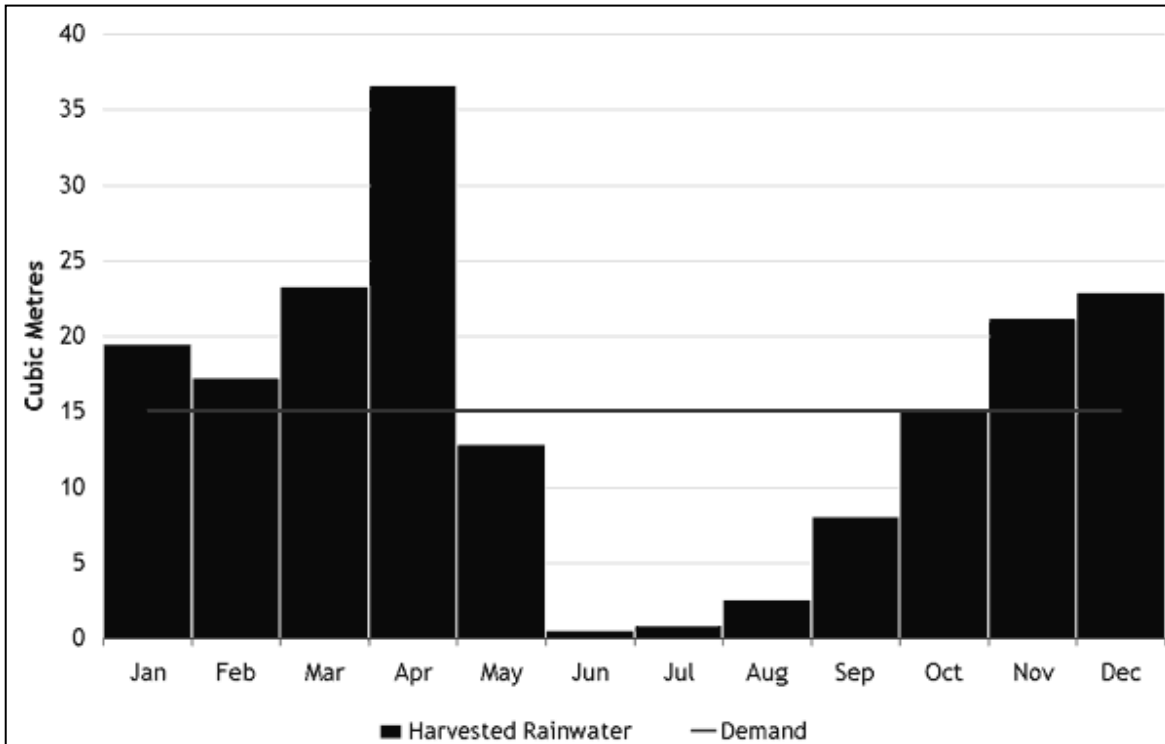


Figure: Monthly water supply and water demand

There is a single rainy season and October is the first month where the rainfall runoff meets the demand. It is assumed that the tank is empty at the end of the dry season in September. The cumulative monthly water supply and demand can be calculated using a spreadsheet (e.g. Microsoft Excel) or by hand in a table (see Table 2.3-1).

Calculation of cumulative supply, demand and storage requirement

Column 1	Column 2	Column 3	Column 4	Column 5	Column 6	Column 7
Month	Rainfall (mm)	Water supply (m ³)	Cumulative supply (m ³)	Water demand (m ³)	Cumulative demand (m ³)	Storage requirement (m ³)
Oct	88	15.05	15.05	15.05	15.05	0.00
Nov	124	21.20	36.25	15.05	30.10	6.16
Dec	134	22.91	59.17	15.05	45.14	14.02
Jan	114	19.49	78.66	15.05	60.19	18.47
Feb	101	17.27	95.93	15.05	75.24	20.69
Mar	136	23.26	119.19	15.05	90.29	28.90
Apr	214	36.59	155.78	15.05	105.34	50.45
May	75	12.83	168.61	15.05	120.38	48.22
Jun	3	0.51	169.12	15.05	135.43	33.69
Jul	5	0.86	169.97	15.05	150.48	19.49
Aug	15	2.57	172.54	15.05	165.53	7.01
Sep	47	8.04	180.58	15.05	180.58	0.00
Total	1056	180.58	-	180.58	-	-

Note: Numbers may not add exactly due to rounding.

Column 2: Average monthly historical rainfall data collected over 12 year period.

Column 3: Monthly water supply = Rainfall (m/month) x Catchment Area (m²) x Runoff Coefficient

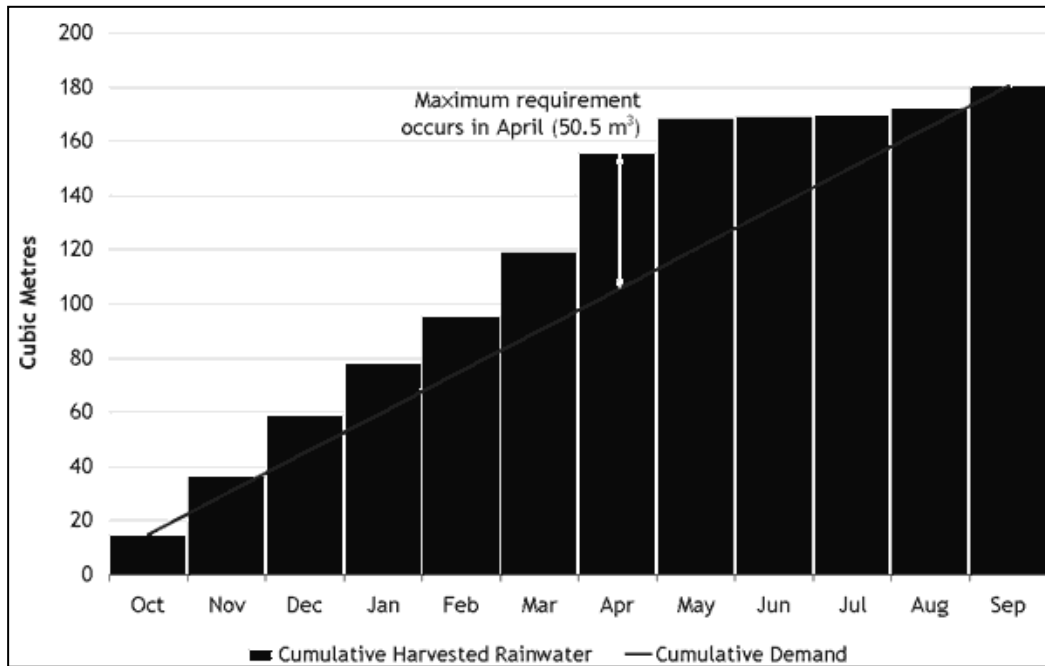
Column 4: Cumulative supply for Nov is found by adding Oct and Nov water supply. Dec is found by adding Oct, Nov and Dec water supply, etc.

Column 5: Water demand is calculated by dividing the total annual water supply by 12 months.

Column 6: Cumulative demand for Nov is found by adding Oct and Nov water demand. Dec is found by adding Oct, Nov and Dec water supply, etc.

Column 7: Difference between Column 4 (cumulative supply) and Column 6 (cumulative demand).

The results from the table can be graphed to help determine the maximum capacity of the storage tank.



Cumulative water supply and estimation of storage requirement

The capacity of the storage tank is determined by the greatest difference between rainwater supply and water demand. Looking at Table 2.3-1 and Figure 2.3-3, you can see that this occurs in April with a storage requirement of 50.45 m^3 . This is the amount of rainwater that has to be stored to cover the shortfall during the dry period.

For ease of calculations in the field, it is not necessary to graph the results from Table 2.3-1 since you can read the storage tank size directly from the table. Some people prefer to graph the data since it visually helps them to understand the data.

For this particular example, a 50 m^3 ferrocement tank was constructed to provide year-round rainwater supply to the hospital.



(Example adapted from DTU, n.d. and ITDG, n.d.)

Figure: Ferrocement tank constructed in Ruganzu Village

Exercise 4: Sizing the Storage Tank Using Graphs

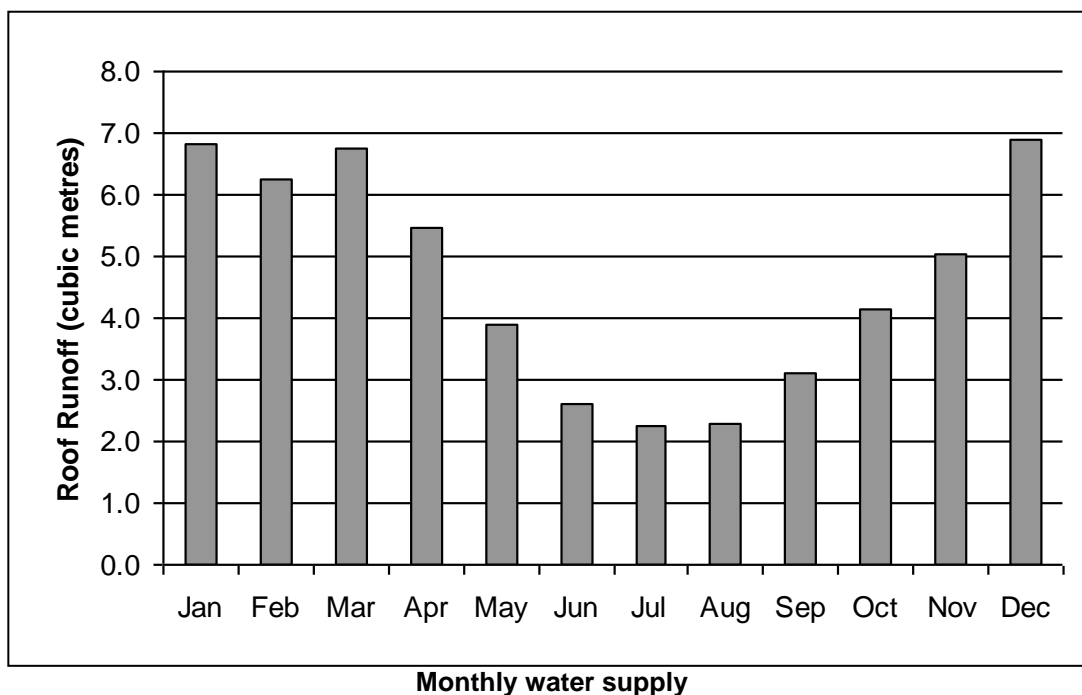
A family living in a *favela* in the outskirts of Rio de Janeiro, Brazil would like to build a rainwater system to help meet their daily water needs. They currently have limited access to the public water supplies and need to purchase additional water from a vendor. There are 5 members in the family and it is estimated that about 30 litres per person per day is required for their drinking and cooking needs. They plan to use the public water supply for other purposes such as toilet flushing, washing and cleaning.

The house has relatively a new corrugated sheet metal roof that provides a catchment area of 63 m^2 with a runoff coefficient of 0.8. You were able to find average monthly rainfall data for Rio de Janeiro on the internet and use this information to calculate the monthly roof runoff in Figure 2.3-3 and Table 2.3-2.

Use the following space to calculate the monthly water demand and storage tank requirements for this family using the graphing method. What is the minimum size of the storage tank needed to provide a year-round supply of rainwater?

Sizing the Storage Tanks Using Graphs Continued

Solutions at end of chapter



(Rainfall data from World Climate, 2005)

Calculation of cumulative supply, demand and storage requirement

Month	Rainfall (mm)	Water supply (m ³)	Cumulative supply (m ³)	Water demand (m ³)	Cumulative demand (m ³)	Storage requirement (m ³)
Jan	135.1	6.8				
Feb	123.9	6.2				
Mar	133.9	6.7				
Apr	108.6	5.5				
May	77.5	3.9				
Jun	51.5	2.6				
Jul	44.7	2.3				
Aug	45.5	2.3				
Sep	61.9	3.1				
Oct	82.0	4.1				
Nov	99.7	5.0				
Dec	137.1	6.9				
Total	1101.1	55.5				

Method 3: Computer Models

Computer models can be used to simulate rainwater supplies and design storage requirements. The output can compare the performance of specific designs under various water demand scenarios.

The results of any simulation exercise should always be treated with some caution since they are only as good as the historic rainfall data entered into the model. Inaccurate assumptions about water demand and future climatic change may also affect the validity of any predictions about the performance of a rainwater catchment system (see page 62 – 63 of Gould and Nissen-Petersen, 1999 for a discussion of computer models).

Computer simulation may be an appropriate design tool if computers, internet access, modelling software, and good quality historical rainfall data are available and applied correctly. While computer applications can be useful, they are not essential for sizing a rainwater catchment system. All of the necessary calculations can be determined by hand using the methods described in the above sections. The time, effort and cost should be considered before attempting any computer-based modelling exercise.

It is beyond the scope of this manual to review the various computer model applications in detail. However, there are a few models which are currently accessible for free from the Internet.

SimTanka developed by the Ajit Foundation is one software program which can be downloaded for free. It was developed in the spirit that it might be useful for meeting the water needs of small communities in a sustainable and reliable manner. SimTanka requires at least 15 years of monthly rainfall records for the place at which the rainwater harvesting system is located. Daily water demand per person is also entered and then the software will calculate optimum storage size or catchment size depending on the requirements of the user. SimTanka also calculates the reliability of the system based on the rainfall data of the previous 15 years. No guarantees of any kind are implied. SimTanka can be downloaded from the following website:

<http://homepage.mac.com/vsvyas/science.html>

The Rainwater Tank Performance Calculator is another computer software that was created by the Domestic Roofwater Harvesting Programme, Development Technology Unit at the University of Warwick. This on-line program calculates the approximate system reliability and efficiency for a selection of tank sizes including one that you can define, using your monthly rainfall data and roof area. You can also define how the rainwater will be used by giving a nominal daily demand and choosing between three water management strategies. By looking at the reported performance for all the tank sizes, you can change your chosen size, nominal demand and management strategy until it reaches an acceptable performance level. The Rainwater Tank Performance Calculator can be accessed at the following website:

www.eng.warwick.ac.uk/DTU/rwh/model/index.html

Summary of Key Points

Historical rainfall data for a period of at least 10 years (longer in drought-prone areas) is ideally required to get an accurate estimate of the potential rainwater supply from a particular catchment area.

It is estimated that the average person in developed countries uses 500-800 litres per day, compared to 60-150 litres per day in developing countries. The minimum target is 20 litres per day for rural residents in developing countries.

Estimating the household water demand should be done with care since consumption may vary over time due to factors such as changes in the season.

Conducting a survey is a good starting point to estimate the household water demand.

The maximum amount of water that can be supplied by a particular catchment area is calculated using the formula:

Supply (m³/year) = Rainfall (m/year) x Catchment Area (m²) x Runoff Coefficient

The runoff coefficient for a well-constructed roof catchment system with properly installed gutters is generally assumed to be about 0.8.

The main calculation when designing a rainwater catchment system will usually be to size the water tank correctly to give adequate storage capacity.

There are a number of sizing methods which vary in complexity and sophistication. Three commonly used methods are:

9. 1 – Dry season demand
10. 2 – Graphing
11. 3 – Computer-based models

Each of the different sizing methods relies on assumptions and good quality input data. While these methods can be useful tools for predicting system performance, they are often subject to a margin of error and should be treated only as a guide.

Self-Assessment Solutions

1. Since rainfall may vary greatly from year to year, it is important to use historical data, preferably from a period of at least 10 years.
2. In this case, it is worthwhile speaking with local people who probably know quite well the seasonality of precipitation. Traditional rainwater harvesting may have also been practiced in the area for long enough that people have a feel for what is an adequate tank size.
3. Variables that affect household water demand include:
 - Number of adults and children (i.e. adults use more water than children)
 - Family members staying at home (i.e. absentee members working or studying away from home for part of the year)
 - Time of year (i.e. more water is used during the hottest and driest seasons)
4. $\text{Supply (m}^3/\text{year)} = \text{Rainfall (m/year)} \times \text{Catchment Area (m}^2) \times \text{Runoff Coefficient}$
5. The runoff coefficient for a well-constructed roof catchment system with properly installed gutters is generally assumed to be 0.8.
6. The different methods all rely on certain assumptions and good quality input data. It is worth remembering that, while these methods can be useful tools for predicting system performance, they are often subject to a significant margin of error. Assumptions regarding human behaviour (i.e. water use and demand) are especially vulnerable to miscalculation. The tank dimensions that are calculated using these sizing methods should be treated only as a guide.

Exercise 1 Solutions

1 Typical Household Survey Questions and Example Responses:

- How many members are there in the household? There are 5 members in the household.
- How many adults and children live in the house? There are 2 parents and 3 teenage children. It is assumed that the children consume the same quantity of water as their parents.
- How much water is used daily for essential purposes only? The average daily water consumption is about 25 litres per person for drinking, cooking, bathing, cleaning, washing, toilet flushing, etc.
- Does the daily water consumption change between the wet and dry seasons? About 30 litres per person is consumed during the dry season and 20 litres per person during the wet season.
- How long do the seasons last? Assume that each season is six months long.
- Is the household satisfied with their current water supply? The family is not happy with the quantity of their current water supply and think that their daily consumption will increase when they install a rainwater catchment system. Assume that their future water consumption will go up to 45 litres per person during the dry season and 30 litres per person during the wet season, averaging 37.5 litres per person throughout the year.
- Do all household members live at home throughout the year? The two oldest children are away for half of the year to go to school in the nearest city. Assume that their time away is split evenly across the wet and dry seasons.
- Does the household use water for any other non-essential domestic purposes? The family has some chickens and a goat that consume about 50 litres of water per day. They also hope to grow a small garden and estimate that it will require about 100 litres of water per day during the dry season.

$$\begin{aligned}
 \text{Essential water demand} &= (3 \text{ people} \times 37.5 \text{ L/person/day} \times 365 \text{ days/year}) + \\
 &\quad (2 \text{ people} \times 37.5 \text{ L/person/day} \times 183 \text{ days/year}) \\
 &= 41,063 \text{ L/year} + 13,725 \text{ L/year} \\
 &= 54,788 \text{ L/year or } 54.79 \text{ m}^3/\text{year}
 \end{aligned}$$

Exercise 2 Solutions

The annual amount of rainwater supply can be calculated using the following equation:

$$\text{Supply (m}^3\text{/year)} = \text{Rainfall (m/year)} \times \text{Catchment Area (m}^2\text{)} \times \text{Runoff Coefficient}$$

In this example, there are actually three different catchment areas which make up the total combined catchment. Let's call these Roof 1, Roof 2 and Courtyard. The supply for each of these catchments needs to be calculated separately and then added to find the total annual rainwater supply.

There are a few variables that we must determine before calculating the total supply.

$$\begin{aligned} \text{Rainfall} &= 12 \text{ inches/year} \times 0.0254 \text{ m/inch} \\ &= 0.305 \text{ m/year} \end{aligned}$$

Roof 1:

$$\begin{aligned} \text{Area} &= 3.5 \text{ m} \times 9 \text{ m} & \text{Runoff Coefficient} &= 0.35 \text{ (machine-made clay tile)} \\ &= 31.5 \text{ m}^2 \end{aligned}$$

Roof 2:

$$\begin{aligned} \text{Area} &= 3.5 \text{ m} \times 7.5 \text{ m} & \text{Runoff Coefficient} &= 0.35 \text{ (machine-made clay tile)} \\ &= 26.25 \text{ m}^2 \end{aligned}$$

Courtyard:

$$\begin{aligned} \text{Area} &= 11 \text{ m} \times 9 \text{ m} & \text{Runoff Coefficient} &= 0.75 \text{ (concrete-lined ground surface)} \\ &= 99 \text{ m}^2 \end{aligned}$$

Now let's calculate the supply for each of the individual catchments.

Roof 1:

$$\begin{aligned} \text{Supply} &= \text{Rainfall} \times \text{Catchment Area} \times \text{Runoff Coefficient} \\ &= 0.305 \text{ m/year} \times 31.5 \text{ m}^2 \times 0.35 \\ &= 3.36 \text{ m}^3\text{/year} \end{aligned}$$

Roof 2:

$$\begin{aligned} \text{Supply} &= \text{Rainfall} \times \text{Catchment Area} \times \text{Runoff Coefficient} \\ &= 0.305 \text{ m/year} \times 26.25 \text{ m}^2 \times 0.35 \\ &= 2.80 \text{ m}^3\text{/year} \end{aligned}$$

Courtyard:

$$\begin{aligned} \text{Supply} &= \text{Rainfall} \times \text{Catchment Area} \times \text{Runoff Coefficient} \\ &= 0.305 \text{ m/year} \times 99 \text{ m}^2 \times 0.75 \\ &= 22.65 \text{ m}^3\text{/year} \end{aligned}$$

Exercise 2 Solutions continued

The total combined supply can be found by adding the supplies from the three catchment areas.

$$\begin{aligned}\text{Total Combined Supply} &= \text{Roof 1 Supply} + \text{Roof 2 Supply} + \text{Courtyard Supply} \\ &= 3.36 \text{ m}^3/\text{year} + 2.80 \text{ m}^3/\text{year} + 22.65 \text{ m}^3/\text{year} \\ &= 28.81 \text{ m}^3/\text{year}\end{aligned}$$

Therefore, the total annual amount of rainwater supply that can potentially be collected by the households is 28.81 m³/year.

Exercise 3 Solutions

The following variables are identified from this problem:

Water demand = 35 litres per person per day

Number of household members = 4 people

Longest average dry period = 90 days

The dry season demand for water supply can be calculated using the following equation:

$$\begin{aligned}\text{Dry season demand} &= 35 \text{ L/person/day} \times 4 \text{ people} \times 90 \text{ days} \\ &= 12,600 \text{ L or } 12.6 \text{ m}^3\end{aligned}$$

Therefore, this household requires a storage tank with a minimum capacity of 12,600 litres to meet their water needs during the dry season.

Exercise 4 Solutions

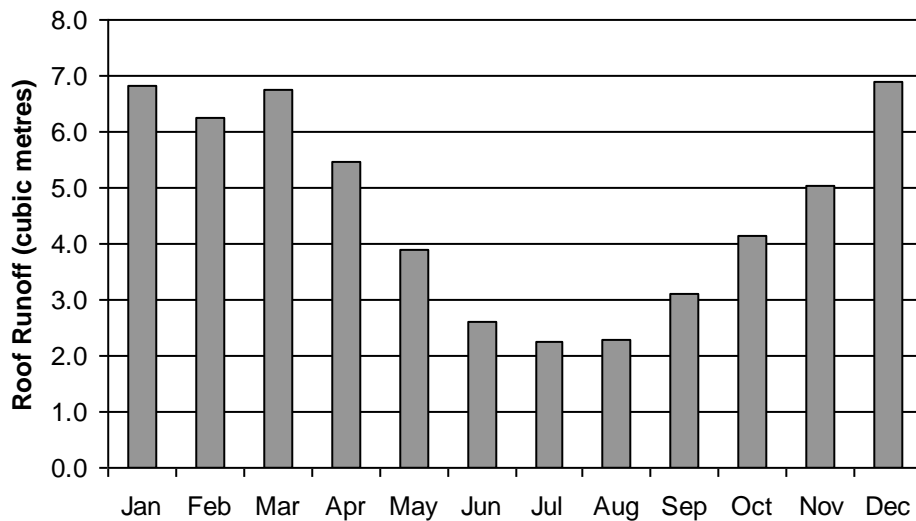
First of all, we can calculate the average monthly water demand.

Water Demand = 5 people x 30 L/person/day

= 150 L/day or 0.15 m³/year

= 4,500 L/month or 4.5 m³/month

From looking at Figure 2.3-3, we see that there is a single rainy season running from approximately December to April. By plotting the average monthly water demand on the graph, it is determined that November is the first month where the roof runoff meets the water demand. It is assumed that the tank is empty at the end of the dry season in October.



Monthly Water Supply

The cumulative monthly water supply and demand can be calculated using a spreadsheet (ex. Microsoft Excel) or by hand in Table 2.3-2. The capacity of the storage tank is determined by the greatest difference between rainwater supply and water demand.

Exercise 4 Solutions Continued

Calculation of cumulative supply, demand and storage requirement

Month	Rainfall (mm)	Water supply (m ³)	Cumulative supply (m ³)	Water demand (m ³)	Cumulative demand (m ³)	Storage requirement (m ³)
Jan	135.1	6.8	6.8	4.5	4.5	2.3
Feb	123.9	6.2	13.0	4.5	9.0	4.1
Mar	133.9	6.7	19.8	4.5	13.5	6.3
Apr	108.6	5.5	25.3	4.5	18.0	7.3
May	77.5	3.9	29.2	4.5	22.5	6.7
Jun	51.5	2.6	31.8	4.5	27.0	4.8
Jul	44.7	2.3	34.0	4.5	31.5	2.5
Aug	45.5	2.3	36.3	4.5	36.0	0.3
Sep	61.9	3.1	39.4	4.5	40.5	-1.1
Oct	82.0	4.1	43.6	4.5	45.0	-1.4
Nov	99.7	5.0	48.6	4.5	49.5	-0.9
Dec	137.1	6.9	55.5	4.5	54.0	1.5
Total	1101.1	55.5	-	54.0	-	-

Looking at the Table, you can see that the maximum storage requirement occurs in April with a capacity of 7.3 m³. The negative storage requirement values in Sep, Oct and Nov indicate that the water tank will be empty during these months. Since the rainfall and existing roof catchment area cannot be changed, the family will have to reconsider their daily water demand and reduce their consumption or find an additional water source to ensure that they have a year-round supply of rainwater, especially during the dry season.

3.6 Additional Resources

The Ajit Foundation, Scientific Resource Centre, Jaipur, India

The Scientific Resource Centre develops tools based on mathematical modelling and information technologies to help Panchayats manage their own water resources. SimTanka was developed by the Ajit Foundation for designing rainwater harvesting systems and can be downloaded free from the internet. No guarantees of any kind are implied.

Available at: <http://homepage.mac.com/vsvyas/science.html>

Domestic Roofwater Harvesting Research Programme, Development Technology Unit, School of Engineering, University of Warwick, UK.

This website contains the Rainwater Tank Performance Calculator; an on-line program that calculates the approximate system reliability and efficiency for a selection of tank sizes including one that you can define, using your monthly rainfall data and roof area.

Available at: www.eng.warwick.ac.uk/DTU/rwh/model/index.html

National Climatic Data Centre

NCDC is the world's largest active archive of weather data. NCDC produces numerous climate publications and responds to data requests from all over the world. NCDC operates the World Data Center for Meteorology. Sample data is provided, however most global data needs to be purchased.

Available at: www.ncdc.noaa.gov/oa/ncdc.html

www.ncdc.noaa.gov/oa/wmo/wdcamet.html

World Climate

This website contains over 85,000 records of historical weather averages, including precipitation data for major cities around the world, from a wide range of sources.

Available at: www.worldclimate.com

3.7 References

Ajit Foundation. (n.d.). Available at: <http://homepage.mac.com/vsvyas/science.html>

Development Technology Unit. (n.d.). Sizing a DRWH System. School of Engineering, University of Warwick, U.K. Available at: www.eng.warwick.ac.uk/DTU/rwh/sizing.html

Environment Canada (n.d.) Freshwater Facts for Canada and the World. Available at: www.ec.gc.ca/water/en/info/facts/e_contnt.htm

Gould, J. and Nissen-Petersen, E. (1999). Rainwater Catchment Systems for Domestic Supply: Design, Construction and Implementation. ITDG Publishing, Rugby, UK.

Intermediate Technology Development Group (ITDG). (n.d.). Rainwater Harvesting Technical Note. Knowledge and Information Services, The Schumacher Centre for Technology & Development, Rugby, UK. Available at: www.itdg.org/docs/technical_information_service/rainwater_harvesting.pdf

International Rainwater Harvesting Alliance. (n.d.). Available at: www.irha-h2o.org

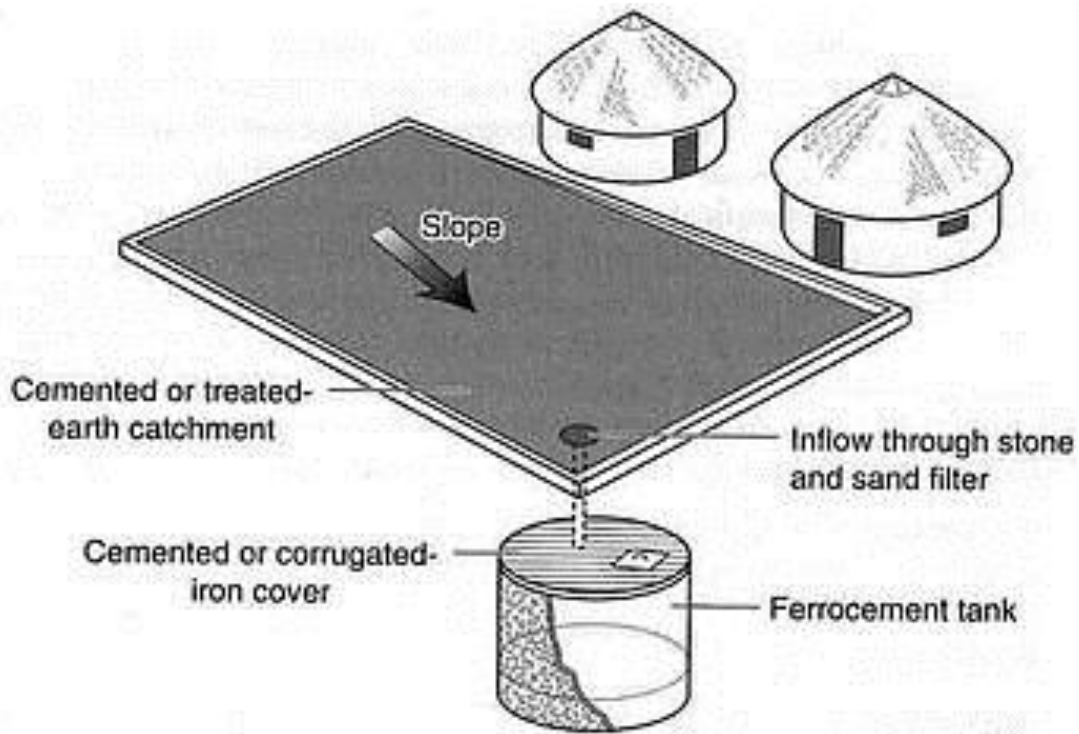
Rainwater Toolkit. (2005). Available at: www.rainwater-toolkit.net/index.php?id=75

Shaw, R. (2005). Drawing Water. Water, Engineering and Development Centre, Loughborough University, U.K. Available at: <http://wedc.lboro.ac.uk/dw/illustrations-water.htm>

United Nations Educational Scientific and Cultural Organization (UNESCO). (2000). Available at: www.unep.org/vitalwater/15.htm#17

World Climate. (2005). Rio de Janeiro Average Rainfall Data. Available at: www.worldclimate.com

4 Ground Catchment Systems



(Gould and Nissen-Petersen, 1999)

Learning Expectations

In this module you will learn about ground catchment systems, including:

- Advantages and disadvantages for domestic use.
- Basic design, construction, operation and maintenance.
- Current applications in developing countries.

4.1 Introduction

Ground catchment systems use the land surface to collect rainwater and are best suited for several households or a community. The catchment can be specifically built to collect rainwater or it may already exist for another purpose, e.g. threshing floor, playground or a road.

Main Advantages:	Main Disadvantages:
<ul style="list-style-type: none"> The larger catchment area can collect more rainwater than a roof system. 	<ul style="list-style-type: none"> Collected rainwater is usually of poor quality since it can become easily contaminated by pollutants and excrement from animals and children.
<ul style="list-style-type: none"> Large quantities of rainwater can be harvested for a community supply. 	<ul style="list-style-type: none"> Ground surfaces are not normally as efficient as roofs for collecting runoff (i.e. they have a lower runoff coefficient).
<ul style="list-style-type: none"> Collects a considerable amount of water in areas where rainfall is very scarce and other sources are unavailable. 	<ul style="list-style-type: none"> People still need to fetch water and sub-surface tanks make it more inconvenient to withdraw water for use.

Since the rainwater collected from these catchments is generally of poor quality, it is recommended that the water only be used for secondary purposes like watering livestock or gardening. The rainwater should be treated if it is intended for drinking. Refer to Module 1.8 for further information about household water treatment technologies.

4.2 Design and Construction

4.2.1 Catchment Area

Rainfall runoff can be collected from a natural surface, however many soils have a high infiltration capacity and a low runoff coefficient. There are three approaches to help reduce infiltration and increase the amount of rainwater runoff collected from a natural ground catchment surface.

1. Covering – Natural surfaces are covered with an impermeable material such as butyl rubber, plastic sheeting, tiles, and metal sheets. While these materials give a higher runoff coefficient and reduce contamination, they are expensive and may not be available locally.
2. Treatment – Materials are added to soil surfaces to try to seal them including cement, lime, paraffin wax, oil, bitumen, asphalt, sodium salts, silicone or clay. Treating surfaces is a cheaper alternative to increase the runoff coefficient, although the cost can still be substantial.
3. Compaction – Natural soil surfaces are compacted and shaped using manual labour or earth-moving machinery. Threshing floors and compounds around rural households often have a compacted surface which can make for a

useful catchment surface. The water quality is generally poorer than covered or treated surfaces and excess sediment may need to be removed from the collected water.

Typical runoff coefficients for various ground surfaces in China

(Mean annual rainfall varying from 200 to 500 mm)

Surface type	Runoff coefficient
Concrete lined	0.73 – 0.76
Cement soil mix	0.33 – 0.42
Buried plastic sheet	0.28 – 0.36
Compacted loess soil	0.13 – 0.19

(Zhu and Liu, 1998)

These figures show the runoff coefficient for the particular catchment types that could be expected 95 percent of the time. The higher number in the range relates to areas with a mean annual rainfall between 400 to 500 mm, while the lower number is for areas receiving just 200 to 300 mm.

Natural land surfaces will normally have a runoff coefficient below 0.3 and these may even be as low as zero (Skinner, 1990).

Exercise: Calculating the Rainfall Runoff of a Ground Catchment

The Thar Desert is a tract of rolling sand hills located partly in the Indian state of Rajasthan and partly in Pakistan. In this region, traditional *kundis* are built to harvest rainwater for domestic use (see description in Current Applications section of this module). The average annual rainfall in the eastern part of the desert is 500 mm, with most of it received during the July to September monsoon.

Assume that your *kundi* has a catchment area of 90 m² and it has been treated with pond silt and *murrum* to reduce infiltration of rainwater into the soil. The runoff coefficient for the treated ground surface is estimated to be about 0.25.

Use the space below to calculate the total amount of rainwater runoff that can be collected by this ground catchment area each year.

Formula: Runoff coefficient = $\frac{\text{Volume of runoff}}{\text{Volume of rainwater}}$

Solutions found in Self Check at the end of this module.

4.2.2 Delivery Systems

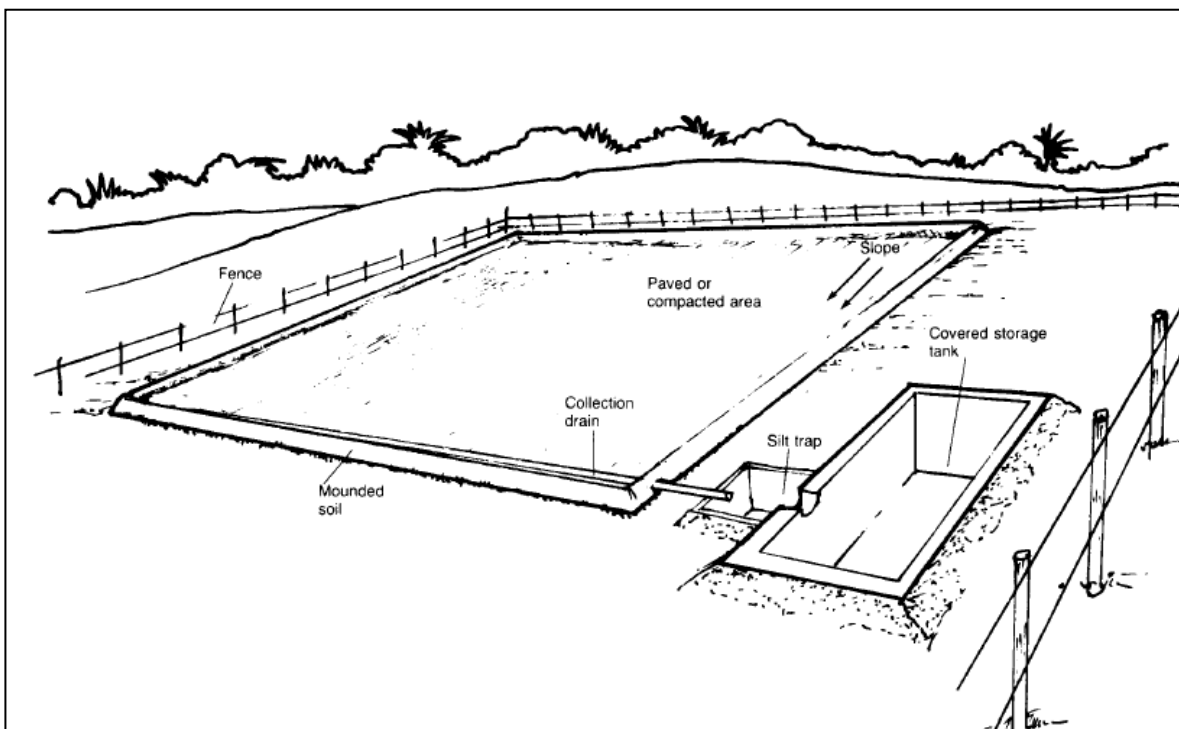
For smaller ground catchment systems, such as threshing floors, the floor normally slopes so the rainfall flows to a storage tank inlet. For larger systems, such as a road, a network of drains and channels is needed to direct the runoff. For example, in semi-arid areas of Kenya, rainfall runoff is diverted from road surfaces for crop irrigation using diversion channels and a canal system (Kirimji, 1999).

4.2.3 Storage Reservoirs

The collected runoff can be stored in various systems to be used as required. Storage reservoirs can be of many different types. They can be located on the surface of the ground or below the surface. Sub-surface tanks can be made from local materials using ferrocement, concrete, brick and traditional clay linings. If suitable to the application, water could be drawn off the reservoir by way of a drain, filtered, and stored in a covered tank (see Figure 2.4-1).

Open surface reservoirs can hold large amounts of water, but they are subject to evaporation and contamination. Open surface reservoirs can also have excessive sedimentation, and become a breeding ground for insects, and thus insect-borne disease (such as malaria).

Usually some sort of inlet filter is needed to prevent sediment and debris from entering the storage tank. It is also important that sub-surface tanks have a cover to prevent children and animals from falling into them. Proper fencing around the reservoir is also highly recommended (see Figure 2.4-1).



(US AID, n.d.)

Figure: Example of a ground catchment design

Storage reservoirs may also use natural features of the land; these will depend on the location (soil type and geography), the materials available, the rainfall (consistent through the year or seasonal), and the intended use of water.

Different types of storage reservoirs have been used throughout the centuries, some of these may combine characteristics of various types of reservoirs. Some of these have been reclaimed/reworked such as those referred to in Case Study 2.4-1 Rejuvenating Ooaranis.

4.3 Current Applications - India

Ground catchment systems are more commonly used for farming and irrigation than for drinking water purposes. The exception is in India where there is a long history of rainwater harvesting for domestic use. The following are a few examples of different ground catchment technologies found in India.

4.3.1 Kundis

The villagers of the Thar Desert have evolved an ingenious system of rainwater harvesting, known as *kunds* or *kundis*, to tackle their drinking water problems. They are more prevalent on the western arid regions of Rajasthan and in areas where the limited groundwater is moderate to highly saline. *Kundis* are owned by communities or privately, with the wealthy having one or more of their own.

The *kundi* consists of a saucer-shaped catchment area with a gentle slope towards the centre where an underground storage tank is situated. The success of a *kundi* depends on the selection of the site, particularly the characteristics of the catchment area. An adequately large area has to be selected or artificially prepared to produce enough rainfall runoff to meet the water supply requirements. The catchment size varies from 20 m² to 2 ha depending on the runoff needed and land availability. The ground surface area is treated to reduce infiltration and increase the amount of rainwater runoff collected. Common sealing materials include pond silt, *murrum*, charcoal ash, and gravel.

The *kundi* storage tanks are generally circular in shape with a depth and diameter ranging from 3 to 4.5 m. Water inlets are usually guarded by a wire mesh to prevent debris, birds and reptiles from entering. The tank is usually covered with a lid where water can be drawn out with a bucket. Lime plaster or cement is typically used to construct the tank since stone is not always available and relatively more expensive (Rainwaterharvesting.org, n.d).



(Centre for Science and Environment, n.d)

Figure: Kundi used in the Thar Desert

4.3.2 Ooranis

Ooranis are constructed tanks or ponds which are designed to harvest and store rainwater to meet the drinking needs of a community. There are as many as 39,000 ooranis in Tamilnadu State alone, and almost every village in the Ramanathapuram District has an oorani.

The pond is created by excavating the soil which is then used to form bunds around the area. Ooranis are generally located in an area with impermeable soil so that water loss due to infiltration is minimized. They are sized to meet the village's consumption requirements and accommodate other losses such as those due to evaporation. The primary use of the stored water is for drinking, although by increasing the storage capacity of the oorani, it may also be used for irrigation (UNEP IETC, n.d.).



(Schwilch, n.d.)

Figure: Constructed oorani in Mayarundi for water harvesting. The last rainfall was received about 45 days previous.

Over the years, many traditional ooranis in communities have been neglected and abandoned in favor of centralized water supply and distribution projects. However more recently, ooranis are being restored and collectively managed by communities when these conventional water systems have failed to meet people's needs.

Rural banks and organizations like the Development of Human Action (DHAN) Foundation are collaborating to provide finance for communities to revive and maintain their ooranis. Launched in 1992, the oorani rehabilitation programme has now spread to around 150 villages, giving rise to 165 Tank Farmers Association (TFA's) in Madhurai, Theni, Thiruvalluvar, Villapuram and Ramanathapuram districts in Tamilnadu and Chittoor district in Andhra Pradesh. Villagers have responded positively by contributing 25 to 50 percent of the total cost of the project (Rainwaterharvesting.org, n.d.).

Case Study 2.4-1 Rejuvenating Ooranis

Puseri is a small village with 250 families in the Ramanathapuram District. The village has five ooranis of which one is used for drinking water and the remaining for other domestic purposes. All of these ooranis supply water for about seven months of the year. During summer, the people used to face severe water scarcity and convinced the government to install a desalination plant to solve the issue. Until the early 1990's, the village was satisfied with the water from the plant and neglected the ooranis.

Over the years, the desalination plant was unable to meet their water requirements and once again the village faced water scarcity. A Tank Farmers Association was promoted in the village and it was decided to renovate the oorani. The total cost was estimated to be Rs. 1.05 lakhs, with 0.35 lakhs intended to be the people's contribution. The villagers decided to contribute labour instead of cash and they completed about 30% of the earthwork within five days.

Over the following three years, the renovated ooranis ensured two fillings of rainwater. The additional storage helped the villagers to meet their drinking water needs, even during the summer (DHAN Foundation, n.d.)

4.3.3 Paar System

Paar is a common water harvesting practice in the western Rajasthan region of India. In this system, the rainwater flows from the *agar* (catchment area) and in the process percolates into the sandy soil. Traditional wells, known as *kuis* or *beris*, are dug 5 to 12 m deep to access the water. Using traditional masonry technology, six to ten of the *kuis* or *beris* are constructed in a *paar*. Rainwater harvested through the *paar* technique is known as *patali paani*.



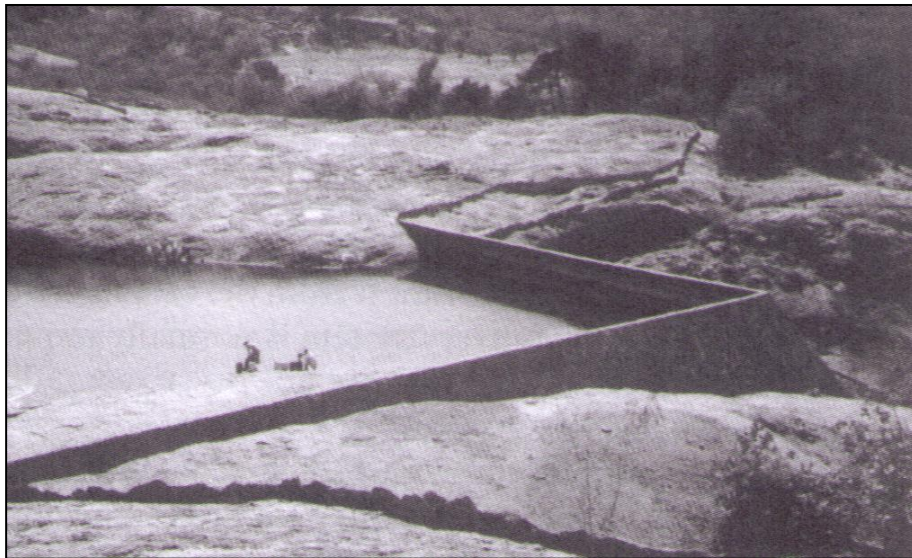
(Rainwaterharvesting.org, n.d.)

Figure: Traditional kui

4.4 Current Application of Rock Catchments

4.4.1 Rock Catchments

Rock catchments can be constructed in natural valleys or hollows by constructing a rubble/stone/masonry dam to contain the water. The least expensive, where suitable sites exist, are naturally occurring rock catchments. They require impermeable, exposed, unjointed bedrock able to hold rain water. Granite rock forms (sometimes called inselbergs) are an ideal rock catchment. Some of these large rocks have natural concave surfaces and can actually hold the water, if the surface is more convex on top, the water running off can be collected into a barrel at the point(s) of greatest runoff. (See Figure 2.4-2)



(Gould and Nissen-Peterson, 1999)

Figure: Rock catchment system at Kaseva, Mutomo in Kitui District, Kenya

4.4.2 Earth Dams, Ponds, Drains (small)

Raised banks of compacted earth help retain water from storms inside earth dams or ponds. The amount of water collected into the ponds can be augmented by the use of bunds or dykes. Water contained in all of these must be treated before domestic use due to high turbidity, sedimentation problems, and high bacterial load.

Hafirs

Hafirs are in many ways another form of earth dams. Hafirs were originally used in the Sudan many centuries ago; they consist of excavated reservoirs in natural depressions. These are best constructed in a clay soil as it seals the bottom of the hafir and retards the water seepage into the surrounding ground. (IWMI, n.d.) The soil from the excavated holes is then used to form the banks around the hafir. The catchment area can be increased by constructing bunds to divert more water into the hafir. As with earth dams, high turbidity, sedimentation, and the bacterial load are common problems.

4.4.3 Check Dams (small)

Small barriers, called check dams, built across the flow of a small creek/river can be especially beneficial to small, rural farmers. They do not submerge large tracts of land and can be used for domestic use or for livestock and agricultural needs. When small check dams are constructed, the resources to build and maintain the dam are minimal.



Construction of a check dam (www.undop.or.th, n.d)

Check dams are a more efficient catchment system when used widely in a watershed than large dams, as they increase the percolation rate of water into the soil, increase the soil moisture, and therefore the vegetation, crops and potential income while possibly reducing erosion from heavy rains.

Check dams, being an open water source, are subject to evaporation, a high turbidity, increased sedimentation, and a high bacterial load. Check dams may also become a breeding ground for insects. The water from check dams must be treated if used for domestic use. (Developing Alternatives, 1999)

Any of the open reservoirs will be subject to seepage and evaporation, often resulting in the reservoir drying out in the dry season, but they will also increase the groundwater levels.

Sand Dams (Sand River Storage)

This method of storing water is excellent for semi-arid regions given the required geography/geology of the area. It requires seasonal (ephemeral) rivers, a bedrock base, and flood river banks.

Sand dams can occur naturally or can be constructed within a sand river / seasonal river. These naturally occurring underground water reservoirs can be identified by the type of vegetation along the edge of the sand dam, and sometimes the ground water level can even be assessed by the vegetation.

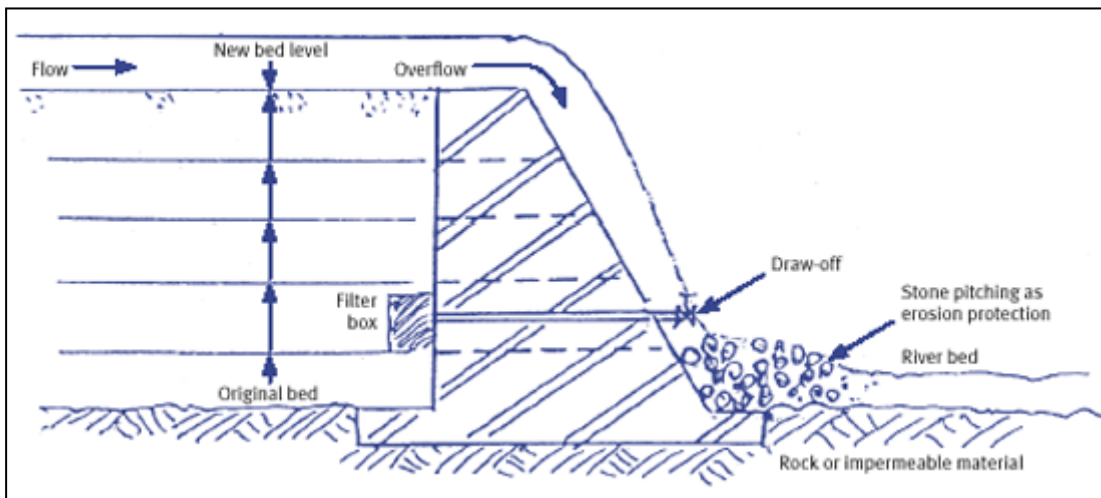


Sand dam in Kitui district of Kenya: (New Scientist Nov 2006)

Construction of a sub-surface dam is begun by building across the river channel (in the dry season) where the sand is shallow and clay/bedrock can easily be exposed to be built upon. Two different methods seem to be used to construct these sand dams:

1. The ridge/dam is built of clay, stone, or masonry in stages (only 0.3 m/year) and the height is increased only after the flood waters from the year have deposited sand to the level of the previous year's dam, increasing the water storage capacity with each new layer. The dam wall can be built to a maximum of 2 to 3m. (Gould and Nissen-Petersen, 1999; Nissen-Petersen, 2000)
2. Construction can also occur all at once with a maximum height of 2 to 3m. (Excellent Development, nd)

The water in the reservoir is then accessed by a water hole or a well with a bucket or pump.



(Water Aid, nd)

Figure: Sand Dam (incremental construction) cross section

See also diagrams in Rainwater Catchment Systems by Gould and Nissen-Petersen, 1999 (p 98)

The great advantages of the sand dams are that the water is held under the surface of the sand, so that evaporation losses are minimal, and the water is protected from contamination. Evaporation rates will depend on the depth of the water table below the sand surface and how fine or coarse the sand is. A further benefit of this method is the higher groundwater level resulting in increased crop production. (Changemakers, July 2003; Practical Action-Sand Dams, nd;)

CASE STUDY: Sand Dams in Kitui, Kenya

In the rural area of Kitui in Kenya, lives are changing due to the construction of sand dams. More girls are now attending school because they no longer have to spend the long hours required to gather water for their homes. Women and girls used to have to walk up to 10 miles to find water, but with the help of the SASOL foundation, 400 sand dams were built – the highest concentration of sand dams in the world. They are built with the community participating in the construction, and is therefore made economically and socially effective. It has also had the effect of seasonal rivers flowing all year long.

Sand dams have been built in the Kitui area for some time, the first being built in 1928 and still functions. These dams require minimal maintenance and are expected to have a life of more than 100 years.

The benefits of the sand dams have been seen in economic and on social fronts. Local residents can now grow produce (from tomatoes, kale, and onions to a variety of fruits). This has changed the area from being an importer of food to being an exporter of produce, household incomes have increased, and because more fruits and vegetables are now being eaten, the health of the women and children particularly is improving.

The communities are proud of how their skills and efforts have brought such positive results to their community. (Source: Changemakers, July 2003)

1. How did this community benefit from the construction of sand dams?
2. Can you come up with any other benefits that the construction of sand dams may have on a community.
3. Would you classify this technology as one that is sustainable?

4.5 Considerations for Design:

The following factors should be accounted for when considering the design of the ground catchment system:

- Rainfall patterns; demand for water
- Source for all water or only a portion when available
- The designed size of a catchment area must increase as the rainfall decreases or is very seasonal.

4.6 Operation and Maintenance

Regular inspection, cleaning, maintenance and occasional repairs of the ground catchment system are essential for its long-term success. The key to its operation and maintenance involves protecting the catchment area and reservoir from pollution and erosion. This requires a regular schedule of inspection, as well as undertaking repairs and sediment removal when necessary.

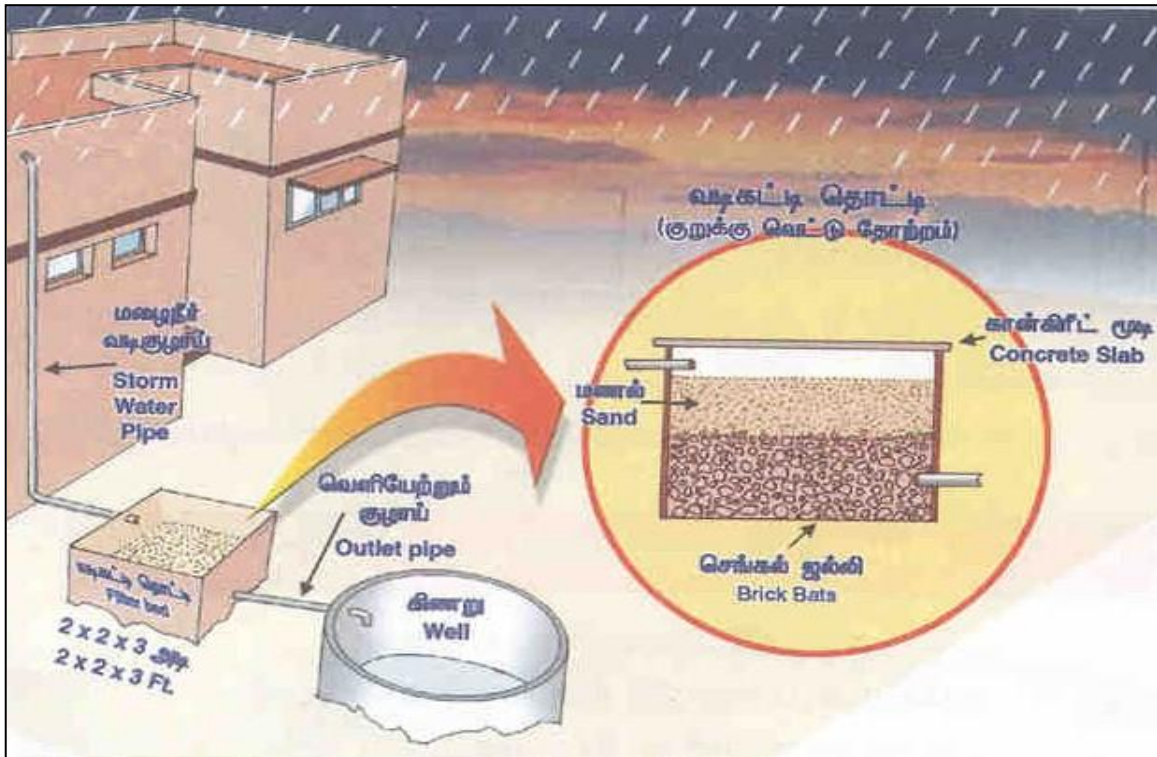
Effective operation and maintenance of ground catchments tends to be more difficult since they are usually managed as communal systems. Clear guidelines need to be established so the community knows who is responsible for undertaking these tasks

4.7 Recharging Underground Aquifers

There are many stories of depletion of groundwater around the world. Water is being pumped from underground sources or rivers and lakes faster than the natural recharge. Not only is it resulting in a lowering of the water table, but along with it can come dangerously high concentrations of fluoride, arsenic, and other components that are normally found in groundwater.

In order to recharge groundwater efficiently, small collection systems can be used to catch the rain. Whether urban or rural, this method could be of great benefit. In urban areas, water cannot infiltrate the ground due to roads, buildings, parking lots, and other hard surfaces. In the rural areas, this can help improve the groundwater levels, help control erosion, and supply water in remote areas.

Any man-made technology that adds water to an aquifer at a rate exceeding that obtained under natural conditions may be considered an artificial recharge system.



(Rain Water Harvesting, DTP, India, 2006)

Figure: Schematic view of a single tank groundwater recharge system

Considerations for site:

- Sub-surface geology must be defined
- Determine presence or absence of impermeable layers that will affect the percolation into the soil
- Determine water table and groundwater flow

(Source: Centre for Science and Environment, nd)

Considerations for design:

- Size of catchment /tank
- Amount of rainfall (maximum) expected during heavy, seasonal rains and rain profile throughout the year
- Ground percolation/ recharge rate (if slow, the tanks that are used will have to hold a greater volume of rainwater) (Source: Design of groundwater recharge structures, Centre for Science and Environment, nd)

Rainwater is collected and returned to underground aquifers in a few basic methods. One such system suggested uses a series of three trenches, dug into the soil, that receive the collected water from the roof, down a gutter or pipe and into the trench (District Rural Development Agency, nd). Others have only a single tank or trench to receive water (Directorate of Town Panchayats, 2006). The water is filtered to remove

silt or other particles that may cause plugging when the water is diverted from the collection tank or trench into an existing well. This can be used in the recharging of shallow or deep underground aquifers, as long as the geology of the area can accept the water.

Other considerations for design:

- a) Roof top area – how much rainfall will flow from roof
- b) type of roof – must be non-toxic; desire smooth, hard, and dense material for maximum rain harvest
- c) gutter and downpipe material – must be non-toxic
- d) filter media – must be non-toxic
- e) 'first flush' system - to divert first rains that may be contaminated

This system will recharge both shallow and deep aquifers – the shallow aquifers throughout the water's journey through the series of trenches, and the deep aquifers when the water exits the pipe into the bore well.

(From: District Rural Development Agency, nd)

A less significant source of water for recharging underground aquifers, is the spill-over water that is pumped from the well. It is simply run into a similar trench or tank system; a smaller volume, but important none the less.



Unused water re-circulated into aquifer (Rain Water Harvesting, DTP, 2006)

Groundwater recharge in hard rock areas is a little different. In these areas, recharging underground aquifers must follow fracture lines in order to gain entry into the aquifer. (Meghalaya Public Health Engineering Dept, nd)

Summary of Key Points

- Ground catchment systems use the land surface to collect rainwater.
- The catchment can be specifically built to collect rainwater or it may already exist for another purpose, e.g. threshing floor, playground or a road.
- Ground catchment systems are generally less expensive to construct than a roof system.
- Catchment systems can be natural or artificially man-made.
- Three methods to reduce infiltration and increase runoff from a natural ground catchment surface are: covering, treatment and compaction.
- The ground surface area is usually sloped towards the storage tank to help drain and collect the rainwater runoff.
- Collected runoff is generally stored in a sub-surface tank.
- Open reservoirs should be fenced and tanks should be covered to keep children and animals away.
- Successful applications in India include the use of kundis, ooranis, and the paar system
- Rock catchment, earth dams, hafirs, check dams, and sand dams are some of the most effective and cheapest types of rainwater storage systems
- Collected rainwater is usually of poorer quality since it can become easily contaminated by pollutants and excrement. It is recommended that the rainwater be treated using a household treatment technology if it is intended for drinking.
- Regular inspection, cleaning, maintenance and occasional repairs of the ground catchment system are essential for its long-term success
- Any man-made technology that adds water to an aquifer at a rate exceeding that obtained under natural conditions may be considered an artificial recharge system.
- Common types of aquifer recharge systems include the three trench system, the single trench, and the spill-over method.

Self-Assessment

Ground catchment systems use the _____ surface to collect rainfall.
True or false? The ground catchment must be specifically built to collect rainwater.

Describe the main advantages and disadvantages of using ground catchment systems.

List the three methods used to reduce infiltration and increase runoff from a natural ground catchment surface.

Where is collected runoff usually stored? _____
Discuss the advantages of rock catchment dams, earth dams and hafirs?

7. What feature makes sand dams unique?

8. Discuss why rainwater collected from ground catchments intended for drinking should be treated using a household treatment technology.

9. Define aquifer recharge.

Solutions

1. Ground catchment systems use the land surface to collect rainfall.

False. Ground catchments can be specifically built to collect rainwater or they can already exist for another purpose, e.g. threshing floor, playground or a road.

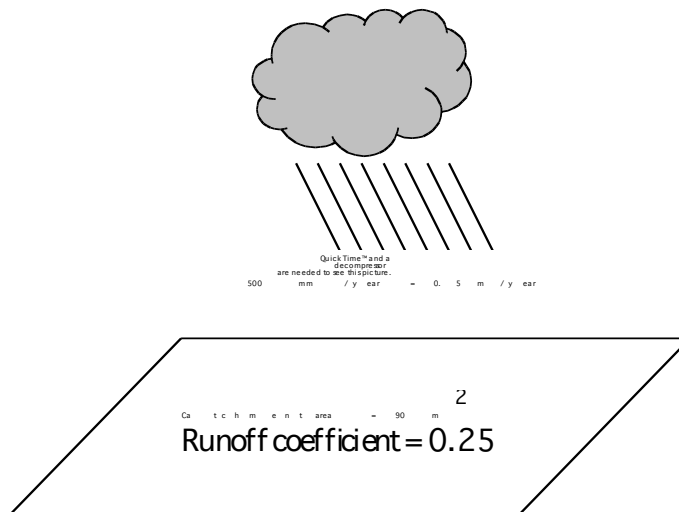
2. Advantages:

- The larger catchment area can collect more rainwater than a roof system.
- Large quantities of rainwater can be harvested for a community supply
- Collects a considerable amount of water in areas where rainfall is very scarce and other sources are unavailable.

- Disadvantages:

- Collected rainwater is usually of poor quality since it can become easily contaminated by pollutants and excrement from animals and children.
 - Ground surfaces are not normally as efficient as roofs for collecting runoff (i.e. they have a lower runoff coefficient).
 - People still need to fetch water and sub-surface tanks make it more inconvenient to withdraw water for use.
3. Three methods to reduce infiltration and increase runoff from a natural ground catchment surface are: covering, treatment and compaction.
 4. Collected runoff is usually stored in sub-surface tanks.
 5. Rock catchment dams, earth dams, and hafirs are cheap and effective. In Sudan and northern Africa, hafirs are traditionally part of the culture.
 6. Sand dams are unique because the water is stored under the sand, therefore there is less risk of evaporation and contamination.
 7. Collected rainwater is usually of poorer quality since it can become easily contaminated by pollutants and excrement from animals and children. It is recommended that the water only be used for secondary purposes like watering livestock or gardening. The rainwater should be treated using a household treatment technology if it is intended for drinking.
 8. Any man-made technology that adds water to an aquifer at a rate exceeding that obtained under natural conditions may be considered an artificial recharge system.

Solutions (Not sure where the questions are ???)



First of all, let's calculate the total amount of rain that will fall on the catchment area:

$$\begin{aligned} \text{Volume of rainwater} &= 0.5 \text{ m/year} \times 90 \text{ m}^2 \\ &= 45 \text{ m}^3/\text{year} \end{aligned}$$

Now let's use the runoff coefficient formula to figure out how much of the rainwater that falls on the catchment area will actually flow into to the storage reservoir:

$$\begin{aligned} \text{Runoff coefficient} &= \frac{\text{Volume of runoff}}{\text{Volume of rainwater}} \\ 0.25 &= \frac{\text{Volume of runoff}}{45 \text{ m}^3/\text{year}} \\ \text{Volume of runoff} &= 11.25 \text{ m}^3/\text{year} \end{aligned}$$

4.8 Additional Resources

Centre for Science and Environment

Website provides a wealth of information, research tools and case studies about rural and urban rainwater harvesting technologies in India.

Available at: www.rainwaterharvesting.org (Jan – 07)

Development of Human Action (DHAN) Foundation

Based in India, the DHAN Foundation works to bring significant changes in the livelihoods of the poor through innovations in themes and institutions. Launched in 1992,

the Foundation's Vayalagam Tank Agriculture Development Programme works for the conservation, development and management of tank (oorani) systems.

Available at: www.dhan.org (Jan – 07)

Environment and Public Health Organization (ENPHO)

This website has several frequently asked questions about Rain Water Harvesting.

Available at: www.enpho.org/ep2005_faq_rain_water_harvesting.htm (Jan - 07)

Excellent Development

Videos can be accessed from the website on building sand dams as well as information on the benefits of sand dams.

Available at: www.excellentdevelopment.com/dams.php (Jan - 07)

International Water Management Institute

The IWMI website provides additional information on water management and agricultural research.

Available at: www.iwmi.cgiar.org (Jan -07)

Manmohan for campaign on recharging groundwater level,

Newspaper article outing India's need to manage ground water.

Available at: www.thehindu.com/2006/07/23/stories/2006072305501000.htm

The World's Single Biggest Threat

Globe and Mail newspaper article explores the issues of inadequate water supply.

Available at www.theglobeandmail.com/series/deathwish/0604.html (Jan -07)

WaterAid

WaterAid provides additional information on sand dams.

Available at: www.wateraid.org (Jan – 07)

World Overview of Conservation Approaches and Technologies (WOCAT)

WOCAT provides tools for Soil and Water Conservation specialists to network and share knowledge with the purpose of supporting decision making during planning and in the field. There are technologies, appropriate approaches, and images databases that are available to the public.

Available at: www.wocat.org (Jan-07)

4.9 References

Bournemouth University, Agbon Cave –Nigeria's Living Rock Shelter, (n.d.), Available at: http://csweb.bournemouth.ac.uk/africanlegacy/agbon_cave.htm

Brahic, Catherine. (2006). New Scientist Sand dams:low-tech weapons against climate change www.newscientist.com/article.ns?id=dp=dn10587&print=true

Centre for Science and Environment (n.d). Design of groundwater recharge structures. Available at: http://www.rainwaterharvesting.org/urban/Design_Recharge.htm

Centre for Science and Environment. (n.d.) Kunds of the Thar Desert. Available at: www.rainwaterharvesting.org/methods/traditional/kunds.htm

Developing Alternatives. (1999). Check-Dams and Irrigation. Available at: www.dainet.org/livelihoods/checkdams2.htm

Directorate of Town Panchayats. (2006). Rain Water Harvesting. Available at: www.tn.gov.in/dtp/rainwater.htm

District Rural Development Agency, Ganjam, Chatrapur, Orissa (n.d.) Rainwater Harvesting. Available at:

<http://drdaganjam.nic.in/INNO-RAINWATER.htm>

Excellent Development (n.d.). Sand Dams. Available at: www.excellentdevelopment.com/dams.php

Good News India. (2003). Farm Ponds' many merits over check-dams. Available at: www.goodnewsindia.com/index.php/Home/printWithImages/413/

Gould, J. and Nissen-Petersen, E. (1999). Rainwater Catchment Systems for Domestic Supply: Design, Construction and Implementation. ITDG Publishing, Rugby, UK.

International Water Management Institute.(no date). Best Practices – Template #33 (Haffir) Available at:

www.iwmi.cgiar.org/africa/west_africa/projects/AdoptionTechnology/RainwaterHarvesting/33-Haffir.htm

Kirimi, P. (1999). Ministry of Agriculture, Soil and Water Conservation Branch, Kenya. Available at: www.fao.org/ag/agl/agll/wocat/wqtsum.asp?questid=KEN11

Kumar, MD (2002). Making the Montage: Setting the Agenda and Priorities for Water Policy Research In India, Water Harvesting and Groundwater Recharging in Western India. Available at:

www.iwmi.org/iwmi-tata_html/PartnersMeet/pdf/Synthesis%Paper.pdf

Meghalaya Public Health Engineering Department. (n.d.). Water Harvesting and Recharging in Hard Rock Areas. Available at:

<http://megphed.gov.in/knowledge/RainwaterHarvest/Chap10.pdf>

Mutiso, G-C. M. (2003). Kitui Sand Dams and Food Security, Kenya; Changemakers www.changemakers.net/journal/03july/kitui.cfm

Nissen-Petersen, E. (2000). Water from Sand Rivers: A Manual on site survey, design construction, and maintenance of seven types of water structures in river beds, Technical Handbook #23, Regional Land Management Unit, Sida, ICRAF House, Nairobi, Kenya

Rainwater Toolkit. (2005). Available at: www.rainwater-toolkit.net/index.php?id=75

Schwilch, G. (n.d.) World Overview of Conservation Approaches and Technologies, Images Database. Available at: www.fao.org/ag/agl/agll/wocat/wctimage.asp

Skinner, B. (1990) Community Rainwater Catchment. Unpublished Report. Water, Engineering and Development Centre (WEDC), Loughborough University, UK. 109p. Cited in Gould and Nissen-Petersen (1999).

UNEP IETC. (n.d.) Sourcebook of Alternative Technologies for Freshwater Augmentation in Some Countries in Asia. Available at:

www.uepep.or.jp.ietc/Publications/TechPublications/TechPub-8e

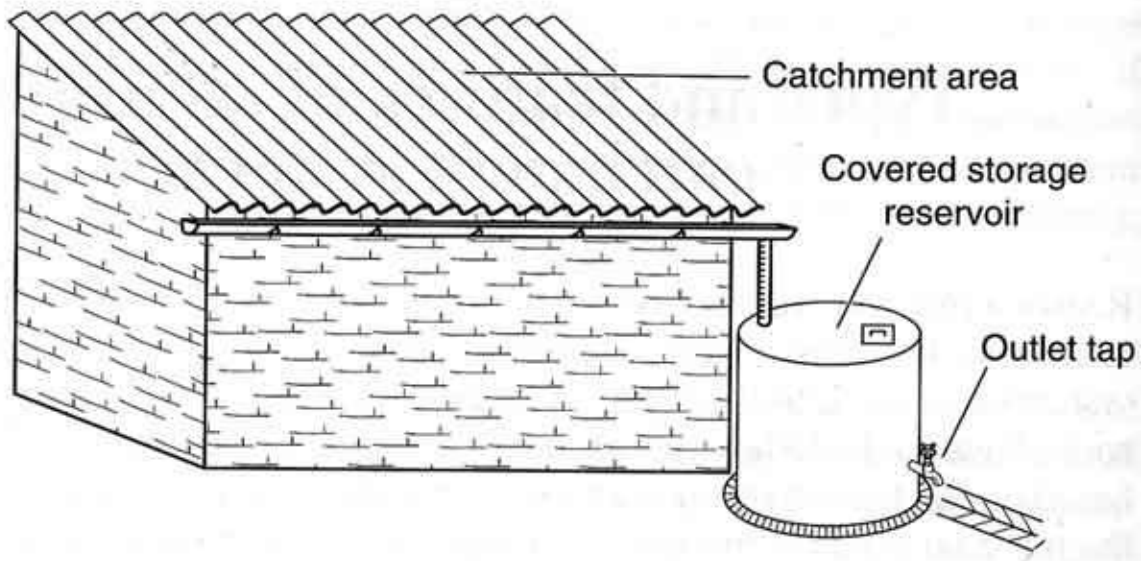
United Nations Development Programme, Photo Essay: Expanding Community Access to Water. (n.d). Available at: <http://www.undp.or.th/focus/photo-essay-waterresources.html#top>

US Agency for International Development (AID). (n.d.) Water the World. Evaluating Rainfall Catchments, Technical Note No. RWS. 1.D.5. Available at: www.lifewater.org/resources/rws1/rws1d5.pdf

WaterAid, (n.d). Subsurface Dams. Available at: www.wateraid.org/international/what_we_do/how_we_work/sustainable_technology_notes/2057.asp

Zhu, Q. and Liu, C. (1998). Rainwater Utilization for Sustainable Development of Water Resources In China. Paper presented at the Stockholm Water International Symposium, Stockholm, Sweden, 8p. Cited in Gould and Nissen-Petersen (1999).

5 Roof Catchment Systems



(Gould and Nissen-Petersen, 1999)

Learning Expectations

In this module you will learn about the basic design, construction, operation and maintenance of roof catchment systems, including:

- Suitable roofing materials.
- Gutter and downpipe systems.
- Surface and sub-surface storage tanks.

5.1 Introduction

The roofs of houses or buildings are most commonly used as rainwater catchment surfaces for domestic use. The main advantages of using roofs include:

- Roofs have a high runoff coefficient since they are designed to shed water.
- Roofs provide relatively good water quality compared to ground catchments.
- Roofs provide a water supply directly at the point of consumption instead of having to be collected and transported or piped to the household.
- The construction cost for the catchment is basically free of charge if an existing building with an impervious roof is used.

There are various configurations of roofing materials, delivery systems and storage reservoirs that can be used to design and construct a roof catchment system. The following sections will discuss the most common methods that are currently being used by households in developing countries. Most of the familiar designs, if properly constructed with good-quality materials, are effective.

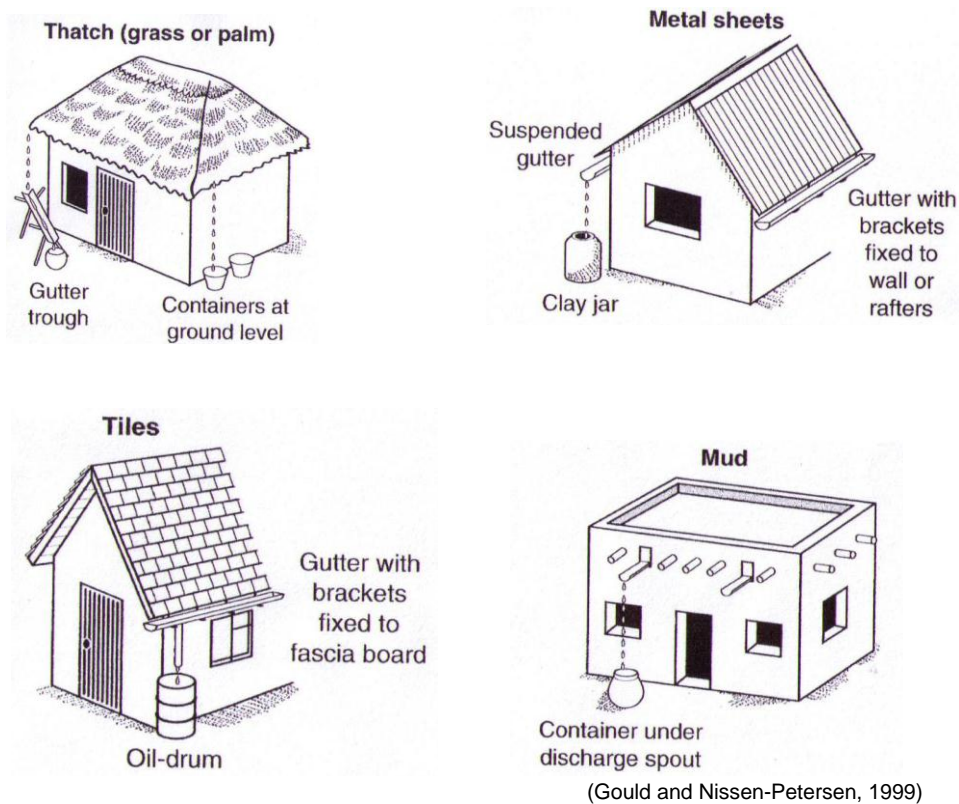


Figure: Examples of roofing materials, delivery systems and storage tanks

5.2 Catchment Area

The roof of a house or building is the catchment area for the rainfall. The material, surface area and slope of the roof affect the overall collection efficiency and rainwater quality. Suitable roofing materials for rainwater collection include:

- Corrugated galvanized iron sheets
- Corrugated plastic sheets
- Asbestos sheets
- Tiles
- Slate

Most palm and all grass thatched roofs are not suitable for rainwater collection since they discolor and affect the taste of the water. Roofs constructed from coconut or anahaw palms can make acceptable catchments if they are tightly thatched. Grass thatch should only be used when there are no other alternatives and for a purpose other than drinking water.

Flat mud roofs are generally not suitable as catchment surfaces, although they are used in some countries, like Mali.

For health considerations when selecting roofing materials see Gould and Nissen-Peterson page 23.

While a runoff coefficient greater than 0.90 can be achieved for a well-designed roof and gutter system, 0.80 is more commonly used to account for occasional water losses due to gutter overflow during intense rainfalls or from temporary blockages by debris (Gould and Nissen-Petersen, 1999).

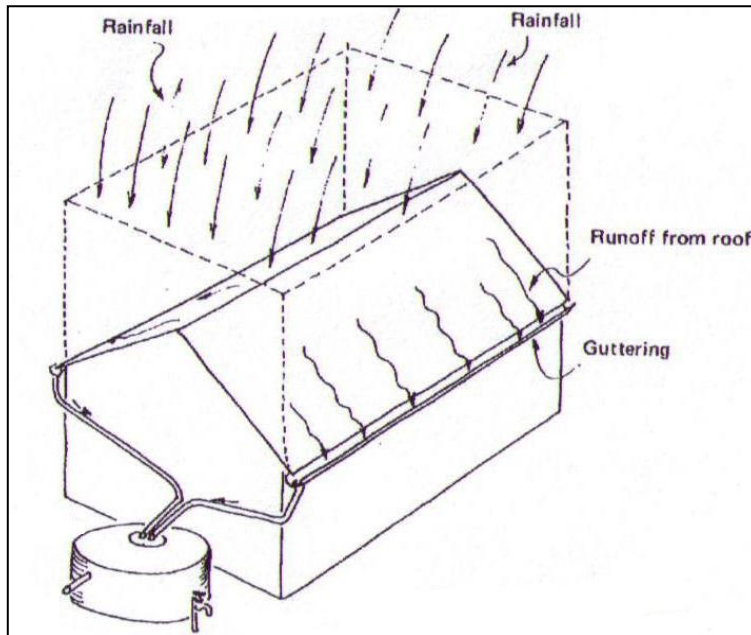
Typical runoff coefficients for various roof surfaces

Surface type	Runoff coefficient
Galvanized iron sheets ²	> 0.90, 0.80 commonly used
Asbestos sheets ²	0.80 – 0.90
Cement tile ¹	0.62 – 0.69
Glazed tile ²	0.60 – 0.90
Clay tile (machine-made) ¹	0.30 – 0.39
Clay tile (hand-made) ¹	0.24 – 0.31
Thatch ²	0.20

(¹ Zhu and Liu, 1998 and ² DTU, 2002)

To calculate the catchment area, the effective area for collecting water is not the roof area itself, but the ground area covered by the roof. A roof with a steeper slope will cover less ground area than a flatter roof even though they have the same surface area. This means that you do not use the dimensions of the roof to calculate the actual catchment

area. Instead you find the catchment area by measuring the dimensions of the ground that is actually covered by the roof.



(Watt, 1978)

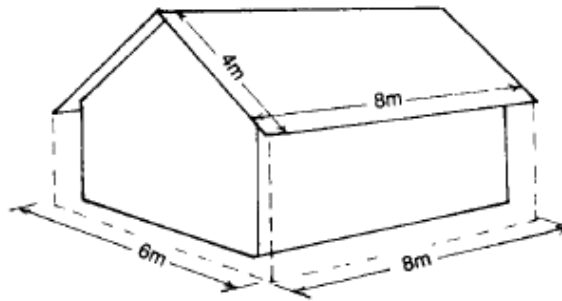
Figure: Effective roof catchment area

Self-Assessment 1

Calculating the Rainwater Runoff from a Roof Catchment

Botswana is a semi-arid country where water resources are extremely scarce in many parts. Despite the water scarcity, the mean annual rainfall ranges from about 250 to 650 mm. You are assisting in designing a rainfall catchment for a rural household to supplement their current water source and help meet their drinking water needs. The average annual rainfall in the region is about 450 mm. The roof was constructed with corrugated metal sheets and the dimensions are shown.

Use the space below to calculate the total amount of rainwater that can be collected by this roof catchment each year.



Formula: Runoff coefficient = $\frac{\text{Volume of runoff}}{\text{Volume of rainwater}}$

Solutions at the end of chapter.

5.3 Delivery System

A gutter and downpipe system is the most common way to convey runoff from household roofs to the storage tank. Guttering is usually fixed to the building just below the edge of the roof and catches water as it runs off the roof.

The ideal gutter system has the following characteristics:

- Cheap to manufacture.
- Efficient in capturing runoff.
- Easy to align and install.
- Resistant to damage.
- Simple to clean, if not completely self-cleaning (DTU, 2002).

While this seems simple enough, in reality gutters are often poorly designed and fail to deliver the water or they are designed too conservatively and are expensive to construct (DTU, 2002).

The practical considerations and realities in the field will ultimately determine the design of the gutter and downpipe system.

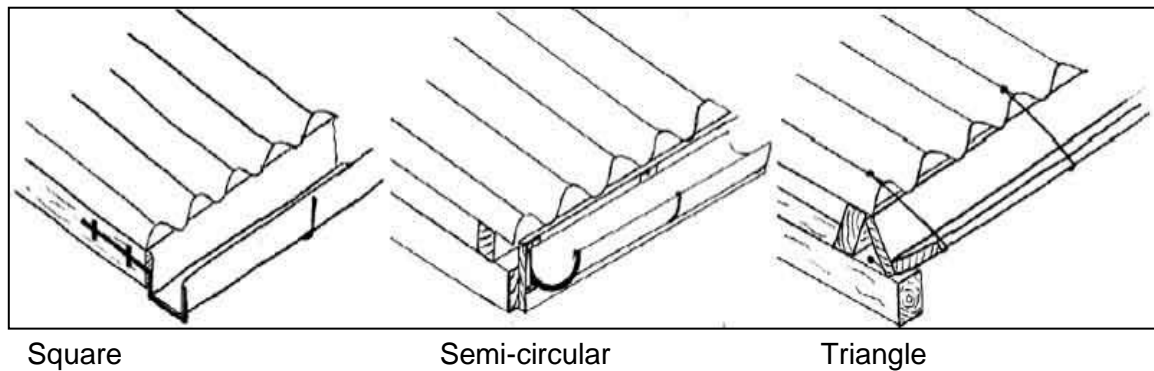
A carefully designed, properly constructed and maintained gutter system is important or any roof catchment system to operate effectively. The importance of the gutter system is often overlooked and it tends to be the weakest link in a roof catchment system. Broken gutters and pipes often result in little or no water reaching the storage tank. Regular inspection, maintenance and cleaning must be done at least once a year.

5.3.1 Material

Guttering comes in a wide variety of shapes and forms, ranging from factory made polyvinyl chloride (PVC) pipes to locally made using wood, bamboo or folded sheet metal. PVC and metal gutters are the most durable and require the least maintenance, but they are often the most expensive. Wood and bamboo gutters are often available locally and less expensive, but they require more maintenance and repair, and in the end they will not last as long.

Common gutter shapes include:

- Square
- Semi-circular
- Trapezoidal
- Triangle (45 or 90 degrees)



Square

Semi-circular

Triangle

(Rainwater Toolkit, 2005)

Figure: Typical gutter shapes

While there is some debate about the most efficient gutter shape, most properly sized gutters will capture over 90% of the rainfall runoff regardless of their shape (Still and Thomas, 2002). The most important consideration should be to use materials that are locally available and inexpensive rather than spending a lot of time and money in search of the optimum gutter material and shape.

5.3.2 Sizing

The gutter should be of sufficient size to discharge water to the tank without any overflow in the gutter. The following table provides recommended gutter widths based on field observations, lab experiments and computer simulations conducted by Still and Thomas (2002).

Table: Recommended gutter widths based on roof area

Gutter width (mm)	Roof area (m ²) served by 1 gutter
55	13
60	17
65	21
70	25
75	29
80	34
85	40
90	46
95	54
100	66

(Still and Thomas, 2002)

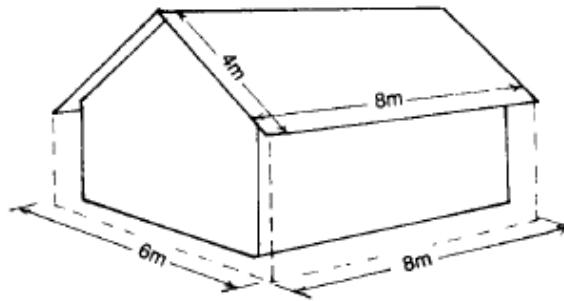
Alternatively, you can use the rule of thumb that there should be at least 1 cm^2 of gutter cross-section for every 1 m^2 of roof area (Hasse, 1989). While simpler, this generalization tends to be more conservative and can sometimes overestimate the actual size of the gutter required.

A downpipe must also be installed to channel the water from the gutter into the storage tank. The downpipe should have similar dimensions as the gutters. The simplest and most efficient downpipe consists of a straight and open extension of the gutter into the tank.

Self-Assessment 2

Sizing Gutters

You are now ready to design the gutters for the rural household in Botswana presented in Exercise 2.5-1. Use the space below to calculate the length and width of the gutters using the two methods presented.

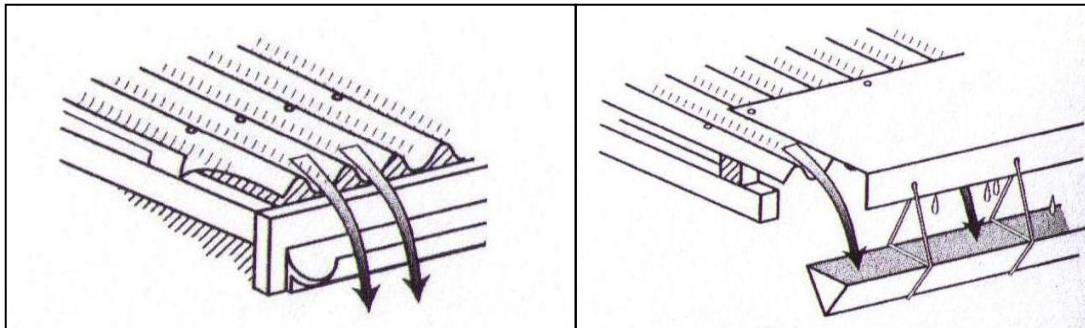


Solutions at the end of chapter.

5.4 Splash Guards

Splash guards are an option that can be incorporated into the design to prevent runoff from overshooting the gutter and spilling onto the ground. They were originally developed in Kenya for corrugated GI roofs to divert all of the runoff into the gutter and prevent any loss.

Splash guards consist of a long strip of sheet metal that is 30 cm wide, bent at an angle and hung over the edge of the roof by 2 to 3 cm. It is nailed on to the roof and the lower half is hung vertically down from the edge of the roof (Gould and Nissen-Petersen, 1999).



Water overshooting a gutter without a splash guard

Water deflected into a hanging gutter with a splash guard

(Adapted from Gould and Nissen-Petersen, 1999)

Figure: Splash guards are used to divert runoff into gutters

5.5 First Flush

Debris, dirt and dust will collect on the roof catchment area and this unwanted material will be washed into the storage tank when the first rainfall arrives. A system for diverting this “first flush” can be incorporated into the catchment design so that it doesn’t enter the tank and affect the water quality.

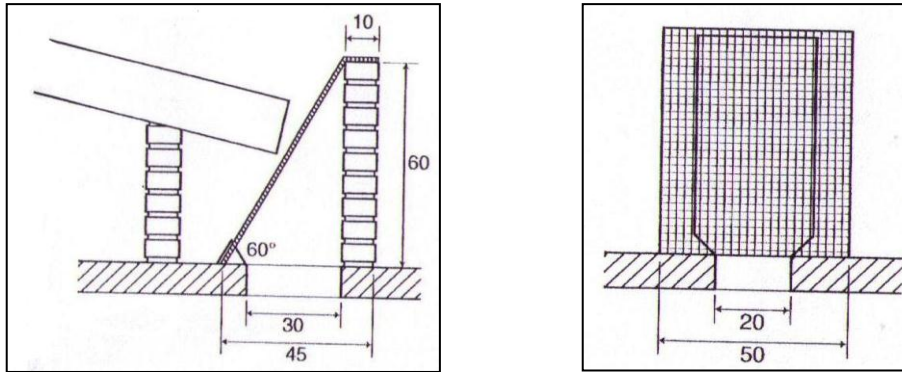
Key criteria for a good first flush device include:

- The filter should be easy to clean or self-cleaning.
- It should not block and any blockages should be obvious and easy to fix.
- It should not provide an entrance for potential water contamination.
- The cost should not be out of proportion with the rest of the catchment system.

(DTU, 2002)

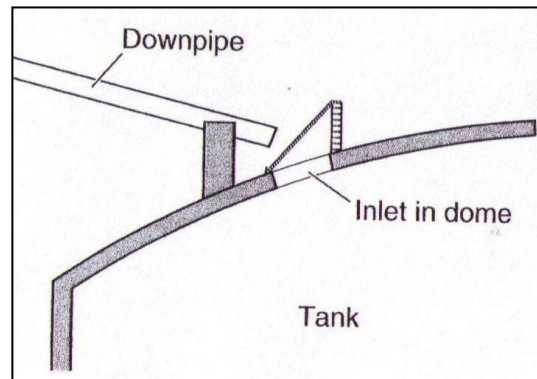
In reality, the use of first flush devices is limited in the field. There are a few simple first flush devices as well as a number of more complex systems. Many of the sophisticated designs have not been widely replicated since they require regular inspection and maintenance to function properly (Gould and Nissen-Petersen, 1999). Practitioners often recommend that very simple, easily maintained systems be used since they are more likely to be repaired if failure occurs.

The simplest method uses a self-cleaning screen at the storage tank inlet. This consists of placing the end of the downpipe about 3 cm from a mesh screen angled 60 degrees in front of the inlet hole (see Figure 2.5-5). Debris larger than the mesh is caught and rolls downward off the screen while rainwater is allowed to pass through into the tank. Periodic cleaning of the screens may be required to prevent clogging and water overflow.



Side view

Front view



Full view

(Gould and Nissen-Petersen, 1999)

Figure: Self-cleaning tank inlet (dimensions in cm)

When using a filter device, any dust or debris finer than the mesh will still flow into the tank and settle at the bottom. This can be prevented by manually moving the downpipe away from the tank inlet and then replacing it after the initial flush has passed (see Figure 2.5-7). This method relies on the user being home at the time and prepared to go out at each rainfall and move the downpipe.

The length of time needed to divert the first flush depends on the amount of debris and contamination that needs to be washed from the roof. It is recommended that at least 20 to 25 litres should be diverted to maintain water quality (Cunliffe, 1998).

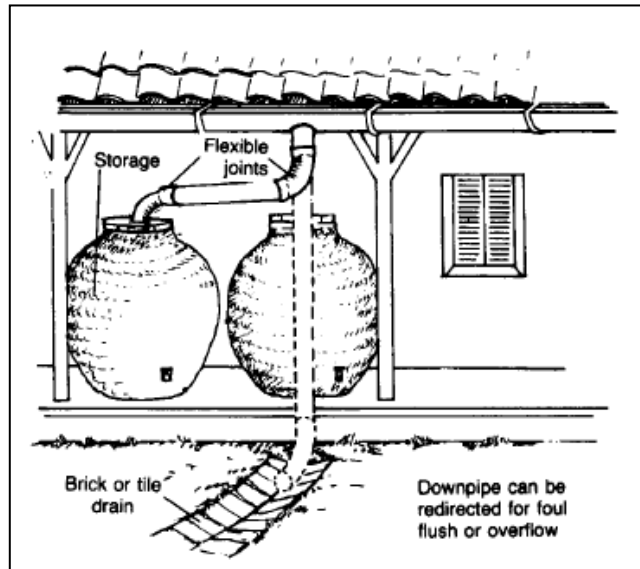


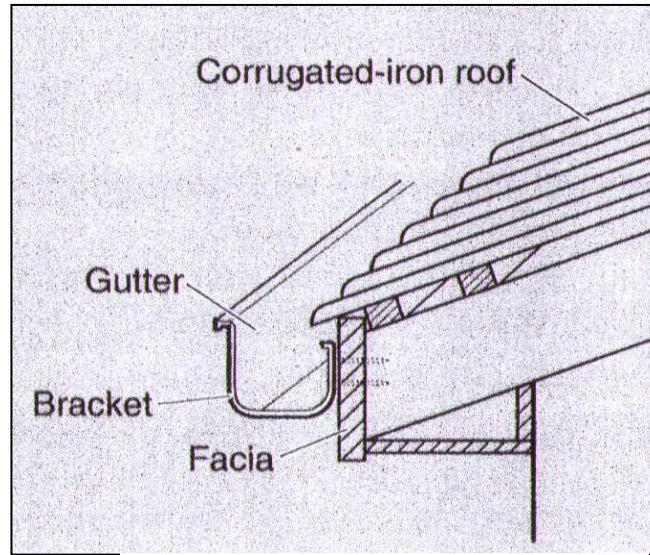
Figure: Flexible downpipe to redirect the first flush

5.6 Construction and Installation

Proper construction and installation of the gutter and downpipe system is crucial. However, particular issues are often encountered in developing countries which can make it difficult to correctly install gutters, such as the roof edge is not straight, fascia boards are frequently missing, and eaves end at a random distance from the roof edge (DTU, 2002).

While there are various ways to install the gutter system, the two most common methods used are:

1. Mounting the gutter system directly to the roof using wire hangers to suspend the gutter (see Figure 2.5-4)
2. Mounting the gutter system to the fascia board using brackets or nails (see Figure 2.5-8).



(Gould and Nissen-Petersen, 1999)

Figure: Gutter mounted to fascia board with bracket

The gutter should be directed towards the storage tank with a slope ideally between 1 and 2 percent. Gutters should not be installed flat since they tend to clog with debris and pool water that provides an ideal breeding ground for mosquitoes.

Step-by-step instructions to construct and install hanging gutters with splash guards are provided by Gould and Nissen-Petersen (1999).

5.7 Storage Reservoirs

The storage tank usually represents the largest capital cost of a rainwater catchment system. Careful design and construction are essential to provide optimal storage capacity while keeping the cost as low as possible (Rainwater Toolkit, 2005). There is a wide variety of storage tanks used around the world ranging from ready-made commercial products to locally designed and built tanks.

The following factors should be considered when selecting an appropriate tank:

- Cost
- Durability
- Transportation requirements
- Availability and suitability of construction materials and skilled labour
- Acceptability

Table: Comparison of Commercial and Locally Constructed Tanks

Commercial Tanks	Locally Constructed Tanks
Quickly erected at the site and operational within days.	On-site construction can take weeks or months to complete.
Generally constructed from durable materials, like metal, plastic and fibreglass.	Requires availability of skilled labour, construction materials and appropriate design.
Subject to economies of scale and quality control.	Voluntary or low-cost labour and construction materials may be available.
Transport costs to rural locations is often high. May be impossible to deliver tanks to certain locations.	Design can be tailor-made to meet specific local needs.
Generally more expensive than locally designed and constructed tanks.	Household and community involvement helps to develop local skills and self-reliance. More likely to properly operate, maintain and repair the system.

(Adapted from Gould and Nissen-Petersen, 1999)

5.7.1 Tank material

Storage tanks can be made from a variety of materials including:

- Reinforced concrete
- Metal
- Plastic
- Fibreglass
- Ferrocement
- Bricks and blocks

Ferrocement tanks are often used in rainwater harvesting projects in developing countries since they are:

- Strong and durable.
- Flexible and able to withstand shock better.
- Relatively inexpensive to construct.
- Can be made locally.

Ferrocement tanks vary in capacity, size and shape. They are constructed by plastering a thin layer of cement mortar onto a steel mesh for reinforcement. Coarse, clean, well-



(WEDC, n.d.)

graded sand and reinforcement mesh, as well as local builders with excellent skills are needed.

Brick and block tanks are also widely used in developing countries since they are often simpler and cheaper to build. The materials are found locally and people can make the bricks themselves from a variety of materials including burned clay, cut stone or stabilized soil. However, brick tanks tend to have poor strength and can require more cement to construct than an equivalent ferrocement tank.



(DTU, 2000)

Figure: Brick jar under construction in Uganda

Organic materials, such as bamboo, sisal fibres or sticks, *should not* be used for reinforcement of water tanks. These materials were promoted in the early 1980s as low-

cost, appropriate technology and used in tank designs in South-east Asia and East Africa. It was discovered that they rotted easily and were not durable over time.

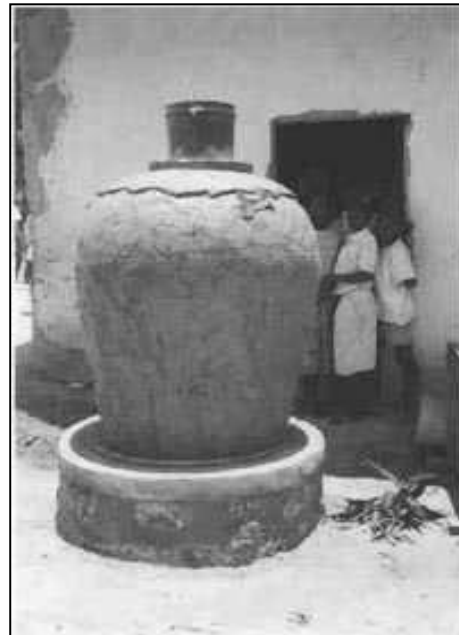
5.7.2 Shape, size and dimensions

Selecting an appropriate shape for the storage tank can optimize the use of materials and increase its wall strength. As a general rule, tanks should ideally be cylindrical or spherical since they are stronger and require less material to construct than cube shaped tanks.

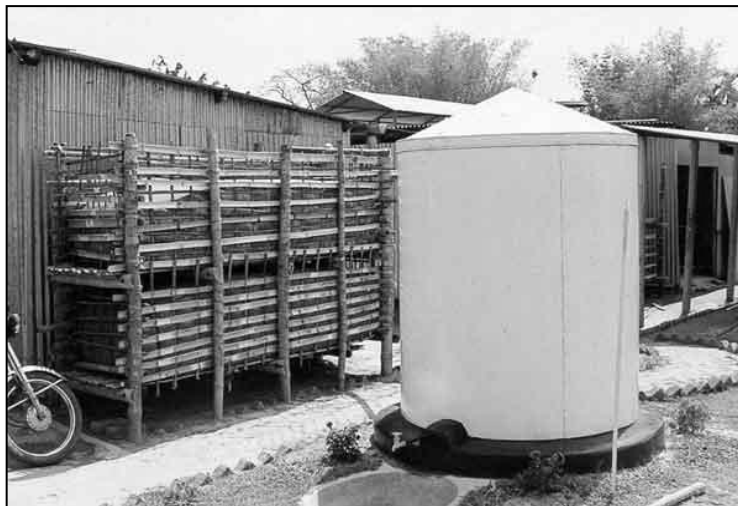
The tank should also be reasonably well proportioned to maximize the storage volume while minimizing the cost. Tall tanks with narrow widths and very low tanks with large diameters require more materials and cost more to construct.



*Spherical pumpkin tank design in Sri Lanka
(ITDG South Asia, n.d.)*



*Ferrocement jar in Tanzania
(DTU, n.d.)*



*Cylindrical metal tank in Bangladesh
(Rainwater Toolkit, 2005)*

Unless extra reinforcement is added, the height of storage tanks should not be taller than 2 m to prevent collapse.

The capacity of the storage tank is determined by the water supply and demand by the household. Refer to Module 2.3 Water Supply and Demand for the steps to determine the appropriate volume of the storage tank.

Self-Assessment 3

Calculating the Dimensions of Different Tank Shapes

Assume that you are designing a storage tank that is 2 m high to hold 8 m³ of rainwater. You are debating between using a cylindrical and cube shaped tank. To help reduce your costs you want to figure out which one will use the least amount of construction materials (i.e. you need to find the surface areas).

Use the space below to calculate the surface area for the two tank shapes. Which shape has the lowest surface area and requires less construction material?

Formulas:

Where: r = radius

h = height

$\pi = 3.14$

Volume of a cylinder = $\pi r^2 h$

Surface area of a cylinder = $2\pi r^2 + 2\pi r h$

Volume of a cube = side x side x side

Surface area of a cube = 6 x side x side

Tip - How to Calculate the Surface Area:

Step 1 – Use the volume formula to calculate the radius or the side dimensions for each shape.

Step 2 – Substitute the radius or side dimensions into the surface area formula for each shape.

Continue working on next page.

Self-Assessment 3 (cont'd)

Solution found in Self Check at the end of this module.

5.8 Surface and Sub-surface Tanks

The following points should be considered when deciding to construct a tank above or below ground.

Advantages:

Surface tanks	Sub-surface tanks
Allows for easy inspection for cracks or leakage.	Surrounding ground gives support allowing for lower wall thickness resulting in lower construction costs.
Water can be withdrawn using a tap.	Unobtrusive and requires little or no space above ground.
Can be raised above ground level to increase water pressure.	Does not lose water supply if the pump breaks down.
Can be drained for cleaning.	Water is stored at a cooler temperature.

Disadvantages:

Surface tanks	Sub-surface tanks
Requires space.	More difficult to withdraw water.
Generally more expensive.	Difficult to detect leaks or failures.
More easily damaged.	Possible contamination from groundwater or flooding.
Exposed to weather conditions.	Structure can be damaged by tree roots or rising groundwater.
Failure can be dangerous.	Children or animals can fall into tank.
Quickly loses water supply if tap breaks down.	Cannot be easily drained for cleaning.

(Adapted from Rainwater Toolkit, 2005)

5.9 Tank Roof or Cover

Roofs or covers play an important role in maintaining water quantity and quality in a storage tank by:

- Preventing water from evaporating away.
- Reducing the risk of contamination by preventing insects, reptiles and birds from entering the tank and preventing algae to grow in the stored water.

The two most common tank roof options are:

- Flat roof built from reinforced concrete.
- Domes constructed from ferrocement.

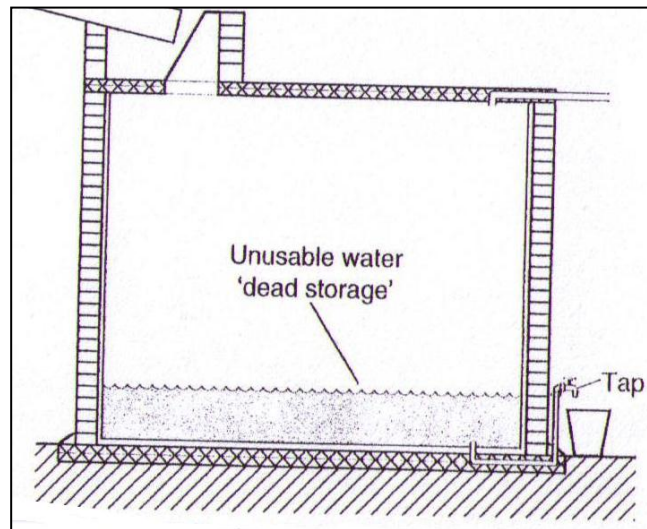
Materials for the two types of roofs cost about the same. The flat roof has the advantage of being easier to construct, whereas the dome roof has the advantage of being able to store water which reduces the size and cost of the tank.

5.10 Water Extraction

Some sort of device is needed to withdraw the water from the storage tank. A user friendly and properly functioning water extraction device is essential for any roof catchment system to operate effectively. Taps are generally used on surface tanks and pumps used where water needs to be lifted from a sub-surface tank.

Broken pumps or taps often make the system useless and defeats the purpose of collecting the rainwater in the first place. A dripping or leaking tap can lose thousands of litres of rainwater and quickly empty an average sized tank. Communal taps are more prone to breakdown than individually owned ones because they are used more frequently and there is less accountability for its maintenance. It is worth spending money on a good quality tap which has a better chance of lasting over the long-term.

The proper placement of the tap on surface tanks is important to avoid dead storage (i.e. impossible to draw water from the part of the tank that is below the level of the tap. See Figure 2.5-9). To avoid this from happening, the tap must be positioned below the floor level of the tank. There are two ways to do this: either the foundation of the tank is elevated around 50 cm above ground level (enough space for a bucket to fit under) or the tap is constructed below the ground level (See Figure 2.5-10). A soak away pit should also be constructed at the tap stand to prevent water from eroding the base of the tank (Gould and Nissen-Petersen, 1999).



(Gould and Nissen-Petersen, 1999)

Figure: Dead storage should be avoided in a water tank

The major advantage that sub-surface tanks with pumps have is that they will not quickly empty if the pump breaks. However, pumps require careful operation and regular maintenance, which is often neglected in rural areas and results in the pump breaking down.

A rope and bucket to withdraw water is also used in many rural areas of developing countries. There is a risk of secondary contamination using this method which can be reduced by using dedicated bucket and windlass to prevent the rope from touching the ground.

5.10.1 Draw-off and wash-out pipe

A wash-out pipe helps in cleaning the tank and should be included in the tank design. To save costs, the draw-off pipe can serve a dual purpose and also be used as the wash-out.

The draw-off pipe should be raised 5 cm above the floor of the tank to prevent dust, sediment and other debris from entering the pipe. Although this design creates a 5 cm dead storage space at the bottom of the storage tank, it has three benefits:

- It prevents sludge on the floor from reaching the outlet tap and protects the water quality.
- It ensures that some water remains in the tank which keeps it moist and protects the tank from cracking in hot weather.
- It allows the pipe outlet to be used as a wash-out where sludge can be removed with wire.

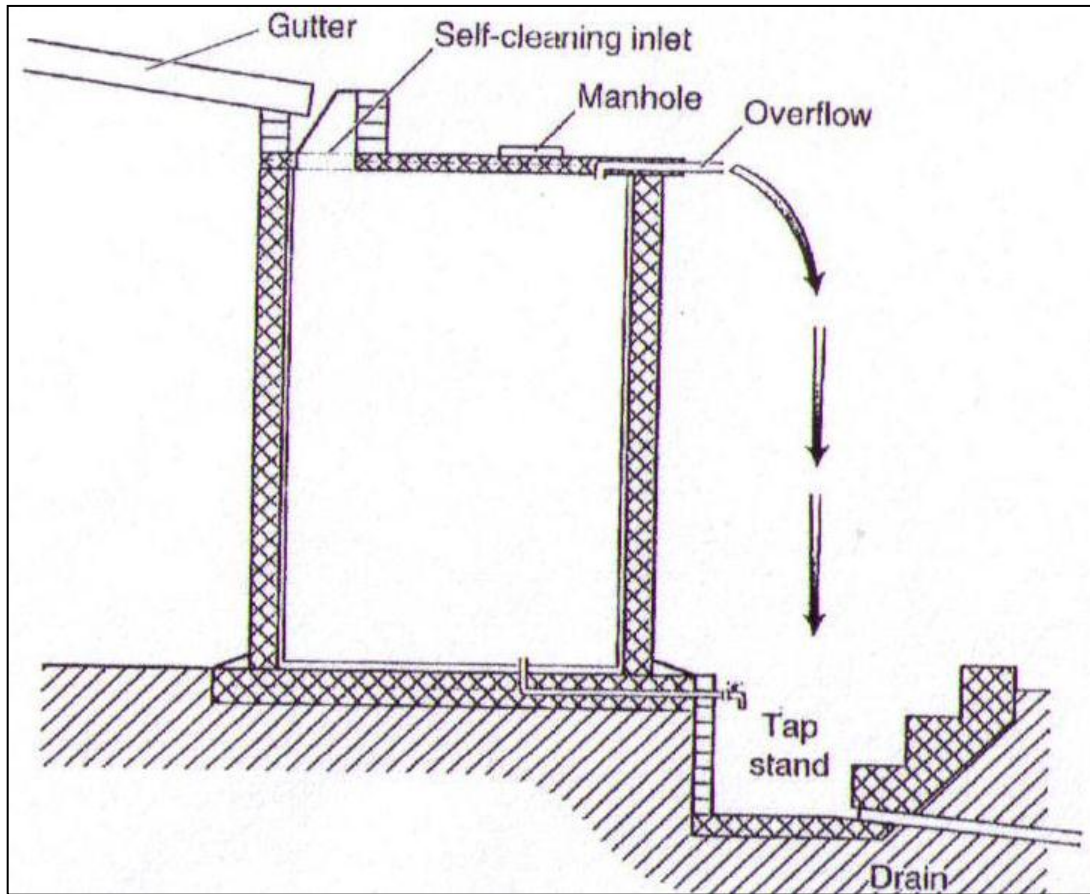
5.10.2 Overflow

An overflow pipe is required in case if more water than the holding capacity flows into the tank. The bottom of the overflow pipe should be placed at the maximum water level of the tank to prevent any additional dead storage. As shown in Figure 2.5-10, it should

also be placed vertically over the tapstand to force water to fall on to the soak away pit (Gould and Nissen-Petersen, 1999).

5.10.3 Access

A manhole and internal ladder can be included in the design to give access into a roofed tank to aid with cleaning and repairs.



(Gould and Nissen-Petersen, 1999)

Figure: Proper water tank design

5.11 Sitting

Tanks should never be located near toilets or pit latrines. They should also be located away from any waste disposal facility or other source of pollution or contamination which can affect the water quality.

Sites where substantial surface runoff may occur during heavy rainfall should be avoided since the soil can erode the foundations of the tank. If this is an issue, bunds or drains could be constructed to divert runoff away from the base of the tank.

The tank should also be convenient for the household to access and not block frequently used areas.

5.12 Construction and Installation

Detailed step-by-step instructions to construct the following tank designs are provided by Gould and Nissen-Petersen (1999) in Appendix 5. The materials and methods recommended have proven to be effective over two decades of application in the field.

- Ferrocement jar (3 m³)
- Concrete in-situ tank (5 m³)
- Burnt brick tank (10 m³)
- Ferrocement surface tank (11 m³)
- Ferrocement surface tank (23 m³)
- Ferrocement surface tank (46 m³)
- Hemispherical sub-surface tank (90 m³)

There are also numerous other texts and manuals describing how to construct a water storage tank, some of which are listed in the Additional Resources section of this module.

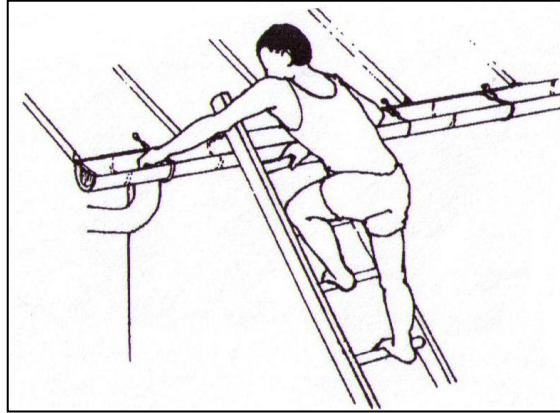
Anyone interested in building a tank should compare a number of designs and methods when deciding which option to select. It is also important to avoid designs that have proved unsuccessful in the past. Several texts and manuals, especially those written in the 1980s, provide design drawings for tanks that use organic materials for reinforcement. As previously discussed, these tanks have not proven to be durable and failed over time.

5.13 Operation and Maintenance

Regular inspection, cleaning, maintenance and occasional repairs of all system components ensure that the maximum amount of good quality rainwater is collected. The following tasks should be done at least once a year to keep the catchment well-maintained:

- Keep the roof in good condition. Repair any holes in the roofing material and replace any broken tiles to prevent leaking. Seal any nail holes that are leaking.
- Clean the roof between rainfalls. Debris and excrement from birds and small animals can be removed by sweeping the roof often.
- Keep the gutters in good condition. Be sure that they are firmly fixed to the roof and that they are joined to prevent spilling. Repair any holes in the gutter to prevent leaking. Check bamboo or wood gutters once a year for rotting. Replace them if there is any sign of rot.
- Periodically remove leaves and other debris from the gutters to avoid clogging and water overflow.
- Periodically clean any screens to prevent clogging and water overflow.
- Regularly inspect pumps and taps to ensure that they are not broken or leaking. A leaking tap can quickly lose thousands of litres and drain a surface tank. Any leaks should be fixed immediately.
- Regularly check tanks for any cracks and holes. Any leaks should be repaired immediately. Tanks should also be cleaned out from time to time.

(A maintenance and troubleshooting guide is available in Appendix B.)



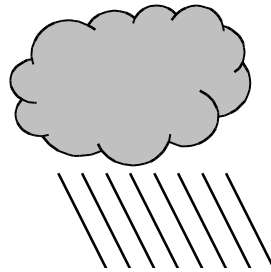
(US AID, n.d.)

Figure: Cleaning the gutters and screens

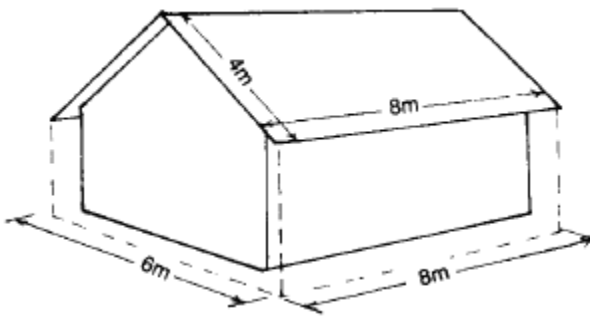
Summary of Key Points

- There are various configurations of roofing materials, delivery systems and storage reservoirs that can be used in a roof catchment system.
- Most of the common designs, if properly constructed with good-quality materials, are effective.
- The local availability of suitable materials and skilled labour should be considered when selecting an appropriate design.
- A runoff coefficient of 0.80 is commonly used for a well-designed roof and gutter system.
- A gutter system is the most common way to convey runoff from household roofs to the storage tank.
- Gutters are often the weakest link in the rainwater catchment system. They must be appropriately designed and properly constructed and installed to be effective.
- There is a wide variety of surface and sub-surface storage tanks ranging from ready-made commercial products to locally designed and built tanks.
- The main components for an effective storage tank design include:
 1. A functional and watertight tank with a roof or cover.
 2. A screened inlet, overflow pipe, soak away pit, and covered manhole.
 3. A water extraction system which protects water quality.
- Storage tanks should have a maximum height of 2 m (unless additional reinforcement is used).
- Organic materials such as bamboo and sisal fibres should not be used for the construction of water tanks.
- Cylindrical or spherical tanks are stronger and more cost effective than cube shaped tanks.
- Tanks should be sited to avoid risks of contamination from pollution sources or damage by erosion.
- **Regular inspection, cleaning, maintenance and occasional repairs of all system components ensure the maximum amount of good quality rainwater is collected.**

Solutions for self-assessment 1



450 mm/year = 0.45 m/year



First of all, let's calculate the catchment area. Remember that the effective roof area for collecting water is not the roof area itself, but the ground area covered by the roof

$$\begin{aligned}\text{Catchment area} &= 6 \text{ m} \times 8 \text{ m} \\ &= 48 \text{ m}^2\end{aligned}$$

Now let's calculate the total amount of rain that will fall on the catchment area:

$$\begin{aligned}\text{Volume of rainwater} &= 0.45 \text{ m/year} \times 48 \text{ m}^2 \\ &= 21.6 \text{ m}^3/\text{year}\end{aligned}$$

Assuming a runoff coefficient of 0.80, we can use the runoff coefficient formula to figure out how much of the rainwater that falls on the catchment area will actually flow into to the storage tank:

$$\begin{aligned}\text{Runoff coefficient} &= \frac{\text{Volume of runoff}}{\text{Volume of rainwater}} \\ 0.80 &= \frac{\text{Volume of runoff}}{21.6 \text{ m}^3/\text{year}} \\ \text{Volume of runoff} &= 17.28 \text{ m}^3/\text{year}\end{aligned}$$

Solutions for self-assessment 2

The gutter length equals the length of the roof section.

Gutter length = 8 m

There are two ways to calculate the width of the gutters. For both of the methods we need to first calculate the roof area that is served by 1 gutter.

Total roof area = 6 m x 8 m
= 48 m²

Roof area served by 1 gutter = 48 m² / 2
= 24 m²

The first method uses Table 2.5-2 to determine the gutter width based on the roof area.

Reading from Table 2.5-2, it is estimated that a 24 m² roof area will require a gutter width of about 70 mm or 7 cm.

The second method uses the rule of thumb that there should be at least 1 cm² of gutter cross-section for every 1 m² of roof area.

24 m² roof area = 24 cm² gutter cross-section

The actual width and height dimensions will depend on the gutter shape that is chosen and local materials that are available. Let's assume a square shaped gutter is going to be constructed locally from sheet metal. The gutter dimensions can be various width and height combinations that equal 24 cm².

Gutter dimensions = 6 cm width x 4 cm height or
= 8 cm width x 3 cm height

In the end, both methods give similar dimensions for the gutter size and they should be considered as guides for actual construction in the field.

Solutions for self-assessment 3

Let's calculate the surface area of the cylinder by first using the volume formula to determine its radius.

Volume of a cylinder = $\pi r^2 h$

$$8 \text{ m}^3 = 3.14 \times r^2 \times 2\text{m}$$

$$r^2 = 8 / 3.14 / 2\text{m}$$

$$r^2 = 1.27 \text{ m}^2$$

$$r = 1.13 \text{ m}$$

Now substitute the radius into the surface area formula.

Surface area of a cylinder = $2\pi r^2 + 2\pi r h$

$$= (2 \times 3.14 \times (1.13 \text{ m})^2) + (2 \times 3.14 \times 1.13 \text{ m} \times 2 \text{ m})$$

$$= 8.02 + 14.19$$

$$= 22.21 \text{ m}^2$$

Next let's calculate the surface area of the cube. We can do this directly by substituting the height into the surface area formula since there is only one variable. For a cube, all sides are the same length so we know that they each equal 2 m.

Surface area of a cube = $6 \times \text{side} \times \text{side}$

$$= 6 \times 2\text{m} \times 2\text{m}$$

$$= 24 \text{ m}^2$$

Therefore, the cylinder has the lowest surface area (22.21 m^2) compared to the cube (24 m^2) and will require less construction material.

Solutions for self-assessment 4

1. A runoff coefficient greater than 0.90 can be achieved for a well-designed roof and gutter system. However, a runoff coefficient of 0.80 is more commonly used to account for occasional water losses due to gutter overflow during intense rainfalls or from temporary blockages by debris.
2. Unless extra reinforcement is added, the height of storage tanks should not be taller than 2 m to prevent collapse.
3. Gutters tend to be the weakest link in a roof catchment system.
4. False. Ferrocement tanks are constructed by plastering a thin layer of cement mortar onto a steel mesh for reinforcement and require experienced skilled labour.
5. True. Organic materials, such as bamboo, sisal fibres or sticks, should not be used for reinforcement of water tanks. These materials rot easily and are not durable over time.
6. The following factors should be considered when selecting an appropriate tank:
 - Cost
 - Durability
 - Transportation requirements
 - Availability and suitability of construction materials and skilled labour
 - Acceptability
7. The main components for an effective storage tank design include:
 - A functional and watertight tank with a roof or cover.
 - A screened inlet, overflow pipe, soak away pit, and covered manhole.
 - A water extraction system which protects water quality.
8. Tanks should never be located near toilets or pit latrines. They should also be located away from any waste disposal facility or other source of pollution or contamination which can affect the water quality. Sites where substantial surface runoff may occur during heavy rainfall should be avoided since the soil can erode and undermine the foundations of the tank. The tank should also be convenient for the household to access and not block frequently used areas.

5.14 Additional Resources

Domestic Roofwater Harvesting Research Programme, Development Technology Unit, School of Engineering, University of Warwick, U.K.

The DTU Technical Release Series provides instructions on construction methods for various storage tank designs including:

- Brick jars (TR-RWH07)

- Ferrocement jars (TR-RWH06)
- Thin-shell ferrocement tank covers (TR-RWH04)
- Partially below ground tanks (TR-RWH01)
- Mortar jars (TR-RWH10)

Available at: www.eng.warwick.ac.uk/DTU/pubs/rwh.html#tr

Ferrocement Water Tanks (WEDC, n.d.)

Technical brief that describes different methods and simplified stages of constructing a ferrocement tank.

Available at: www.lboro.ac.uk/well/resources/technical-briefs/36-ferrocement-water-tanks.pdf

Ferrocement Water Tanks and Their Construction (Watt, 1978)

This handbook describes for field workers how to construct ferrocement water storage tanks up to 150 m³ in capacity. While the book is dated, it covers very well the basic principles, practice and theory behind this technique.

Available from publisher.

5.15 References

Cunliffe, D. (1998). Guidance on the Use of Rainwater Tanks. National Environmental Health Forum Monographs, Water Series 3, Public and Environmental Health Service, Department of Human Services, Australia, 28p. Cited in Gould and Nissen-Petersen, 1999.

Development Technology Unit. (1999). Report A1 – Current Technology for Storing Domestic Rainwater. Project Report, Domestic Rainwater Harvesting in the Humid Tropics. ERB 1C18-CT98-0276. School of Engineering, University of Warwick, U.K. Available at:

www.eng.warwick.ac.uk/DTU/rainwaterharvesting/index.html

Development Technology Unit. (2000). Brick Jars Instructions for Manufacture, Technical Release Series TR-RWH07. School of Engineering, University of Warwick, U.K. Available at: www.eng.warwick.ac.uk/DTU/pubs/rwh.html#tr

Development Technology Unit (DTU). (2002). Very Low Cost Domestic Roofwater Harvesting in the Humid Tropics: Existing Practice. Report R1, DFID KAR Contract R7833. School of Engineering, University of Warwick, UK. Available at: www.eng.warwick.ac.uk/DTU/rwh/dfidocs/r1.pdf

Gould, J. and Nissen-Petersen, E. (1999). Rainwater Catchment Systems for Domestic Supply: Design, Construction and Implementation. ITDG Publishing, Rugby, UK.

Rainwater Toolkit. (2005). Available at: www.rainwater-toolkit.net/index.php?id=47

Still, G. and Thomas, T. (2002). The Optimum Sizing of Gutters for Domestic Roofwater Harvesting. Development Technology Unit, School of Engineering,

University of Warwick, U.K. Available at:
www.eng.warwick.ac.uk/DTU/pubs/wp/wp56/wp56.pdf

US Agency for International Development (AID). (n.d.). Water for the World. Constructing, Operating and Maintaining Roof Catchments, Technical Note No. RWS. 1.C.4. Available at: www.lifewater.org/resources/rws1/rws1c4.pdf

Watt, S. (1978). Ferrocement Water Tanks and Their Construction. Intermediate Technology Publications, London, U.K.

Zhu, Q. and Liu, C. (1998). Rainwater Utilization for Sustainable Development of Water Resources In China. Paper presented at the Stockholm Water International Symposium, Stockholm, Sweden, 8p. Cited in Gould and Nissen-Petersen (1999).

6 Rainwater Quality



(Resource Development International Cambodia, n.d.)

Learning Expectations

In this module you will learn about various rainwater quality issues, including:

- Potential sources of rainwater contamination.
- Preventative measures to protect water quality.
- Treating stored water using household technologies.
- Perceptions of rainwater quality aesthetics

6.1 Introduction

The issue of water quality is complex and sometimes controversial because rainwater does not always meet WHO or national drinking water standards, especially with respect to bacteriological water quality.

While rainwater quality may not always reach these standards, when compared with most unprotected, traditional water sources, rainwater provides an improved water supply for millions of households around the world. The combination of a rainwater catchment system paired with a household water treatment technology further offers a significantly improved supply of safe drinking water.

The chemical and physical quality of stored rainwater is normally high and relatively easy to maintain. The bacteriological quality of stored rainwater is usually the main concern since water tanks will generally contain a range of microorganisms from one or more sources. However, except to the severely immunocompromised, these organisms are not considered to represent a significant health risk through normal uses of drinking water supplies (WHO, 2002) and reports of illness associated with roof rainwater tanks are relatively infrequent (Government of Australia, 2004; Gould and Nissen-Petersen, 1999).

Is Rainwater Safe to Drink?

Rainwater collected from a roof catchment is probably safe to drink untreated and unlikely to cause any illness for most users, providing that the rainwater is clear, has little taste or smell and is from a properly designed and well-maintained system.

Rainwater collected from a ground catchment system is usually of poor quality due to contamination from children and animals and is not recommended for drinking without treatment.

Those who are immunocompromised such as the very young or very old, cancer patients, people with diabetes, organ transplants, or those who are HIV positive should consider treating rainwater before drinking.

(Government of Australia, 2004)

6.2 Sources of Rainwater Contamination

Except in heavily urbanized and industrialized areas or regions adjacent to active volcanoes, atmospheric rainwater is very pure and any contamination usually occurs after the water contacts the catchment system.

The types and potential sources of contaminants that may be found in collected and stored rainwater are summarized in Table 2.6-1.

Types and sources of rainwater contamination

Contaminant	Potential Sources	Health Risk
Pathogens such as bacteria, viruses and protozoa	<ul style="list-style-type: none"> • Roof catchments: Bird or animal faeces. • Ground catchments: Human, bird or animal faeces. 	<ul style="list-style-type: none"> • Greatest water quality concern. • Roof catchments: Reports of illness are infrequent. • Ground catchments: Usually poor water quality and should be treated before drinking.
Dust and ash	<ul style="list-style-type: none"> • Volcanic activity • Bushfires. 	<ul style="list-style-type: none"> • Does not pose a health risk. • Can affect turbidity, taste and colour.
Heavy metals (e.g. lead, copper, zinc, manganese, cadmium)	<ul style="list-style-type: none"> • Old roofs constructed with lead flashing and lead based paint. • Severe air pollution in urban areas from industry and vehicles. 	<ul style="list-style-type: none"> • Serious contamination is rare under normal circumstances. • Risk is minimized by avoiding lead flashing and lead based paint.
Sulphur dioxide (SO ₂), nitrogen oxides (NO and NO ₂), hydrocarbons	<ul style="list-style-type: none"> • Air pollution in urban areas from industry and vehicles. 	<ul style="list-style-type: none"> • Increasing concern in urban areas. • Insignificant risk in rural areas.
Pesticides and herbicides	<ul style="list-style-type: none"> • Agricultural practices, such as spraying and crop dusting. 	<ul style="list-style-type: none"> • Increasing concern in areas of intensive farming.
Asbestos	<ul style="list-style-type: none"> • Old roofing materials. 	<ul style="list-style-type: none"> • Although asbestos fibres are dangerous to inhale, it is not believed that asbestos in drinking water poses a health risk.
Mosquito larvae	<ul style="list-style-type: none"> • Mosquitoes laying eggs in gutters, tanks or ground catchments. 	<ul style="list-style-type: none"> • Particular concern in tropical areas where mosquitoes act as vectors for diseases, such as dengue fever, yellow fever and malaria. • Risk minimized by using tank inlet screens and not allowing water to pool in gutters.

(Gould and Nissen-Petersen, 1999; Government of Australia, 2004; Mosley, 2005)

The Effects of Acid Rain

Acid Rain is caused by the emission of sulphur dioxide and nitrogen oxides into the atmosphere. The sulphur dioxide and nitrogen oxides react with the oxygen in the air to create sulphuric acid. Generally acid rain is defined as any type of precipitation with a pH that is unusually low.

Sulphur dioxide is readily produced from industrial smelters and coal burning plants whereas nitrogen oxides are readily released from car exhaust systems. Hence in areas such as Brazil, India, China, and South-east Asia, acid rain is becoming an increasing problem since these areas, along with their increasing populations, are dependent on coal-based economies.

Despite the concerns of atmospheric pollution however, the contamination levels of natural rainfall remain low. (Gould and Nissen-Petersen, 1999).

6.3 Protecting Rainwater Quality

The best way to protect rainwater quality is through prevention by ensuring a good system design and proper operation and maintenance. The following simple precautionary measures can significantly reduce the likelihood of microbial or chemical contamination of the rainwater supply.

- Collect and store rainwater so that contamination from human, chemical or animal sources is minimized. If possible, store drinking water in an above-ground tank rather than in an underground tank to avoid contaminated groundwater seeping into the tank.
- Ensure that surface runoff, channel water, irrigation water, leakage from sewer pipes or sanitation facilities, or shallow underground seepage cannot enter the drinking water supply.
- Do not collect water for drinking from recently painted roofs, wood roofs preserved with chemicals, roofs coated with lead-based paints or tar-based coatings, or parts of roofs near flues from solid wood heaters. Most other roof types will normally be safe for water collection, provided they are kept clean.
- Regularly clean the roof and gutters to remove leaves, animal or bird remains, dust and other debris.
- Prune overhanging branches from trees away from the roof.
- Screens should cover all inlets to prevent any insects, frogs, toads, snakes, small animals and birds from entering the water tank.
- The first rainfall after a dry period usually collects most of the contaminants on the roof. Installing a 'first flush' device will prevent this water from entering the water tank.
- If the house is over sprayed by aerial chemical spraying for nearby farms, divert the collection pipe from the rainwater tank to prevent any pesticides from entering the tank. Clean the roof or wait until after the next rainfall before reconnecting the pipe.
- Keep the tank covered to exclude all light and prevent the growth of algae and microorganisms.

- Regularly clean and maintain the water tank and remove accumulated sludge from the bottom.

(Adapted from State Government of Victoria, 2005)

If all reasonable measures are taken, the water quality should not deteriorate in the tank. Rather than becoming stale with extended storage, rainwater quality usually improves over time provided that light and living organisms are excluded from the tank and inflows do not stir up any sediment (Gould and Nissen-Petersen, 1999).

In the absence of hygienic and safe handling practices, rainwater supplies can be subjected to secondary contamination during storage, transportation from tank to household, and during use. Any rainwater harvesting project must have a hygiene and sanitation education component to ensure its long-term success. The following modules provide further information about these topics (Note these references may no longer be valid):

- Module 1.4 Sanitation
- Module 1.5 Hygiene
- Module 1.9 Safe Storage of Water

6.4 Treating Stored Rainwater

The combination of a rainwater catchment system paired with a household water treatment technology offers a significantly improved supply of safe drinking water.

There are several affordable water treatment technologies that have been developed and proven for use in households.

Module 1.8 explains the following water treatment processes, their pros and cons, and the best application for each process.

- Sedimentation
- Filtration
- Disinfection

Rainwater Harvesting and the Biosand Filter Together in Uganda

Although Uganda is known in East Africa for its green landscape and two wet seasons, there is also a dry season when many of the drinking water sources dry up partially or completely. The Village Health Project is planning to pair rainwater collection tanks with the biosand filters as an efficient and economical way to provide clean water year-round to rural Ugandan communities.

(Village Health Project, n.d.)

6.5 Testing Rainwater Quality

Testing the quality of stored rainwater is generally not practical or feasible in developing countries, and as a result, it is not a common practice. If testing is possible, the main focus should be on microbial testing since this is the main water quality concern. Module 1.7 provides further information on water quality testing and analysis.

Given the current lack of testing of rainwater quality, it is essential that households are provided with sufficient awareness, education and training on the importance of maintaining their storage tanks to ensure good quality water.

6.6 Rainwater Quality Aesthetics

Taste plays a major role in the acceptance of rainwater. The absence of a distinctive taste or odours is a feature of good quality rainwater (Government of Australia, 2004). Countries with a long and successful history of rainwater harvesting, such as China and Thailand, often prefer drinking rainwater to other sources since it is normally clear and sweet tasting. However, in some parts of the world, mud, bark, leaves and other flavourings are sometimes added to rainwater to improve its taste (Pacey and Cullins, 1986). In Nepal, people living in rural areas will try to avoid using rainwater that has been stored overnight since they believe that it is stale compared to flowing water (UNEP IETC, n.d.).

The lack of taste is also sometimes perceived to be a sign of poor quality and people are reluctant to drink rainwater. People in rural Sri Lanka prefer to use groundwater supplies and rainwater is not widely accepted as a good drinking water source. Rainwater tends to only be used for drinking in parts of the country where the groundwater is mineralized or too saline (Ariyananda, 2001).

Doubts about rainwater quality may be put to rest if the rainwater catchment system is paired with a household water treatment technology. While treating the water will not add any minerals or taste, people can be assured that the water is safe to drink despite the lack of taste.



(Shaw, 2005)

Summary of Key Points

- While rainwater quality may not always meet WHO or national drinking water standards, when compared with most unprotected, traditional sources, rainwater usually provides an improved water supply.
- Rainwater collected from a roof catchment is probably safe to drink untreated and unlikely to cause any illness for most users, providing that the rainwater is clear, has little taste or smell and is from a properly designed and well-maintained system.
- Rainwater collected from a ground catchment system is usually of poor quality due to contamination from children and animals and is not recommended for drinking without treatment.
- The combination of a rainwater catchment system paired with a household water treatment technology offers a significantly improved supply of safe drinking water.
- While there is a degree of microbial contamination in rainwater tanks, reports of illness or disease outbreaks from roof water sources are rare.
- Chemical and physical quality of stored rainwater is normally high. Care should be taken to avoid any possible sources of lead or heavy metals in the roofing materials.
- Rainwater tanks can provide breeding sites for mosquitoes, which in some regions act as vectors for diseases such as dengue fever, yellow fever and malaria. Important to make sure that tank inlets are screened to prevent mosquitoes from laying eggs in the water.
- Good system design, operation and maintenance are essential to protect water quality. Precautionary measures can significantly reduce the likelihood of microbiological or chemical contamination of the rainwater supply.
- Any rainwater harvesting project must have a hygiene and sanitation education component to minimize secondary contamination of water supplies.
- The absence of a distinctive taste or odours is a feature of good quality rainwater. However, the lack of taste is sometimes perceived to be a sign of poor quality and people may be reluctant to drink rainwater.

Solutions

1. True. Rainwater collected from a roof catchment is probably safe to drink untreated and unlikely to cause any illness for most users, providing that the rainwater is clear, has little taste or smell and is from a properly designed and well-maintained system.

2. False. Rainwater collected from a ground catchment system is usually of poor quality due to contamination from children and animals and is not recommended for drinking without treatment.

3. The chemical and physical quality of stored rainwater is normally high and relatively easy to maintain. The bacteriological quality of stored rainwater is usually the main concern since water tanks will generally contain a range of microorganisms from one or more sources.

4. Roof catchments: Bird droppings, small animal faeces.

Ground catchments: Bird droppings, animal faeces, human faeces (usually from children playing in the area).

5. Some precautionary measures to protect water quality include:

- Regularly cleaning the roof and gutters to remove leaves, animal or bird remains, dust and other debris.
- Pruning overhanging branches from trees away from the roof.
- Covering all tank inlets with screens.
- Installing a 'first flush' device.
- Keeping the tank covered to exclude all light and prevent the growth of algae and microorganisms.

Regularly cleaning and maintaining the water tank and removing accumulated sludge from the bottom.

6. Rainwater tanks can provide breeding sites for mosquitoes, which in some regions act as vectors for diseases such as dengue fever, yellow fever and malaria. Important to make sure that tank inlets are screened to prevent mosquitoes from laying eggs in the water.

6.7 Additional Resources

Guidance on the Use of Rainwater Tanks

This document was created by the enHealth Council in response to the increased interest in using domestic rainwater tanks in both rural and urban areas in Australia. It consolidates the most up-to-date information on the range of potential hazards that can threaten water quality, measures that can be used to prevent these hazards from contaminating rainwater, straightforward monitoring and maintenance activities, and corrective actions.

Available at: http://enhealth.nphp.gov.au/council/pubs/documents/rainwater_tanks.pdf

Harvested Rainwater Quality Literature Review

Tammie Stark has put together a well researched literature review that addresses the complexities of the rainwater quality issue. While the paper focuses mainly on American regulations, quality parameters and testing, it is still a worthwhile resource to consider for applications in developing countries.

Available at:

www.eugenerainwater.com/Education/Harvested_Rainwater_Quality_Lit_Review.pdf

6.8 References

Ariyananda, T. (2001). Quality of Collected Rainwater from Sri Lanka. Paper submitted for 26th WEDC Conference, Dhaka, Bangladesh. Available at: www.webasia.com/rainwaterharvesting/pubs/prs/qocrwfl2001.pdf

Government of Australia. (2004). Guidance on the Use of Rainwater Tanks. enHealth Council, Department of Health and Aged Care. Available at: http://enhealth.nphp.gov.au/council/pubs/documents/rainwater_tanks.pdf

Gould, J. and Nissen-Petersen, E. (1999). Rainwater Catchment Systems for Domestic Supply: Design, Construction and Implementation. ITDG Publishing, Rugby, UK.

Mosley, L. (2005). Water Quality of Rainwater Harvesting Systems. South Pacific Applied Geoscience Commission (SOPAC) Miscellaneous Report 579. Available at: www.sopac.org/data/virlib/MR/MR0579.pdf

Pacey, A. and Cullis, A. (1986). Rainwater Harvesting: The Collection of Rainfall and Runoff in Rural Areas. IT Publications, London, UK, 216p. Cited in Gould and Nissen-Petersen (1999).

Rainwater Toolkit. (2005). Available at: www.rainwater-toolkit.net/index.php?id=32

Shaw, R. (2005). Drawing Water. Water, Engineering and Development Centre, Loughborough University, U.K. Available at: <http://wedc.lboro.ac.uk/dw/illustrations-water.htm>

Stark, T. (2004). Harvested Rainwater Quality Literature Review. Eugene Rainwater, Oregon, USA. Available at:
www.eugenerainwater.com/Education/Harvested_Rainwater_Quality_Lit_Review.pdf

State Government of Victoria, Australia, Department of Human Services. (2005). Rainwater Tanks – Your Private Drinking Water Supply. Available at:
www.health.vic.gov.au/environment/water/tanks.htm

UNEP IETC (n.d.) Sourcebook of Alternative Technologies for Freshwater Augmentation in Some Countries in Asia. Available at:
<http://www.unep.or.jp/ietc/Publications/TechPublications/TechPub-8e/>

Village Health Project. (n.d.) Biosand Filter Project. Available at:
www.villagehealthproject.org/6.html

World Health Organization (WHO). (2002). Heterotrophic Plate Count Measurement in Water Safety Management. Geneva, Switzerland. Cited in Government of Australia (2004).

7 Social, Economic and Environmental Considerations



(Shaw, 2005)

Learning Expectations

In this module you will learn about various social, economic and environmental issues, including:

- The role of culture, health, gender and politics.
- The importance of community participation.
- Household affordability and various financing mechanisms.
- Environmental feasibility and impact.

7.1 Introduction

The success of any technical project in a developing country depends on more than just the technology itself. Social, economic and environmental factors are important considerations in the selection, development and implementation of an appropriate technology. More often than not, these factors are not given their due consideration, resulting in many useless and failed projects around the world.

For a rainwater harvesting project to be successful, it must use an integrated and holistic approach that takes into account more than just the technical details. The best approaches combine an appropriate and affordable design with a socially and environmentally acceptable implementation strategy.

7.2 Social Considerations

Social considerations are a broad category that encompasses the following issues related to any rainwater harvesting project:

- Social – Relates to a need felt within a community and its' social acceptability.
- Cultural – Relates to the customs and belief systems of any society.
- Health – Impact of improved water supply on public health.
- Gender – Role of men and women members within the household and community.
- Politics – Household, local, regional, national and international levels.
- Community participation – Meaningful involvement of community members.

7.2.1 Social Issues

The needs, desires, beliefs, perceptions, experiences, and existing practice of a community influence the social acceptability of a project. Conducting a social assessment is a worthwhile exercise to understand the community's current perceptions and practices with respect to rainwater harvesting.

A history of failed rainwater projects in the region may make people reluctant to accept and use a new technology. People may also have misconceptions about the quality of rainwater or the linkage between hygiene, sanitation and their health. To some extent, these perceptions and misconceptions can be changed through awareness-raising and public education campaigns.

The social structure, organization, administration and leadership of a community are also important factors that can influence the success of a project. Communities with a history of cooperation are more likely to successfully implement a project than a community with no such history.

Community Cooperation in Kenya

In Kenya, the tradition of *harambee* (to pull together) has greatly assisted many villages with the affordable implementation of rainwater harvesting systems. Community spirit is strong amongst local people and there tends to be a well-defined social system for assisting each other with self-help activities.

(Gould and Nissen-Petersen, 1999)

Cultural factors also relate to other influences, such as personal preferences on the taste of rainwater. For example, someone may prefer the “sweet” taste of rainwater compared to the “salty” groundwater they are used to, while someone else used to drinking mineral-rich water from a limestone aquifer may consider rainwater to be flat and tasteless.

Cultures may also be resistant or reluctant to change their current habits and behaviours. This can be especially true when foreigners are responsible for promoting change in a community. There may be feelings of resentment or fear of outsiders and their ideas. It is important to be sensitive to these cultural issues, especially if you are an outsider trying to bring a new project to a community.

7.2.3 Health Issues

While improved water supply is linked to improved health, it is often difficult to evaluate and prove a direct connection. This may be because other factors such as water handling, hygiene and sanitation practices can cause secondary contamination and degrade rainwater quality after it has been collected. This issue highlights again why it is essential to incorporate sanitation and hygiene education components to support the implementation of a rainwater project.

People are also sometimes forced to supplement their rainwater supply with poor quality traditional water sources during droughts or dry seasons due to the lack of rainfall. This is another reason why the introduction of an appropriate household water treatment technology is an important component of ensuring an improved water supply.

7.2.4 Gender Issues

Women and men use water and are involved in water management in different ways. For example, it is mainly women and girls who fetch and use water for domestic purposes, while men and boys generally use water for farming and livestock.

The table shows how the gender responsibility for carrying water can vary between seasons, water source and regions. Table 2.7-2 shows the time burden that is spent walking long distances to fetch water.

Table: Gender Responsibility for Fetching Water for Domestic Use

Performance of Task	Sri Lanka	Ethiopia	Uganda	
			Wet season	Dry season
Women	80 %	40 %	80 %	37 %
Girls	10 %	45 %	15 %	4 %
Men	5 %	5 %	1 %	25 %
Boys	5 %	5 %	1 %	4 %
Water vendors	-	5 %	3 %	30 %

(Bishop-Sambrook and Akhter, 2001)

Table: Daily Activities Associated with Fetching Water

Daily Activities per Household	Ethiopia		Sri Lanka	
	Wet season	Dry season	Wet season	Dry season
Number of trips	2	2	3	3
Total travel time	1 hour	1 hour	1.5 hours	1.5 hours
Total queuing time	0.5 hours	1 hour	1.5 hours	3.5 hours
Total time fetching water	1.5 hours	2 hours	3 hours	5 hours

(Bishop-Sambrook and Akhter, 2001)

Box 2.7-3 Improvements to Women's Daily Lives in Uganda

Installation of household rainwater systems in Oruchinga Valley, Uganda has significantly impacted the daily lives of local women. Time that used to be spent fetching water is now directed to agricultural activities, housework, personal hygiene, and some leisure and social activities. Many of the women report that without the constant worry about how to get water they have gained a new peace of mind. This has affected their motivation to work and take up new challenges such as raising livestock or trying new agricultural methods (Rainwater Toolkit, 2005).

Despite the significant role that many rural women play in household water resources and the direct impact it has on their lives, they are often overlooked when it comes to the planning, design and construction of a household rainwater harvesting system.

Adopting a gender sensitive approach means that the different needs of men and women are both accounted for throughout all stages of project implementation. Local gender roles need to be understood and efforts made to ensure the fullest possible participation of both women and men. Excluding either group from consultation and decision-making will have a negative impact on the project's sustainability (SOPAC, 2004).

The following measures can be undertaken to ensure that the perspectives and input of both men and women are sought from the outset of any rainwater project:

- Analyzing any data collected about the community to identify differences between women and men.
- Arranging project meetings so that it is possible for both women and men to attend. This may involve consideration of the time and place of meetings, how invitations are extended and communicated, seating arrangements and the facilitation of speaking out. Sometimes separate meetings with women and men may be necessary to enable full participation.
- Encouraging women to take on planning and decision making roles (e.g. being part of committees).

- Expanding traditional tasks by the teaching new skills (e.g. regular maintenance tasks required for rainwater harvesting systems can be taught to women as well as men).



Women fetching water in the Thar Desert, India. (Holman, 2000)

7.2.5 Political Issues

Politics is found at every level, from the household, village committee, district offices, and regional council, to national ministry, bilateral agency and international organizations. Politics at any of these levels can positively or negatively influence the prospects of any rainwater project.

Gaining support of policy and decision-makers, usually senior officials in government and donor organizations, is often the first step towards ensuring a successful project. While these individuals may not be directly involved in project implementation, their support may enable a project to receive subsidies or funding necessary to get it off the ground.

7.3 Community Participation

Another key factor in project success is to promote the active participation of community members during every stage of the project. Experiences in many countries show that the following benefits can be realized where community participation and ownership are fostered:

- More is accomplished at a lower cost.
- People become more independent and are not reliant on others' skills, especially those brought by foreigners who generally leave the community after the project has been constructed.
- Valuable local knowledge is applied.
- Health benefits are maximized.
- Projects are more likely to be self-sustaining.

- Further development takes place at the initiation of the community because a sense of responsibility is encouraged (SOPAC, 2004).

Rainwater harvesting projects that are predominantly run by local people have a much higher rate of success than those operated by foreigners to an area. As well, those projects to which the community has contributed ideas, funds and labour tend to have greater success than those externally planned, funded and built (UNEP IETC, n.d.).

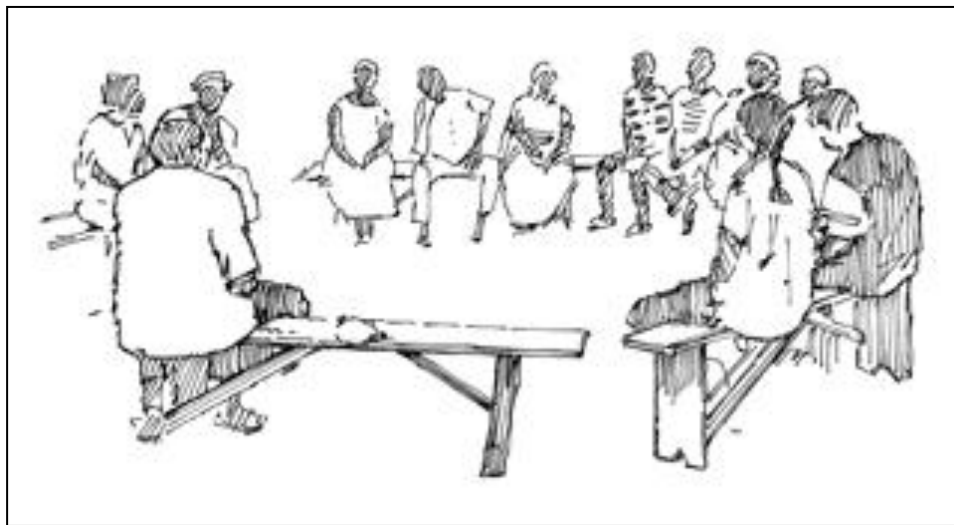
Project plans, especially those developed by foreigners, commonly refer to community participation but very often the overall structure and format of the project has already been decided by the time consultation with the community takes place.

To be truly participatory, the community must be fully engaged at every stage of the project, including:

- Identifying their water-related problems and needs.
- Decision-making based on informed choices.
- Sharing local knowledge and experience in designing the project.
- Selection of rainwater harvesting systems.
- Training for construction, operation and maintenance.
- Developing financing mechanisms.
- Evaluating the project and making changes when necessary (SOPAC, 2004).

Community participation needs to be meaningful and include the voices of the community who may disagree with the original concept and steer the course of the project in a new direction.

The major issue with encouraging community participation is that it can take a long time for a community to make the necessary commitments and decisions for project implementation. This time lag does not normally tie in with scheduling, budgeting and planning constraints of supporting donor and government agencies. Projects should therefore be implemented over a much longer time-span allowing participatory approaches to take effect and create full ownership by communities (SOPAC, 2004).



7.4 Economic Considerations

It is often difficult to take economic considerations into account when implementing a water supply project. There is usually an inverse relationship between the cost of water and the ability to pay.

Another important economic consideration that is sometimes overlooked is the time and energy involved in collecting water. Roof catchment systems for households reduce time and energy costs to near zero which is rarely accounted for in the total systems cost. While the economic value of the time saved may be small in the case of a poor rural community, the benefits in terms of improved quality of life and livelihoods can be dramatic. Women and children are freed from the daily burden of collecting water and their time can be redirected to child care, education, food production, income generating activities, and social interests.

7.4.1 Costs of Rainwater Systems

The relative costs of roof catchment systems vary from place to place and over time. It is difficult to compare costs since they depend on several factors such as exchange rate fluctuations, inflation, and accounting for administrative overheads, volunteer labour, local materials, transportation and technical advice.

Despite these limitations, the following generalizations can be made about the cost of constructing a roof catchments system:

- Initial capital costs are relatively high compared with available alternatives, such as shallow wells and springs. Constructing the tank and installing a new roof (if an existing roof is not available) make up the largest portion of the system costs.
- Operating costs are low, especially when compared to boreholes and piped systems.
- Sub-surface tanks are generally cheaper than surface tanks.
- Economies of scale makes costs per cubic metre decrease as storage tanks become larger (Gould and Nissen-Petersen, 1999).

Section 3 Project Planning and Implementation will help you go through an exercise of determining the true cost of a rainwater harvesting project.



7.4.2 Affordability

Affordability is a key constraint for many rainwater harvesting projects. Hundreds of millions of people could benefit from installing a catchment system, but simply cannot afford the costs.

Although many households have limited resources available when compared to the relatively high cost of a roof catchment system, almost all households have some resources which could be invested even if cash is not available.

These resources may include the following:

- Labour capacity.
- Local construction materials (e.g. sand, stones, boulders).
- Livestock which can be sold.
- Surplus cash crops (e.g. coffee, beans).
- Surplus vegetable production.

Where affordability is an issue, incremental approaches have proven to be successful. Installing smaller, cheaper systems will allow more households to take advantage of rainwater harvesting in the short term with less financial risk. Additional tanks can be added in the future as households have more available resources to invest.

7.4.3 Financing

Project financing strategies depend on the financial resources of the community. It is important to gain an understanding if systems are affordable and if people are willing to pay for them. Some kind of funding mechanism may be required if people are willing to pay but the costs are too high.

Project financing can be provided through the following mechanisms:

- Loans
- Subsidies
- Revolving funds
- Income-generating activities

Loans

Experiences with loans and subsidies for rainwater catchment systems have been mixed. It is important that any loans are set at realistic levels and the following conditions exist ahead of time:

- The recipient wants the loan, understands the conditions, and is willing and able to make the repayments.
- Recipient is willing to enter into a formal legal contract regarding the loan.
- Recipient is willing to comply with the loan conditions (e.g. down payment, provision of local materials and labour).
- There are some non-financial controls to encourage timely repayment

Subsidies

Subsidies are sometimes necessary to make rainwater catchment systems available to the poor; however they should be used with care. A 100% subsidy is seldom appropriate since they are unsustainable and limit the number of people that can benefit. By contributing towards a rainwater system, a household not only signals a desire to acquire it, but also demonstrates some ownership, responsibility and self-reliance. One

of the best forms of subsidy can be providing tools to a community or local NGO which may be used for other projects, training, and skill development.

Revolving Funds

Revolving funds have also shown some success in helping people to afford a roof catchment system. Groups of households can agree to make small regular monthly contributions to a central fund. The amount raised each month should be enough to pay for at least one tank. Each month a tank can be constructed and the household selected through a lottery, vote or other agreed upon method. A group of 12 participating households could each have a tank after one year. Members of the group are also expected to provide labour and collect construction materials. This approach has been especially successful in Kenya and used to a lesser extent in Asia.

Income-Generating Activities

Organizing income-generating activities such as selling crafts, cooking, animal rearing or selling produce is another way to raise funds. In Indonesia and the Philippines, loans and income-generating activities have been more popular than using revolving funds.

For example, the Dian Desa rainwater tank project in Jogjakarta gave participating households two she-goats along with a rainwater tank. When the goats gave birth (up to four goats), two would be sold to assist with the loan repayment, two were kept by the household, and the original two were passed on to the next household.

For examples of financial lessons learned from the field see Gould and Nissen-Peterson, 1999 pg. 160.

7.5 Environmental Considerations

The two main environmental considerations for rainwater harvesting are its environmental feasibility and its environmental impact.

7.5.1 Environmental Feasibility

The environmental feasibility of a roof catchment system depends primarily on the amount and pattern of precipitation in the area. Ground catchment systems may also need to consider the local geology, soil conditions, and hydrology for an effective design.

7.5.2 Environmental Impact

The environmental impact of a roof catchment system is usually minimal since an existing structure is commonly used.

Larger-scale ground catchment systems tend to have positive rather than negative environmental impacts. For example, they can help to reduce surface water runoff that may cause flooding and soil erosion in the area. Some concern has been raised that groundwater recharge may suffer in areas where widespread rainwater harvesting is practiced. While this may be theoretically possible, in practice the catchment area is usually only a small fraction of the total area where rain falls, and much of the rain that hits the ground runs off anyway and does not contribute to groundwater recharge.

In most cases, small-scale rainwater projects designed for domestic use should not require an environmental impact assessment (EIA). Large-scale projects which could impact downstream water uses may need some form of environmental assessment. If

you have any questions about the need and requirements for an EIA, you should contact the local Ministry of Environment or Natural Resources for advice.

Summary of Key Points

- Social, economic and environmental factors are important considerations in the selection, development and implementation of an appropriate rainwater technology.
- The best project approaches combine an appropriate and affordable design with a socially and environmentally acceptable implementation strategy.
- It is essential to take social aspects into consideration for any rainwater project, including culture, health, gender, politics and community participation.
- Community participation is a key factor in long-term project success by promoting the active and meaningful involvement of community members during every stage.
- It is difficult to compare costs since they depend on several factors such as exchange rate fluctuations, inflation, and accounting for administrative overheads, volunteer labour, local materials, transportation and technical advice.
- Affordability is a key constraint for many rainwater harvesting projects. Almost all households have some resources which could be invested. Using an incremental approach to build smaller, cheaper systems will allow more households to take advantage of rainwater harvesting in the short term with less financial risk.
- Project financing can be provided through various mechanisms, including loans, subsidies, revolving funds and income-generating activities.
- Environmental impacts and issues should always be considered; however in most cases, household rainwater projects will not require an environmental impact assessment.

Self-Assessment

1. True or false? The success of any technical project in a developing country depends on just the technology itself.
2. Discuss some of the gender issues related to water.
3. Identify some measures that can be undertaken to ensure that the perspectives and input of both men and women included in a rainwater project.
4. Discuss the role of community participation for the successful implementation of a rainwater harvesting project.
5. Identify some approaches that can be undertaken to address the issue of affordability?

Solutions

1. False. The success of any technical project in a developing country depends on more than just the technology itself. Social, economic and environmental factors are important considerations that contribute to long-term project success.

2. Women and men use water and are involved in water management in different ways. For example, it is mainly women and girls who fetch and use water for domestic purposes, while men and boys generally use water for farming and livestock. Time spent fetching water is taken away from raising their children, agricultural activities, housework, personal hygiene, and some leisure and social activities. Despite the significant role that many rural women play in household water resources and the direct impact it has on their lives, they are often overlooked when it comes to the planning, design and construction of a household rainwater harvesting system.

3. The following measures can be undertaken:

- Disaggregating any data collected about the community to identify differences between women and men.
- Arranging project meetings so that it is possible for both women and men to attend.
- Encouraging women to take on planning and decision making.
- Expanding traditional tasks by the teaching new skills.

4. The active and meaningful participation of community members is a key factor in long-term project success. Many benefits can be realized, including:

- More is accomplished at a lower cost.
- People become more independent and are not reliant on others' skills.
- Valuable local knowledge is applied.
- Health benefits are maximized.
- Projects are more likely to be self-sustaining.
- Further development takes place at the initiation of the community because a sense of responsibility is encouraged.

Rainwater harvesting projects that are predominantly run by local people who have contributed ideas, funds and labour tends to have greater success.

5. Almost all households have some resources which could be invested even if cash is not available, including labour, construction materials, livestock, surplus cash crop and vegetable production.

Installing smaller, cheaper systems will allow more households to take advantage of rainwater harvesting in the short term with less financial risk. Additional tanks can be added in the future as households have more available resources to invest.

7.6 Additional Resources

Harvesting the Heavens: Guidelines for Rainwater Harvesting in Pacific Island Countries

SOPAC's most recent involvement in rainwater harvesting in the region has been with a UNEP pilot project carried out in Vava'u, Tonga through the Ama Takiloa programme of the Tonga Community Development Trust (TCDT). The project was part of a UNEP initiative to promote rainwater harvesting both in Africa and the Pacific region.

The guidelines developed from the SOPAC pilot project are for people who are interested in building or maintaining a rainwater harvesting system in Pacific Island countries. It is also for NGOs, CBOs, regional organisations and donor agencies that are involved in the implementation of rainwater harvesting projects. The intention of the guidelines is to help in the sustainable implementation of rainwater harvesting projects as well as to assist in improving the quality of the water supply. It contains technical design, operation and maintenance information as well as discussing social, economic and environmental approaches to project implementation and sustainability.

Available at: www.sopac.org/tiki/tiki-index.php?page=CLP+Rainwater+Harvesting

7.7 References

Bishop-Sambrook, C. and Akhter, S. (2001). Social and Gender Analysis: Findings from the Inception Phase. Development Technology Unit, School of Engineering, University of Warwick, UK. Available at:

Development Technology Unit (DTU). (2002). Very Low Cost Domestic Roofwater Harvesting in the Humid Tropics: Existing Practice. Report R1, DFID KAR Contract R7833. School of Engineering, University of Warwick, UK. Available at: www.eng.warwick.ac.uk/DTU/rwh/dfidocs/r1.pdf

Gould, J. and Nissen-Petersen, E. (1999). Rainwater Catchment Systems for Domestic Supply: Design, Construction and Implementation. ITDG Publishing, Rugby, UK.

Holman, B. (2000). Photo available at: <http://gbh2000.tripod.com/ontheroadaglenn/id5.html>

Rainwater Toolkit. (2005). Available at: www.rainwater-toolkit.net

South Pacific Applied Geoscience Commission (SOPAC). (2004). Harvesting the Heavens: Guidelines for Rainwater Harvesting in Pacific Island Countries. SOPAC Joint Contribution Report 178. Available at: www.sopac.org/tiki/tiki-index.php?page=CLP+Rainwater+Harvesting

UNEP IETC. (n.d.). Sourcebook of Alternative Technologies for Freshwater Augmentation in Latin America and the Caribbean. Available at: www.unep.or.jp/ietc/Publications/TechPublications/TechPub-8c/index.asp

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<http://www.oas.org/dsd/publications/Unit/oea59e/ch10.htm>

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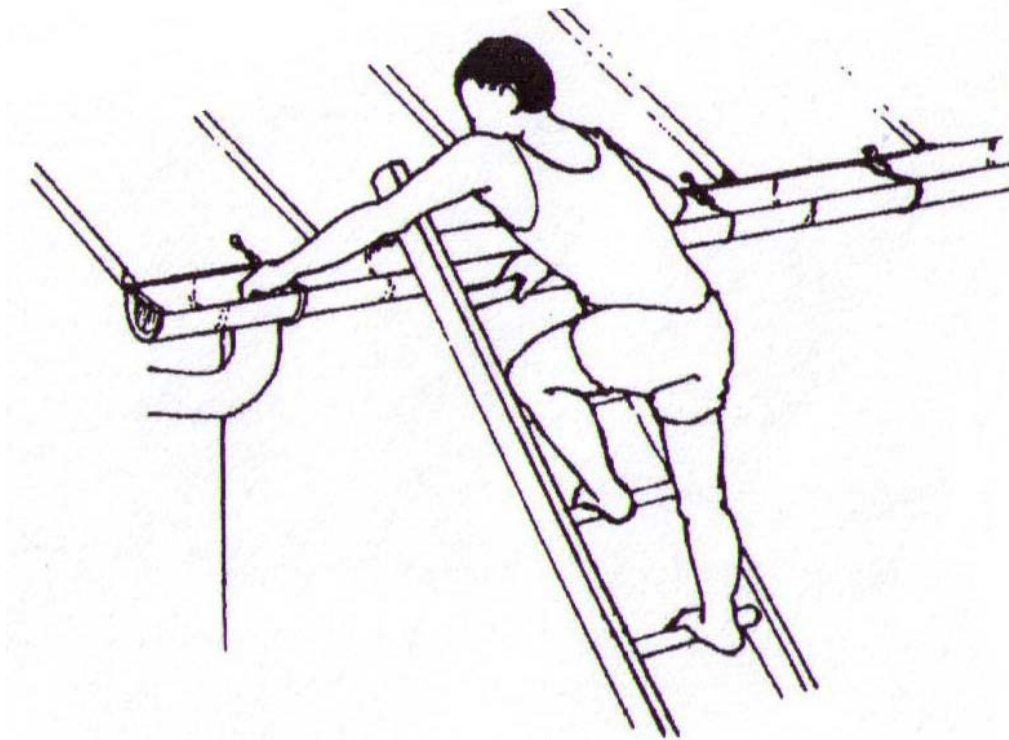
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Appendix B – Maintenance and Troubleshooting Guide



(US AID, n.d.)

Table 1: Maintenance Guide

The following tasks should be done at least once a year to keep the rainwater system operating properly and well-maintained.

Component	Ongoing Maintenance	How Often?
Roof	Clean or sweep debris from the roof.	Between rainfalls and especially after a long period of dry weather.
	Prune and cut overhanging branches.	Check tree growth every 6 months and prune when required.
	Replace or paint over any rusted roofing material.	When required.
	Repair any holes in the roofing material and replace any broken tiles to prevent leaking.	When required.
	Seal any nail holes that are leaking.	When required.
Gutters and Downpipe	Remove leaves and other debris from the gutters to avoid clogging and water overflow.	Monthly and especially after a long period of dry weather.
	Clean any screens to prevent clogging and water overflow.	Monthly and especially after a long period of dry weather.
	Check screens and mosquito mesh on inlets and other openings. Repair any rips or holes.	Check every 6 months and repair when required.
	Check bamboo or wood gutters for rotting. Replace them if there is any sign of rot.	Once a year.
	Check that gutters are slanted to ensure steady flow and avoid pooling of water and collection of debris.	Once a year.
	Check that gutters are firmly fixed to the roof and that they are joined to prevent spilling.	Once a year.
	Repair any holes in the gutter to prevent leaking.	When required.
Tank	Drain and clean inside of tank if it has a removable lid or cover. See Factsheet 1 for instructions.	Once a year.
	Remove accumulated sludge if the tank has a draw-off/wash-out pipe.	Once a year
	Disinfect tank. See Factsheet 2 for instructions.	When required.
	Repair any holes or cracks that are leaking.	Immediately when required.
	Remove nearby tree roots.	When required.
Tap	Repair any leaking taps.	Immediately when required.
	Sponge out excess water to ensure that it does not pool or collect.	When required.
	Place stones or gravel at the tap stand to help drainage.	When required.
Overflow	Securely fasten mosquito screen over the end of the overflow pipe.	When required.
	Repair any rips or holes in screens.	When required.
Fence	Repair any gaps or holes in fencing to keep out animals and children.	Check every 6 months and repair when required.

Fact Sheet 1: How to Clean Your Water Tank

These instructions describe how to clean a tank with a removable lid or cover.

Materials Needed

- Liquid chlorine bleach (plain household grade unscented and uncoloured with 4% active chlorine) or chlorine tablets
- Bucket
- Brush
- Eye and hand protection (e.g. glasses and rubber gloves)

Procedure

Step 1. Drain any water in the tank to level of the tap. Transfer water to another clean storage tank or temporary vessel.

Step 2. Add 1 bottle of chlorine bleach or X number of chlorine tablets (read instructions on label) to the remaining water in the tank.

Step 3. Climb inside the tank. Thoroughly scrub the bottom and sides of the tank.

Step 4. Remove the water and bleach solution with a bucket.

Step 5. Refill the tank with water.

Step 6. Let the water settle overnight before using it.

Health and Safety Considerations

- Be sure to wear proper eye and hand protection when preparing and handling chlorine solutions to avoid burning skin and damaging eyes.
- Be sure that there is good ventilation to help minimize fumes.
- Be careful when climbing into the tank and make sure that you have somebody to help you and in case of emergency.
- Do not climb into a tank that is full of water.

(Adapted from SOPAC, 2004)

Fact Sheet 2: How to Disinfect Your Water Tank

You should disinfect your water tank only when one or more of the following situations are present.

- People are getting sick from drinking the water with sore stomachs and diarrhoea.
- Animal or human excrement, including bird droppings, have entered the tank.
- A dead animal has been found in the tank.
- After tank maintenance or repairs where people have entered the tank.
- There are sulfide, rotten egg or sewage odours coming from the tank.
- The water has been tested and there is known bacterial contamination.

Procedure

Step 1. Add 125 ml of liquid chlorine bleach (plain household grade unscented and uncoloured with 4% active chlorine) to every 1,000 litres of water currently stored in the tank.

Amount of water in tank	Amount of bleach
1,000 litres	125 ml
2,000 litres	250 ml
3,000 litres	375 ml
Etc.	Etc.

Step 2. Wait 24 hours after putting in the chlorine to allow enough time to disinfect the water before you drink it. Any chlorine smell and taste in the water will go away after a short time. If you find that the taste of chlorine is unacceptable, you can boil the water for at least 1 minutes before drinking it.

Health and Safety Considerations

- Be sure to wear proper eye and hand protection when preparing and handling chlorine solutions to avoid burning skin and damaging eyes.
- Be sure that there is good ventilation to help minimize fumes.

(Adapted from SOPAC, 2004)

Table 2: Troubleshooting Guide

Problem	Cause	Preventive Measure	Monitoring	Corrective Action
1. Faecal contamination from birds and small animals.	a) Overhanging branches resulting in birds nesting and excreting onto the roof.	Prune tree branches to prevent birds from nesting over the roof.	Check tree growth every 6 months.	Prune tree branches. Disinfect water using chlorine (see Fact Sheet 2).
	b) Bird or animal access to tank.	Protect all inlets, overflows and other openings with screens to prevent entry into the tank.	Check access covers are kept closed. Check inlets, overflows and other openings every 6 months.	Repairs gaps or holes in screens. Secure access cover. Disinfect water using chlorine (see Fact Sheet 2).
		Maintain integrity of tank roof and wall to prevent access points.	Check structural integrity of tank.	If a dead animal is found, empty and clean the tank. If this has to be delayed, remove animal remains and disinfect water using chlorine (see Fact Sheet 2).
2. Faecal contamination from humans (surface tank).	Human access to tank.	Prevent access. Ensure tank is roofed and access covers are secured.	Check access covers are secured, especially in hot weather.	Secure access cover. Disinfect water using chlorine (see Fact Sheet 2).
3. Faecal contamination from humans and livestock (ground catchment and sub-surface tank).	a) Surface water gets into sub-surface tank.	Ensure tank is protected from surface water runoff and tank walls are intact.	Check structure annually and after heavy rainfall events to ensure that surface runoff does not enter tank.	Repair or line inside of tank walls. Construct bunds or drains to divert surface runoff away from tank. Disinfect water using chlorine (see Fact Sheet 2).
	b) Children and livestock accessing ground catchment and storage area.	Construct fence around catchment and storage area to restrict access.	Check structure every 6 months.	Repair gaps or holes in fencing.
4. Mosquitoes	Access to stored water in tank.	Protect all inlets, overflows and other openings with mosquito-proof mesh.	Inspect water for presence of larvae at least every month.	Repair mesh to prevent access. Treat tank with domestic kerosene (5 ml per 1000 litres). Note: Commercial or industrial kerosene should not be used.

Problem	Cause	Preventive Measure	Monitoring	Corrective Action
5. Lead contamination	a) Lead based paints and primers used on roof.	Check suitability of paint before painting roof.	-	Do not collect rainwater from roofs painted with products containing high levels of lead.
	b) Lead flashing used on roof.	Paint over existing lead flashing or use pre-coated products.	Inspect roof every 6 months to ensure that lead flashing is coated.	Paint over if large amounts of uncoated flashing is present.
	c) Increased corrosion of gutters due to low pH from long periods of contact between rainwater and leaves.	Keep gutters clean.	Inspect gutters monthly and especially after a long period of dry weather.	Clean gutters. Increase frequency of cleaning if large amounts of leaves are observed on a regular basis.
	d) Resuspension of accumulated sediment after rainfall.	Reduce amount of sediment in tank by using first flush device or inlet screens to filter water. Regularly clean tank to remove accumulated sediment.	Inspect tank every 2 to 3 years. Inspect roof, gutters, first flush device and inlet screens every 6 months.	Clean tank if required. Clean roof, gutters and inlet screens as required. Ensure that first flush device is working properly.
6. Other contamination from roof materials	a) Preservative-treated wood.	Inspect roof before installing tank.	-	Do not collect rainwater from roofs covered with exposed treated wood. Seal or cover wood to prevent exposure to rainwater.
	b) Bitumen-based material.	Inspect roof before installing tank.	-	Do not collect rainwater from roofs with bitumen-based products.
7. Sulfide, rotten egg or sewage odour.	a) Anaerobic microbial growth in accumulated sediment at the bottom of tank due to lack of oxygen.	Clean tank once a year to remove accumulated sediment.	Inspect tank every 2 – 3 years.	Clean tank if required. If cleaning is not practical, disinfect water with chlorine and flush chlorinated water through all pipework.
	b) Slime and stagnant water in pipework.	Avoid u-bends or underground pipework that can hold stagnant water. Install drainage points on pipe work.	Inspect tank every 2 – 3 years.	Clean tank if required. If cleaning is not practical, disinfect water with chlorine and flush chlorinated water through all pipework. If possible, reconfigure pipework to avoid pooling water.

Problem	Cause	Preventive Measure	Monitoring	Corrective Action
8. Musty or vegetable type taste and odour.	Accumulated vegetation (e.g. leafs, branches, pollen) on roofs and gutters.	Remove overhanging branches from trees. Keep gutters clean. Install self-cleaning screens on gutters.	Inspect gutters monthly and especially after a long period of dry weather.	Clean gutters. Increase frequency of cleaning if large amounts of leaves are observed on a regular basis. Disinfect water using chlorine (see Fact Sheet 2).
9. Musty, vegetable or fishy taste and odour.	Algal growth due to light entering into tank or pipework.	Make sure tank is completely covered and light does not enter. Make sure that tank and pipework is impervious to light. White pipes can allow light to pass through.	Inspect water every 6 months.	Repair tank roof. Paint pipework with a dark colour. Disinfect water using chlorine (see Fact Sheet 2).
10. Bitter taste.	New concrete tank.	Do not drink water from first tank fill and use for other purposes. Taste will diminish in subsequent fills.	Water quality and taste will improve with tank age.	Problem will diminish with time.
11. Metallic taste.	New metal tank.	Do not drink water from first tank fill, use it for other purposes. Taste will diminish in subsequent fills.	Water quality and taste will improve with tank age.	Problem will diminish with time.
12. Plastic taste.	New plastic tank.	Do not drink water from first tank fill and use for other purposes. Taste will diminish in subsequent fills.	Water quality and taste will improve with tank age.	Problem will diminish with time.
13. Detergent taste or frothy water.	Newly painted roof.	Do not collect water from first 2 – 3 rainfalls after painting.	Water quality and taste will improve with age.	Problem will diminish with time.

Problem	Cause	Preventive Measure	Monitoring	Corrective Action
14. Coloured water	a) Accumulated wet leaves in gutter.	Keep gutters clean. Install self-cleaning screens on gutters.	Inspect gutters monthly and especially after a long period of dry weather.	Clean gutters. Increase frequency of cleaning if large amounts of leaves are observed on a regular basis.
	b) Coloured coating from tiles washed into tank. Resuspension of sediment after rainfall.	Use tiles that are colour-through or do not have coloured coating.	Inspect water quality after rainfall.	Clean tank to remove sediment.
15. Insects in water.	Access to stored water in tank.	Protect all inlets, overflows and other openings with insect-proof mesh.	Inspect water for presence of insects and larvae at least every 6 months.	Repair mesh to prevent access. Use simple coarse filter to remove remaining insects from water.
16. Small white flakes in water.	Microbial growth encouraged by nutrients from plant and soil material accumulated in gutters or at the bottom of tanks.	Keep gutters clean. Install self-cleaning screens on gutters.	Inspect gutters monthly and especially after a long period of dry weather. Inspect tank every 2 – 3 years.	Clean gutters and tank if required. Disinfect tank with chlorine.
17. Slime on the inside of the tank.	Microbial growth. All tanks that continuously store water will develop a biofilm on surfaces below the water level.	None required.	None required.	None required. This is naturally occurring and not harmful to most people.
18. White deposits on the surface of metal tanks with a slimy or waxy feel.	Known as white rust.	Not required.	None required.	None required since the deposits are not harmful. Physical removal of the deposits could damage the surface of the tank and increase the potential for corrosion.
19. Erosion at foundation of the tank.	Surface water runoff is eroding soil at the base of the tank.	Ensure tank is built on a solid concrete foundation.	Check tank annually and after heavy rainfall events to ensure that surface runoff is not eroding foundation.	Construct bunds or drains to divert surface runoff away from tank.

(Adapted from Government of Australia, 2004)

Appendix C – Ferrocement Tank Construction Instructions

Material Requirements for Making Ferrocement Tank

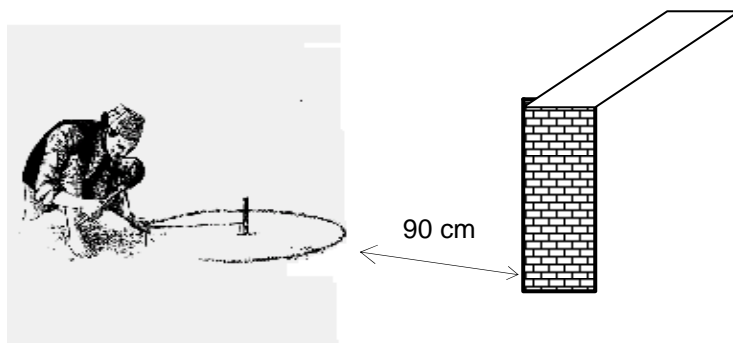
Material requirements	1000- litre jar (1m diameter)	2,000 litre jar (1m diameter)	3,200 litre jar (1.5 m diameter)
Cement	3 bags	4 bags	7 bags
Sand (coarse and clean)	2 cubic meter	3 cubic meter	4 cubic meter
Aggregate	0.3 cubic meter	0.3 cubic meter	0.4 cubic meter
G I Plain Wire 3.5 mm diameter	3 kgs	4 kgs	5kgs
Binding Wire	500 gm	500 gm	1 kg
Chicken Mesh (25 mm)	7m	10 m	18 m
PVC pipe (wash out)	110 cm (2" dia.)	110 cm (2" dia.)	135 cm (3" dia.)
PVC Elbow	1 pc (2" dia.)	1 pc (2" dia.)	1 pc (3" dia.)
Gate Valve	1 pc (2" dia)	1 pc (2" dia.)	1 pc (3" dia.)
Over flow PVC pipe	2" dia, 6" long	2" dia, 6" long	3" dia, 6" long
½" – 6" long GI Nipple pipe	1 pc	1 pc	1 pc
½" GI socket	1 pc	1 pc	1 pc
1/2" brass or plastic Tap	1 pc	1 pc	1 pc
PVC Cap for inlet	1 pc (2" dia.)	1 pc (2" dia.)	1 pc (3" dia.)
Iron bars	8 mm (36 m long)	8 mm (60m long)	10 mm (60m long)
9 " thick brick or stone for soling	0.30 cum	0.30 cum	0.50 cum

Note: iron sheets, bamboo baskets or wood can be used to make framework

Ferrocement Tank Construction

Lay out of foundation

The ferrocement tank should be situated a minimum 90 cm away from the wall of the house. Its good to keep a tank higher than the ground level in order to

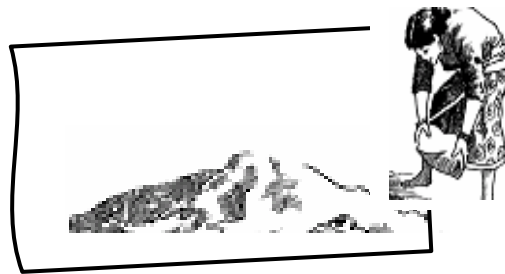


use the tap of the tank more easily. The size of the tank can be determined according to the household needs and affordability.

For the foundation setting, draw the circumference of the foundation using a string tied to a peg (as shown in the figure). For a firm and level foundation, 20 to 25 mm stone or brick soling is done on the ground. The soling of the foundation should have 10-15 cm projection from the tank's outer surface. For example if you are building a 1000L tank with a diameter of one-meter diameter, you must add 15 cm (or 10 cm) both sides which comes to a total of 1.30 m.

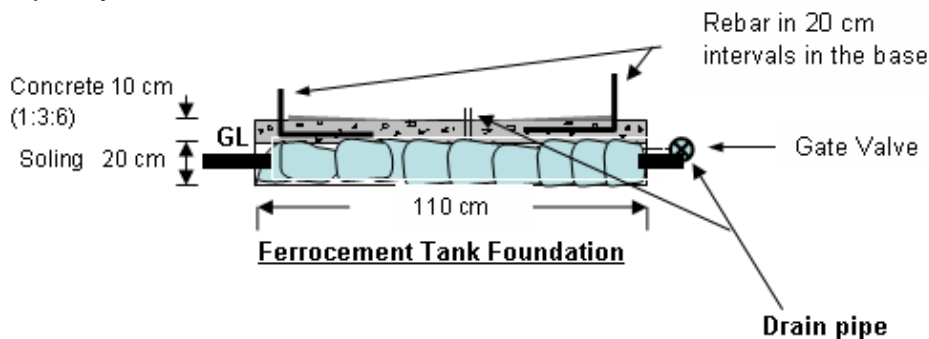
Working place to mix the concrete

Iron sheets, flagstones or wooden planks can be used to make a temporary working platform for mixing concrete. The platform should be ready before the tank construction work begins. The area of platform should be more than one square meter area or large enough for two people to work.



Concrete base

The base of the concrete has to be more than 10 cm thick. Usually the ratio of the concrete is 1:3:4 (one part cement: 3 part sand and 4 part 1/2-3/4" aggregate). The flush out pipe that has a minimum 5 cm diameter needs to be in the base. In rural areas use of plastic pipes are common which are relatively cheaper compared to galvanised iron pipe. Appropriate end-cap or gate valve is fixed to open the pipe for the cleaning purposes. L- shaped rebars are kept vertically in 15-20 cm interval which depends on the basis of the tank size. The diameter of the rebar depends on the capacity of the tank.



Framework for tank

Iron sheets, plastic sheets, HDP pipes, bamboo baskets or wooden planks can be used to make the framework for the tank. The support of the interior part should be firm enough to sustain the load from the plaster. Vertical rebars (as shown in the above figure) are kept perpendicular with the rebar of the base and it has to be tied up by using binding wires.



The figure shown is the framework of corrugated iron sheets. Iron sheets are tied with vertical bars and knots in the inner part of the tank so that it will be easy to cut to take out the iron sheet. The surface of the framework materials should be smooth which makes it easy to take out.

Wall construction

Chicken mesh should be wrapped tightly around the framework and tied up by using binding wires. Overlapping of chicken wire has to be more than 20 cm. A 3 mm galvanised iron wire is wrapped tightly in 30 cm interval. Chicken wire and galvanised wires has to be tight with in 32 mm interval in the bottom and 64 mm interval in the middle and top. It is time consuming but necessary to tie up to get full strength.

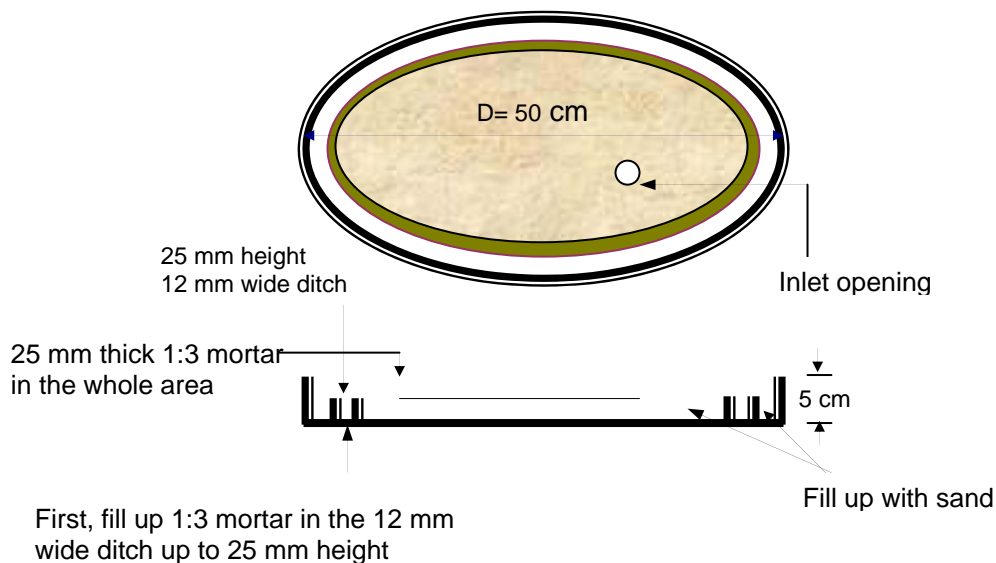
The outer plaster work is difficult while using iron sheets or plastic framework due to their plain surface. However, 1:3 cement mortar with less water (paste) can be used for the plaster work. It takes time; therefore, mortar has to be prepared in small quantities to be used within the first 30 minutes. The thickness of the plaster should be 15mm and after the completion of the first layer it'll need 2 or 3 hours for the initial setting before doing another coat.

Lid construction

Iron sheets, wooden or concrete lids are usually used for the ferrocement tank. Concrete lid is the most common of them all. The diameter of the ferrocement tank is usually 40-50 cm dia. so people can go inside the tank for cleaning purpose.

45 cm diameter ferrocement lid

1. Make a cardboard or wooden plain in a circle of 50 cm diameter with 5cm height edge. From the edge of the circle we need to mark 25 mm and make a 12 mm wide ditch.

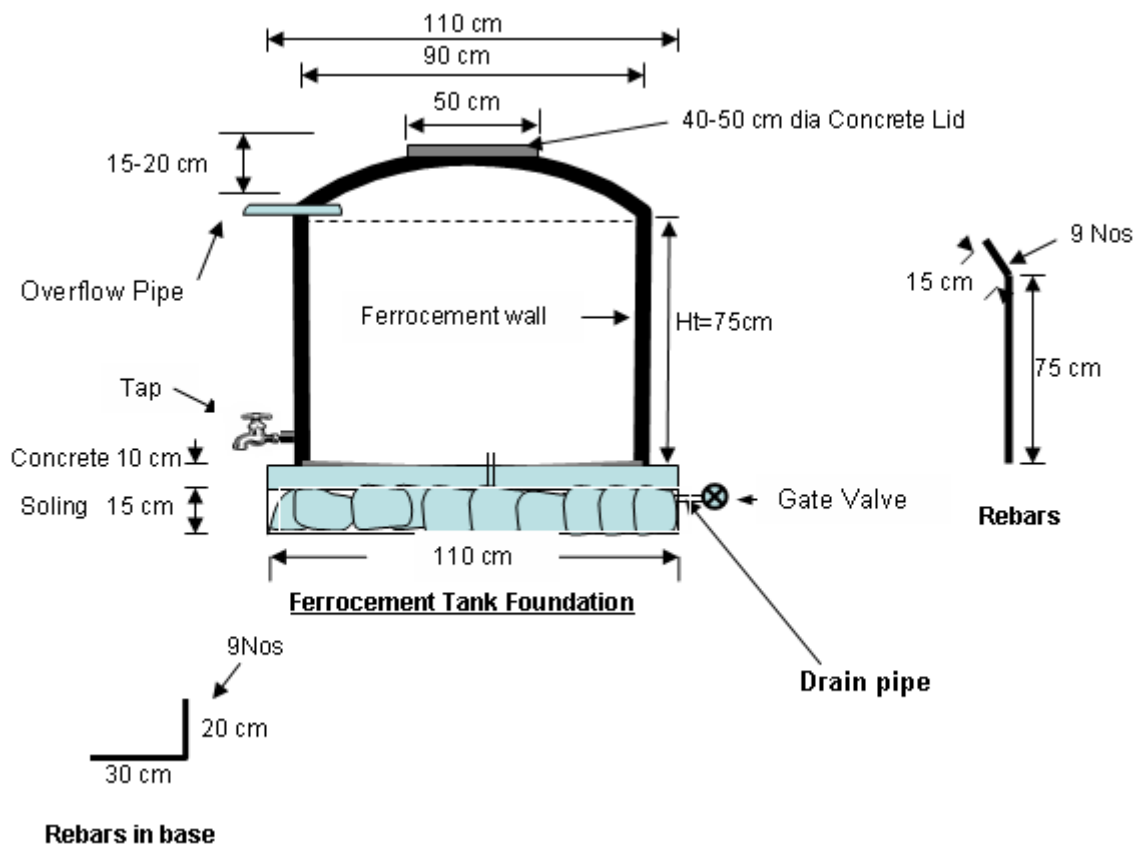


2. Fill the middle space and near the edge with sand. Provide support to the surrounding the edge of the outer perimeter. Cover the whole surface with plastic to keep card board solid. 1:3 ratio mortar is poured into 12 mm wide ditch until it reaches the top surface of the sand. Keep chicken in the middle of the plaster and then fix the 8 mm or (6 mm) rebar handle.
3. A minimum of three days of curing is essential for the lid.

Plaster work inside of the Ferrocement Tank

After plastering the outside part of ferrocement tank, it needs to cure for a minimum of five days. After 5-7 days, the ferrocement can be taken out. Within five or seven days the ferrocement tank may not be fully matured; therefore, the framework has to be taken out carefully. Do not hammer or give a point force in the wall of the ferrocement tank. After removal of the framework, add ½" cement plaster to the inner part of the tank. The Nil (punning) i.e. cement slurry is also practice to add in the inner part of the ferrocement tank. However, if the Nil becomes too thick than hair cracks will appear after a few months. Three to five days of curing is necessary for the inner plaster. For a few weeks in the beginning, the ferrocement tank water gives a smell which may discourage drinking purposes however it can be used for other domestic purpose.

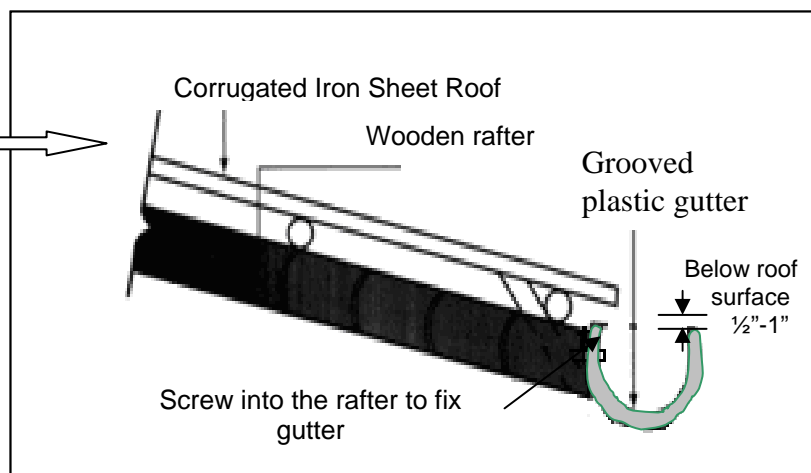
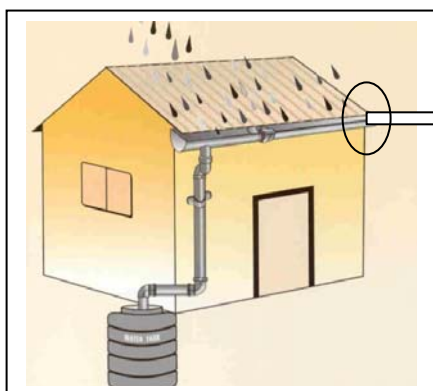
450 liters Capacity Ferrocement Tank

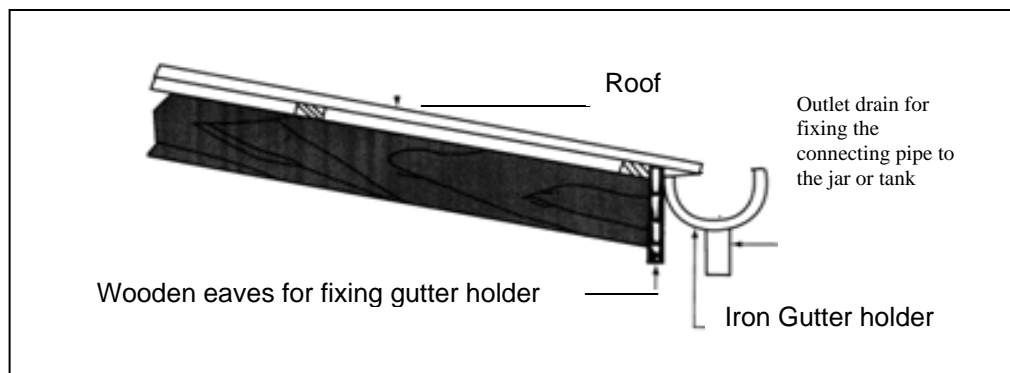


Appendix D – Fixing the Gutter to the Roof Structure

Fixing the PVC Gutter

1. Cut either a 3" (7 cm) or a 4" (10 cm) diameter PVC or High Density Polythene (HDP) pipe according to the length of roof size. For example, for a roof size that is 25 feet (8 m) in length and 12 feet (4m) in width cut a 3" diameter pipe. For a roof with a greater surface area, a 4" diameter pipe would be best.
2. Cut a 1" (2.5 cm) horizontal strip along the length of the pipe to serve which will serve as a grooved plastic gutter.
3. Fix the gutter, $\frac{1}{2}$ " (1.25cm) - 1" (2.5cm) below the roof level on the eaves drop as shown in the figure below with screws.
4. Gutter should be fixed with a gentle slope 1 in 100. For example, for every hundred feet, (starting from one corner to the storage tank) the gutter should slope downwards one foot.





Fixing the V-Shaped Galvanized Iron Sheet Gutter

1. Cut a plain galvanised iron sheet according to the length of the roof.
2. Form a plain sheet into a V- shape according to the roof size. Typically the V shape should be between 4"-6" (10-15cm) in size for a 180 -250 sqft (16-23 sqm) roof.
3. Make a [1/2" (1.25cm) to 1" (2.5cm)] cross-fixed wooden gutter holder as shown in the figure to support the gutter. Typically one cross-fixed wooden gutter should be made for every 8 feet.
4. The cross-fixed wooden gutter holder can be fixed in the rafter by screws as shown in the figure.
5. The gutter should be fixed in a gentle slope of 1 in 100. For example, for every hundred feet, (starting from one corner to the storage tank) the gutter should slope downwards one foot.

