TECHNICAL PERFORMANCE EVALUATION OF DOMESTIC ROOF WATER HARVESTING SCHEMES
(THE CASE OF MINJAR AND SHENKORA WOREDA SCHEMES)

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Technical Performance Evaluation of Domestic Roof Water Harvesting Schemes;
(The Case of Minjar and Shenkora Schemes)

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LIST OF ABBREVATIONS AND ACNORYMS

AAU	Addis Ababa University
amsl	above mean sea level
CSA	Central Statistics Authority
DRWH	Domestic Roof Water Harvesting
ERHA	Ethiopia Rainwater Harvesting Association
ESRDF	Ethiopia Social Rehabilitation and Development Fund
FC	Faecal Coli form
FGD	Focus Group Discussion
GI	Galvanized Iron
hh/hhs	Household/households
l/c/d	litters per capita per day
MoFED	Ministry of Finance and Economic Development
MoWR	Ministry of Water Resource
NGO/NGOs	Non Governmental Organization/None Governmental Organizations
NTU	Nephelometers Turbidity Unit
O & M	Operation and Maintenance
PA/PAs	Peasant Association/Peasant Associations
PASDEP	Plan for Accelerated Sustainable Development to End Poverty
PVC	Polyvinyl Chloride
RWH	Rainwater Harvesting
SNNPRS	South Nation and Nationalities People Regional State
TPL/TPs	Tradition Pit Latrine/Tradition Pit Latrines
UV	Ultra Violet
WatSan	Water Supply and Sanitation
WHO	World Health Organization
WMS	Welfare Monitoring Survey
WWDSE	Water Works Design and Supervision Enterprise

ABSTRACT

The objective of the study is to diagnoses the technical performance of DRWH schemes implemented by Water Action (an indigenous NGO) in Minjar and Shenkora Woreda, Amhara Regional State. The key selected technical performance evaluation indicators are reservoir capacity, capacity of gutter and down pipes and water quality.

The study is conducted on all of the DRWH schemes implemented by water Action in the woreda. The study methodologies employed are literature review, semi-structured interviews, questionnaires, PRA and RRA has been employed to probe more information on the grass root level. The mass curve technique and the SIMTANKA software are also used to establish optimal tank/reservoir/ size.

Traditionally excavated pounds, River and deep wells are the major sources of water supply for human being and livestock watering in the woreda. As compared to other water sources traditional excavated ponds are the most reliable sources of water supply though exposed for various contaminants and serves for a few months.

Rainwater harvesting is back after having been ignored for decades. For arid and semi-arid regions, DRWH has proven track-record of providing safe water next to the house. The increased interest has been facilitated by a number of external factors among others includes the shift towards more community based approaches, the decrease in the quality and quantity of ground and surface water, the failure of many piped water supply system due to poor O & M, etc.

The study reveals that, in general, lack of awareness, policy issues, poor system operation or management; lack of regular monitoring and maintenances are among the main technical performance problems on the promotion and implementation of the technology.

CHAPTER ONE

1. INTRODUCTION

1.1. Background

Efforts have been made by Governmental and non-governmental institution /organization to improve the provision of safe, adequate water supply and sanitation service in the rural and urban area of the country.

The technical option varies from place to place and to some extent related with the experience of institutions on promoting the service. The choice of the technological options mainly depends on the natural complexity of the available water resources. In general specking development projects expected to be technical feasible, socially acceptable, and financially viable and environmentally sound.

Provision of safe and adequate WatSan is now becoming an indicator for poverty measurement. Studies and assessments made at various levels in the country shows that the level of services in WatSan is very low and getting worse in the rural and remote ends of the country. The level of infrastructure coverage of the country remains remarkably low as compared to elsewhere in the world, for instance based on 2002 population data as established in the PASDEP; Ethiopia improved water supply coverage is only 24 Percent, average developing countries 79 Percent, Sub-Sahara Africa 58 Percent and Low income countries 76 Percent (MoFED, 2005).

WatSan in both the rural and urban centres has received much attention during the past two decades. Given the fact that more people that live in small town and rural villages; receive relatively less service than the urban centres. Urban centres or capital town like Addis Ababa (99 Percent), Dire-Dawa (90.8 Percent), and Harari (73.3 Percent) contribute the highest access to safe water supply coverage in their respective regions. Access to potable water in urban (excluding Addis Ababa) parts of the country is about 65.3 percent and 15 percent in the rural areas. Sanitation services, even in urban centres excluding Addis Ababa, are almost non-existent (MoWR, 2002).

One of the indicators of the well being of the hhs incorporated in the WMS is the availability and quality of toilet facility. According to the survey results, only about 28 Percent of hhs have access to a pit latrine; and the vast majorities (68 Percent) do not have access to any kind of toilet facility. Among rural hhs more than 78 Percent do not have any toilet facility, and 20 Percent have pit latrines. From a sanitation and health point of view, it is even more serious to observe that almost a fifth of urban hhs do not have access to any kind of toilet facility, and have to use open fields. While these results are striking by international standards, it is important to note that there has been substantial improvement over the past surveys, with the proportion having some form of toilet rising from 13 Percent eight years ago to 31 Percent today (CSA, 2004).

Considering sustainable service and management; Government, NGOs, Multilateral and Bilateral international financer have been promoting and implementing community managed rural WatSan projects through utilization and dissemination of appropriate technologies. Among the various options DRWH system becoming one of the most appropriate technological option; especially where the quantity, quality and the development techniques of both surface and sub-surface water sources are complex and remote.

DRWH has been a traditional practice in some cultures for centuries and as such many technologies are the result of a long evolutionary process. Even the current resurgence of interest in RWH as sources of water supply has been in existence for over twenty-five years and more in some countries like Australia (Warwick University, 2005).

In this regard the role of Water Action, an indigenous non-governmental institution established to alleviate poverty through provision of safe and adequate water supply sanitation and hygiene education to the rural and marginalized community has been enormous. Water Action is the founder of ERHA via financial and technical supports under its premises.

Water Action has been promoting and implementing a number of DRWH projects in many parts of the country since 1996; mainly in the Amhara and SNNPRS. For instance, by the end of 2001 the organization invests more than 1.5 Million Birr (equivalent to about 173,410 USD) to improve the potable water supply and sanitation services in a few kebeles of Minjar and Shenkora Woreda, Amhara regional state. The major components of the projects were construction of institutional and hh Reservoirs or Water tanks, public water point, TPLs and provision of sanitation and hygiene education to the user community (Water Action, 2001).

Figure 1-1: Typical 40 M^3 Ferro Cement Reservoirs in Chele Primary Second Cycle School, Minjar and Shenkora Woreda

Government and NGOs and individuals have made efforts on the dissemination and utilization of the RWH systems for various purposes in different corners of the country. However, the technological option of DRWH is not so far widely recognised as it would have been a number of merits, in terms of technical, economical, social and Environmental parameters, as compared to the conventional options; under specific conditions.

Moreover, there are a number of pieces of DRWH schemes that have been serving the intended community for log period of time nonetheless their performances might not be assessed or evaluated to improve the level of services.

Hence, this calls the need to evaluate the performance of existing DRWH schemes in terms of technical; social; economical and health aspects. Such evaluation enables to measure or reviews the appropriateness of the technology; the technical approach in terms of the design and construction standard; the effectiveness of the system management set up and its contribution to the national effort to improve the level of WatSan coverage.

Due to resources limitation this research shall focus only on the technical performance evaluation of DRWHS implemented by Water Action in Minjar and Shenkora Woreda, Amhara Regional State.Long services period is one of the major criteria for the selection of the scheme to be part of this study as compared to other similar schemes elsewhere implemented by the organization.

1.2. Statement of Problem

It is difficult to imagine any clean and sanitary environment without water. Human being have been using water since the down of history; but the realization of its importance and, in some instances, of its danger, to health is a relatively recent development.

Facts about the Ethiopia water Resources potential indicate that the annual surface runoff from the nine river basins amounts to 122 billion cubic meters. The three largest river basins (Abbay, Baro-Akobo and Omo-Gibe) contribute 76 percent of the total runoff from a catchment area comprising only 32 percent of the total area of the country (MoWR, 2002).

The ground water potential is estimated to be 2.6 billions of cubic meters. The country per capita [1]freshwater resources is about 1,924 m^3 and of course it has the largest surface freshwater resources in sub-Sahara Africa (MoWR, 2002).

Having all these resources Ethiopia is considered to be the water tower of Africa, however studies and assessments at different level indicate that the level of services in WatSan is very low. The most common sources of potable water supply as established by WMS indicate that 32.39 Percent of the rural hhs obtain water from River/Lake, unprotected well/springs 42.08 Percent, protected wells/springs 14.45 Percent, from public tap-locally called BONO 10.2 Percent and own tap 0.6 Percent (CSA, 2004).

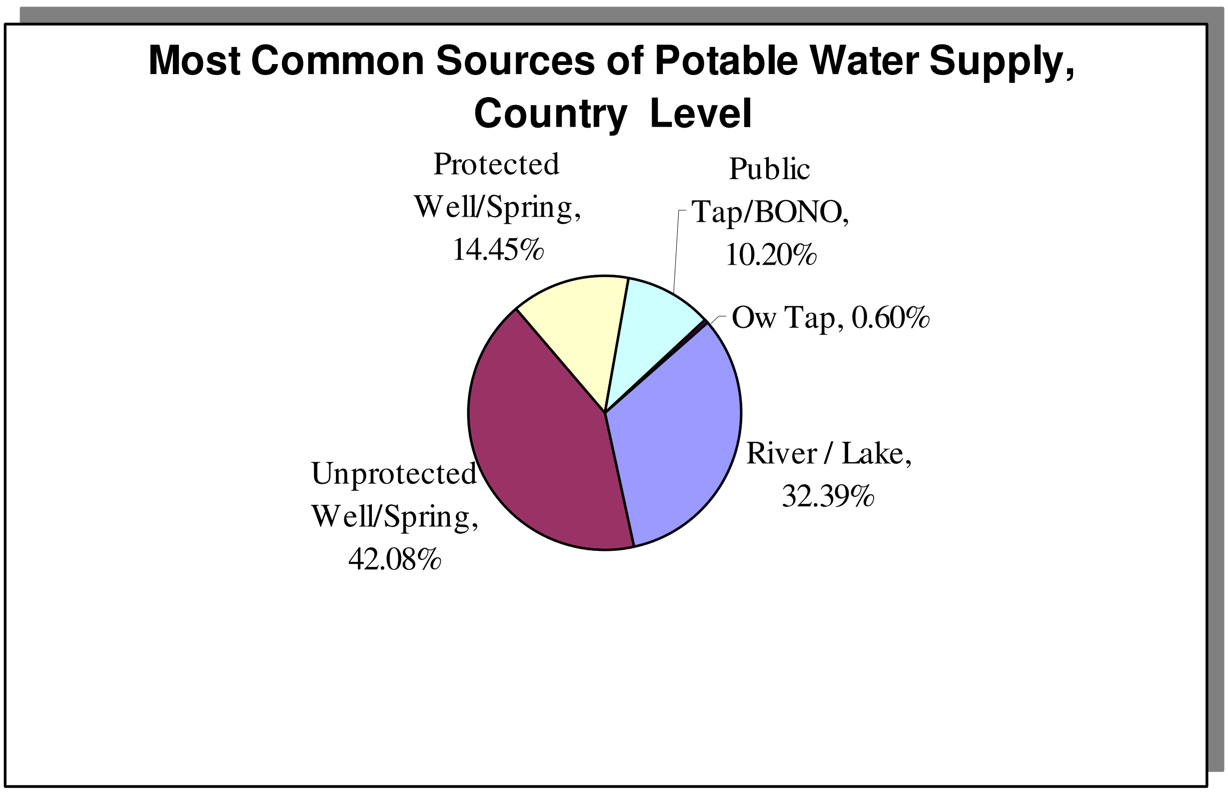

Figure 1-2: Most Common Sources of Potable Water Supply of the Rural Population, Country Level

One could learn from this the sources of domestic water supply in the rural community are concentrated on the conventional sources and about 75 percent use unsafe water for domestic

[1] Fresh water is water with less than 0.5 parts per thousand dissolved salts

uses. Moreover some of the techniques such as protected well might be very complicated and might not appropriate options in some specific conditions.

Lack of awareness, skill/knowledge and standards are some of the major problems that hindered the efficient utilization and dissemination of DRWH technique. For instance both the national Water Resource Management Policy as well the sector development programs are not given emphasizes about rainwater harvesting as an alternative sources of domestic water supply.

However, recently realizing the multidimensional benefits of RWH a number of institutions (government and non-government) and individual have made efforts on the dissemination and utilization of the RWH systems to improve the low level food security and safe water supply coverage of the country.

1.3. General background of the study Areas

Water Action has implemented two independent DRWH schemes in Minjar and Shenkora woreda namely Sama Senbet Roof Water Harvesting Project and Minjar and Shenkora Low Land PA's Roof Water Harvesting, Sanitation and Hygiene Education Project. The former Project was mainly financed by OXFAM UK (an international NGO) while the later by the ESRDF.

1.3.1. Physical Aspect of the Minjar and Shenkora Woreda

1.3.1.1. Location and topography

Minjar and Shenkora Woreda is located in the Amhar Region, which is one of the biggest regional states in the country with a total population of 19,120,005 and majority of the population are ethnic of Amhar (91 percent) adhere to Orthodox Christian and the remaining 9 percent of the population are composed of diverse ethnic groups belonging to, Oromo, Agew, Kemant, Tigraway etc. (CSA, 2006)

The total surface area of the region is about 159,174 Km^2 that supports a population density of about 120 persons per Km^2.

The Capital town of Minjar and Shenkora woreda Arerti is about 120 Km for Addis Ababa. The woreda could be specifically located in $39^0$15' to $39^0$45' East Longitude and $8^0$45'to $8^0$55' North latitude. The nearest biggest town Modjo (which is under the Oromia regional state) is located at about 50 Km from Arerti. The total surface area of the woreda is estimated to be 1,521.72 Km^2 and population density 90 person per Km^2.

The topography is mainly rugged and rolling with wide terraces and steep escarpment along Shenkora River. The maximum altitude is 2670m amsl at the north extreme and descends to 1400m amsl to the south-east.

1.3.1.2. Climate and Rainfall

1.3.1.2.1. Rainfall Amount and Distribution or pattern

Since there is no metrological station, any class, in Minjar and Shenkora Woreda the research uses the nearest metrology station located in Modjo town. Modjo is located about 50 Km from the woreda town. (Refer Annex 1-2: Mean Monthly Rainfall; Modjo Station).

Minjar and Shenkora Woreda could be categorized under Dega and Woyna-Dega agro climatic Zones. As per the NMSA classification, the woreda could be classified under region A Bimodal Type-1.

The small rain BELG occurs from March to May and the main rain MEHER occurs from June to August. The annual rainfall ranges from 637 to 1520 mm and the mean is about 940mm. The rainfall amount is higher at the northern part while decreasing as it moves towards the south-east, as the altitude descends from north to south-eastern direction.

1.3.1.2.2. Temperature and Evaporation

The mean annual maximum temperature varies from 27 to 29 C^0 and the mean minimum temperature varies from 10 to 13 C^0.The average annual evaporation is estimated to be 2041mm (Refer Annex 1-3: Mean Monthly Maximum and Minimum Temperature, Modjo Station).

1.3.2. Population

The total population of the woreda is about 99,402 and majority of the population are ethnic of Amhar (94 percent) adhere to Orthodox Christian and the remaining 6 percent of the population are composed of diverse ethnic groups belonging to, Argoba, Oromo, Tigraway etc.(CSA, 1994). Based on the 1994 population data and assuming constant population growth rate (2.45 percent) the current projected population is estimated to be about 136,160.

1.3.3. Existing water supply and sanitation situation

The woreda is characterized by poor surfaces and subsurface water resources potential. Regardless the quality of water Runoff harvesting via construction of pond is the most common sources of water supply both for domestic and animal watering. Construction and system management of ponds is becoming a typical practice of the Minja and Shenkora Woreda people

Figure 1-3: Typical Pond in Kiticha Kebele, Minjar and Shenkora Woreda

Though there are a number of limitations of using ponds as sources of domestic water supply; the limited period of services in a particular year, storage of polluted water and regular desilting are the major problems with the system. Theses characterized the low level performance of the major existing sources of water supply the study area. Thus, it is evident that people in the woreda have been suffering from multi dimensional safe water supply problem such as long travel time, regular desilting and health problems are among others.

The other types of existing sources of water supply are rivers and deep wells. In most of the cases wells are drilled to a depth ranging from 200 to 260 m and yields 0 to 11 l/sec. A typical well drilled to a depth of 240 m within the catchment area of the DRWH schemes yields a discharge of 0.61 l/sec, these revels that the ground water potential is very low in the study area (Water Action, 1996).

1.4. Objectives

1.4.1. General Objective

The general objective of the study is to diagnoses the technical performance of domestic DRWH schemes implemented by Water Action in Minjar and Shenkora Woreda.

1.4.2. Specific Objective

- ✓ To provide an overview of the DRWH technology;
- ✓ To evaluate the overall technical performance of DRWH schemes in terms of reservoir capacity and water quality;
- ✓ To indentify the main challenges on the promotion of DRWH schemes/projects; and
- ✓ To propose design standard and criteria for the various components of DRWH technology

1.5. Data sources and methodology

1.5.1. Data Sources

The beneficiary or user community that are obtaining the services, field measurements and observations are the primary sources of data for the study. In order to achieve the objectives of the study secondary data are also used. These data are obtained from the woreda water desk, project offices, and agriculture & rural development offices that are found at grass root level. In addition to these literatures, different WebPages, project documents or proposals, project evaluation and completion reports are also refereed.

1.5.2. Methodology

The unit of analysis for the study is specifically related to the numbers of schemes or observed sample schemes that have been implemented by the institution in different timeframe.

Data were collected using semi-structure interviews, different questionnaires (Refer Annex 1-4), discussion with the WatSan committee and water management boards, discussion with the user community, physical observation and measurement of components, water sampling from selected schemes.

Quantitative services indictors established by WHO for water quality has been used in this study (WHO, 1996).

Parameter	Recommended Level
Faecal Coli forms	0 per 100 ml
Turbidity	< 5 NTU[2]
Disinfectants residual	0.2-0.5 mg/l
PH	6.5-8.5

The mass curve technique and the SIMTANKA software has been used for determining the optimal capacity of reservoirs or tanks size.

1.6. Justification for the Study Area

The evaluation of the schemes has started from the identification of existing DRWH schemes that have fair time frame to evaluate the envisaged technical quality and services performances.
The DRWH schemes implemented by Water Action in Minjar and Shenkora are selected for the assessment due to the following main reasons:

- ✓ The projects are implemented in 1997 and 2001, so it may be a fair time frame to evaluate the technical performance of a WatSan schemes;
- ✓ The project has crucial surface and sub surfaces water resources problems;
- ✓ DRWH has been exercised as an appropriate technological option to improve the safe and adequate water supply provision in the woreda; and

[2] NTU Naphelometric Turbidity Unit-naphelometer is a modern commercial instrument used to measure turbidity

- ✓ Experience and direct exposure of the researcher.

1.7. Limitation of the Study

- ✓ Institutional DRWH schemes like those implemented in school compounds the turnover of the water committee is nearly every year, so basic information about income and expenditure and scheme management and other information can't be easily found.

- ✓ It is also found difficult to know the exact number of beneficiaries of each of the schemes as the number of beneficiaries depends on the availability of water in the traditional ponds or more specifically on the length of dry period.

- ✓ It is difficult to find information such as the reservoirs operation i.e. tanks filling and empting time, the total services duration or the fraction of time when the tank is completely depleted and the like
- ✓ Unwillingness of water committees to discuss about water revenue and current capital and financial management system etc.

1.8. Organization of the thesis

The thesis is organized in seven chapters. ***CHAPTER ONE*** deals with introduction that covers the general background of the study area, the problem statement, objectives of the research, the research question, justification, limitation of the study, organization of the study. C***HAPTER TWO*** deals with an overview of DRWH technology. ***CHAPTER THREE*** covers standard design criteria and approaches. ***CHAPTER FOUR*** discuss about construction material, management and repair. ***CHAPTUER FIVE*** covers data analysis. CHAPTER SIX covers the result of the study. The last but not least chapter is **CHAPTURE SEVEN** that deals with conclusion and recommendations.

CHAPTER TWO

2. overviews of DRWH system

2.1. General

Water professionals are becoming increasingly worried about water scarcity. The UN world water development Report of 2003 states that population growth, climate change are likely to be combined to produce a drastic decline in water supply.

Many efforts have been made by the government and non-governmental organization to improve the provision of safe and adequate water supply to the rural communities by employing different techniques. The technical options in some case are so simple but in most of the cases the solutions are to some extent complicated or difficult to insure sustainable service and management at the capacity /technical knowledge/ of the intended beneficiary community.

Rainwater harvesting technology is gaining popularity in a new way. Rainwater harvesting is enjoying renaissance of sorts in the world, but its traces its history to biblical times. Extensive rainwater harvesting apparatus existed 4000 years ago in the Palestine and Greece. In ancient Rome, residents were built with individual cisterns and paved courtyards to capture rainwater to augment water from city’s aqueducts (Directorate of town panchayats, 2007).

In Australia the use of domestic rainwater tanks has been a long standing and relatively common practices. In 1994 a survey by Australian Bureau of statistics showed that about 13 percent of all Australian hh use rainwater tanks as sources of drinking water. Similar survey conducted in the southern Australia in 1996 showed that 82 percent of the rural population use rainwater as primary sources of water for drinking (David A Cunliffe, 1998).

The history of rainwater harvesting in Ethiopia dated back as early as the pre Axumit period (560 BC). It was a time when rainwater was harvested and stored in ponds for agricultural and water supply purposes. Anthropologist has documented evidences of the remains of ponds that were once used for irrigation during this period (Fattoyich, 1990).

Other evidences include the remains of one of the old castles in Gonder (Fasiludus), constructed in the 15-16th century, which used to have water harvesting set up and pool that was used for religious rituals by the king (Getachew,1999).

RWH systems can be categorized in to two categories based on type of catchment surface and uses. According to catchment type, RWH could be roof catchments, rock catchments, ground catchment and according to use check and sand dams. Roof and rock catchment systems could be directly used for domestic purposes with little effort exerted on improving water quality while ground and check or sand dams could be used for livestock watering, nurseries and small-scale irrigation and some domestic purposes.

DRWH system provides an innovation solution to meet local water needs. In recent years, the system has become cheaper and more predictable in the performance. DRWH systems deliver a good quality water directly (at the Get) or at every shorter distance to the targeted community or hh. This qualifies it to be one of the options of water supply via reducing burden of water caring particularly for women and female children who are traditionally believed to be responsible. Moreover, RWH is not limited as mean for provision of water supply rather it is more importantly practiced in the developing countries as supplementary water sources during long dry spells for food production i.e. vegetables and subsistence crop production (Lakew, 2004).

A number of researches have been carried out in the world to improve the technology of DRWH techniques to be a chipper (affordable to the community), sustainable, safe source of water supply. Subsequent sections shall discuss the definition and Principles, benefits, components, overviews of Global and national DRWH experiences.

2.2 Conceptual Frame work

As per the information obtained from national water resources management policy water is a naturally endowment to all citizen and as far as possible it should be deliver to the people in safe way. Population is regressively increasing and the world climate is changing and worsens from time to time due to natural and manmade ecological disturbances. Thus, the degradation of the natural resource and the increase in population causes water to be a scares resource So sustainable utilization of the available water resources for socio-economic transformation becoming a strategic objectives of both the developing and the develop world (MoWR, 200).

The basic source of all water on the earth is rainfall/precipitation, snow etc. about 70 Percent of the precipitation that reach on the land area is evaporated or transpired directly back to the atmosphere; 10 Percent socks in and becomes ground water, and 20 Percent runs off in to lakes, streams and rivers (B.C.Punmia, J.Ashok, J.Arun (1995).

Thus using DRWH system we can use the rainwater/rainfall before any of the losses mentioned in the above paragraph and avoid the difficult to regain it back by investing huge amount of money for pumping, construction of Dams or reservoirs, construction of purifications or treatment plants and convey the stored water from head works to each house through various pipes size and length etc. Figure below shows the main forms of rural water supply (T.H.Thomas, 2003)

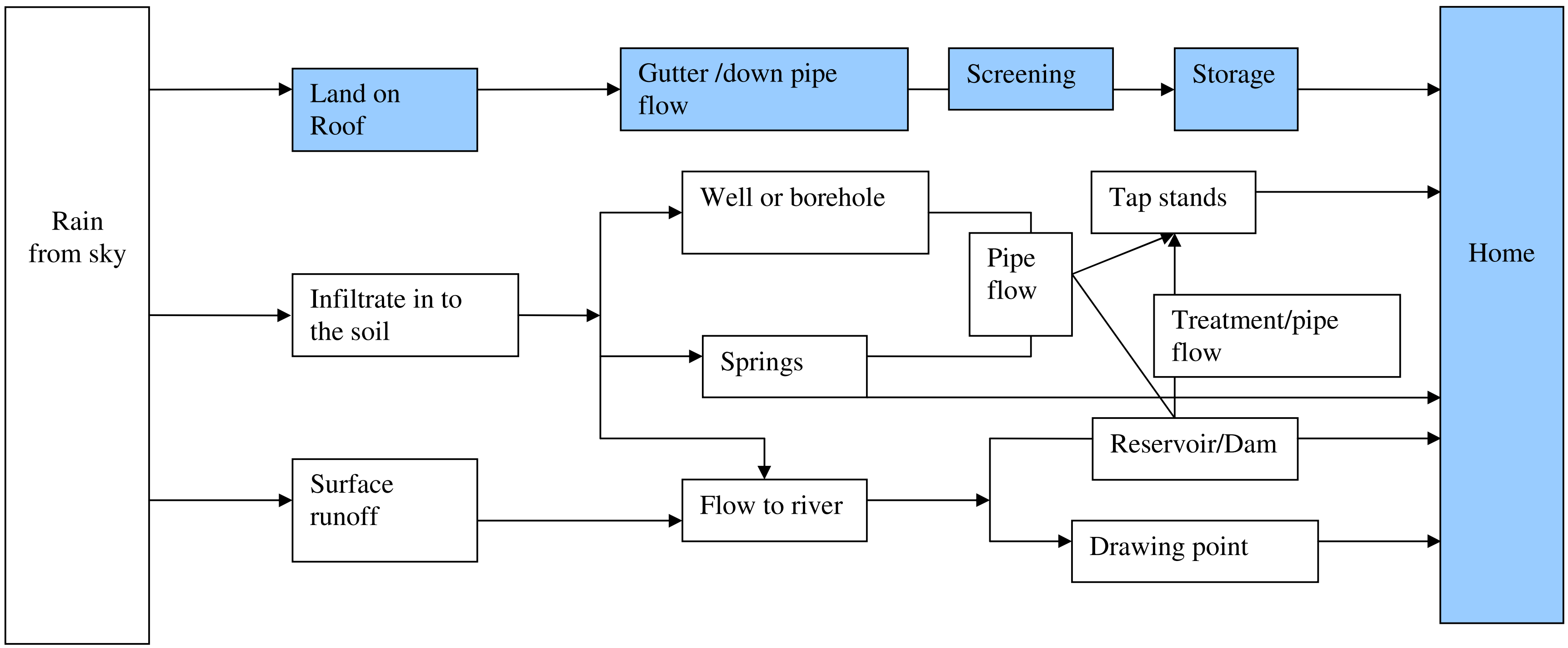

Figure 2-1: Model Rainwater Harvesting System (Adopted from T.H Thomas,2005)

2.4. Definition of DRWH

The term DRWH has two elements Domestic and RWH. So it may be useful to define both of the terms to clearly understand the meaning and scope of DRWH.

WHO defines domestic water supply as being 'Water used for all usual domestic purposes including consumption, bathing and food preparation' (WHO, 1993; 2002).

Different authors define RWH as follows:

RWH could be defined as collecting and diverting the naturally endowed rainfall for pre-specified purpose at the required demand and quality.

RWH is the collection of water that could be otherwise have gone down the drainage system, into the ground or been lost to the atmosphere through evaporation (UK Environmental Agency, 2007)

RWH is an art of harvesting; storing, utilizing and managing rainwater system.

RWH is broadly defined as the collection and concentration of runoff for productive use (crop, fodder, pasture or threes production, livestock and domestic water supply) it includes all method of concentrating, diverting, collecting, storing and utilizing and managing runoff for productive use.

RWH technique broadly includes roof water harvesting, run-off harvesting, flood water harvesting and sub-surface water harvesting (Finkel and Segerros, 1995)

More technically, one could define rainwater harvesting as the means of taking water out of the hydrological cycle for either human or agricultural uses. The rainfall is intercepted and collected on prepared watershed (E.J.Schiller and B.G Latham, 1996).

Thus based on the above possible definitions; one could define DRWH as:

A system of RWH by which Roofs are an obvious choice of a catchment surface (as their elevation protects them from contamination and damage) to harvest the natural endowed rainfall and store for pre-specified domestic purposes (T.H.Thomas, 2003)

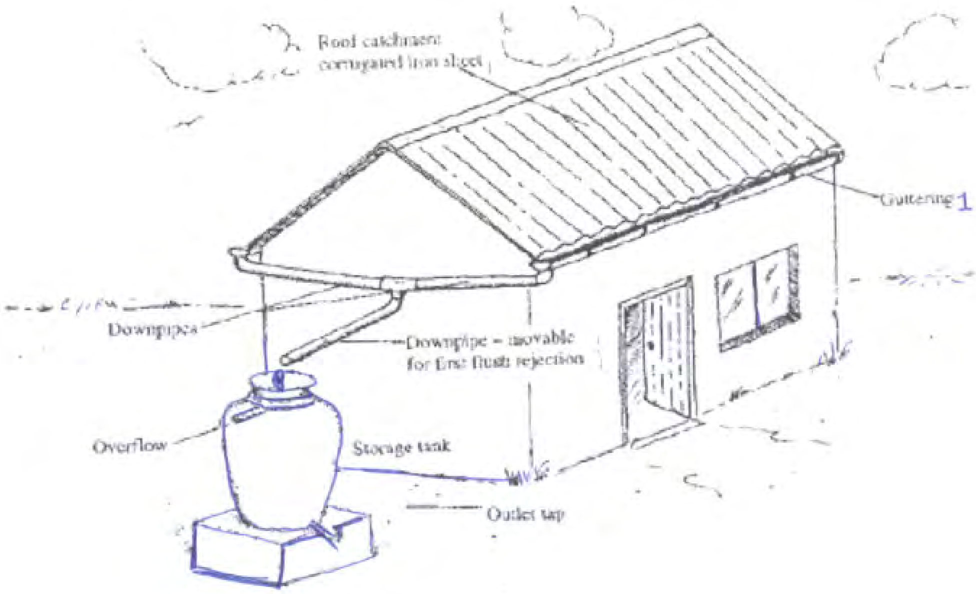

Figure 2-2: A Simple but Widely Used DRWH System in developing countries

2.5. Why and when RWH/DRWH?

RWH is essential because on the one hand surface water is inadequate to meet all of our demands and we have to depend on ground water, which in most of the cases is an expensive option; on the other hand due to rapid urbanization, infiltration of rainwater into the sub-soil has decreased drastically and recharging of ground water has diminished. Therefore we required to harvest rainwater for future uses such as crop production, domestic water supply; garden watering; car and street washing etc.

DRWH has a number of areas of technical options depending on the prevailing natural water resources condition of a specific area; these include:

- ✓ Where ground water is either difficult to access or need special treatment to remove excess minerals such as Fluorine, salinity (salt intrusion), Arsenic etc;
- ✓ Where limited rain fall, Poor surface water quality and distances between individual consumers make this an attractive option;
- ✓ Where annual rainfall is plentiful but long dry season exist;
- ✓ Area where housing development is resulting in new Roof materials replacing traditional thatched materials; and where clear water is needed for drinking purpose; and
- ✓ Where existing water price is significant (urban centres) and to subsidized in relatively wet season

2.5. Advantages and disadvantages of DRWH system

2.5.1. Advantages

DRWH surpass the conventional sources of safe water supply schemes in terms of:

- ✓ An available natural resource that should not simply wasted;
- ✓ Rather than noting the opportunity of capitalizing on cases of abundant rainfall, it was felt that DRWH/RWH was particularly advantageous in areas where more conventional (communal or piped) water supply technologies were not available, either due to an existing lack of coverage or perhaps due to a shortage of surface and groundwater supplies;
- ✓ The quality of rainwater is high, especially in developing country (where the level of industrialization is very low and the occurrence of [3]acidic rain is minimal);
- ✓ The system is independent, and therefore suitable for scattered settlement;
- ✓ It empowers users, placing the authority and responsibility to manage, operate and maintain the system right at the hh (consumer) level. This includes control over the quality of harvested water overtime;
- ✓ Systems built on a family basis and attached to the family home generate a powerful sense of ownership and responsibility;

- ✓ Local materials and craftsmanship can be used in DRWH system construction;
- ✓ No energy costs are needed to run the system;
- ✓ Ease of maintenance by the owner/user;
- ✓ It is inclusive; all members of the family can become involved;
- ✓ Convenience and accessibility of water; and
- ✓ Valuable time and energy is saved in collecting water

In addition to the above major listed advantages the system has a number of benefits, among others include:

- ***Time saving in fetching water from conventional sources***

  Especially in the rural area where adult women and children are traditional considered as responsible for water collection and fetching to the family; significant amount of time and energy could be saved for other income generating activities. Moreover, children school dropout significantly would reduce, as they might have enough time to go to school as well as for study.

- ***Use of extra water***

By putting in place DRWH system we can avail additional water to the hh so that significant hygiene and sanitation benefits will be exercised.

- ***Use of thanks as a storage medium***

  Water tanks during the dry period can be used as storage for water from the conventional sources.

- ***Money saved for purchasing water***

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[3] Acidic rain ; water with PH<5.6

Whatever the scale of a public water supply system may be water will have cost that shall be used at least for O and M of the scheme. Studies indicate that using rainwater for garden watering, toilet flushing and washing machines can save up to 50 percent of hh water use i.e. we can cut down the monthly water Bill by 50 percent (UK Environmental Agency, 2007)

Sir Lanka, enhanced access to water by household roof water harvesting has contributed 50 to 70 percent to the total household water requirement (Lanka Rainwater Harvesting forum, 1999).

- ***Money earn by selling water***
  In some community where water is so scarce, harvested rainwater could be a source of income by selling to the neighbours.

- ***Exposure to new technologies and new skill***

  The rural community will have a new exposure and experience i.e. build its capacity to develop alternative sources of safe water.

- ***Improve safety for hh members***

  Studies and outputs of survey findings reveal that women have faced a number of problems while travelling to access safe water from a distance location. For instance rape and abduction are the most common cases reported mainly in the rural part of our country.

2.5.2. Disadvantages

Some of the disadvantages or limitation of DRWH system are:

✓ High initial capital cost may prevent a family (specially the poor) from buying the system;

- ✓ The amount of water harvested is limited by rainfall amount and available Roof area or size and quality. Supplementary water sources may be needed; for long dry seasons, the required storage volume may be too high/ expensive;
- ✓ Mineral-free water has a flat taste while people may prefer the test of mineral-rich water and
- ✓ Mineral-free water may cause nutrition deficiencies in people who already on mineral-deficient diet

Challenges to Overcome

- ✓ Systems need to be carefully designed to optimise the coverage that a system can provide each year for a given level of investment. Systems that are more reliable need greater storage capacity and are more expensive to build. System reliability follows the law of diminishing returns and 100% reliability is prohibitively expensive to achieve;
- ✓ System reliability depends on statistical analysis of rainfall data. Data quality is therefore very important;
- ✓ Harvested water quality is a concern. Potential for contamination is high and is related to system design especially true for first-flush systems, unseen seepage into underground tanks (leakage of stored water can also be a problem) and water management/abstraction techniques;
- ✓ Systems can become a health hazard due to breeding of vectors such as mosquitoes and
- ✓ Systems require expensive roofing and are therefore less accessible to poorer families.

2.6. Planning and Development of DRWH

The initial steps in planning and development of DRWH involve an appraisal of the feasibility of the system. The feasibility can be determines in light of at least three constraints: technical, economical and social.

2.6.1. Technical

2.6.1.1. Supply

The initial consideration of the feasibility of DRWH concentrates on availability or depth of Rainfall as compared to its use or demand. The yield or supply of water depends on how much depth of rainfall the area received under normal and worst condition or the dependable average annual rainfall of the area.

As per the NMSA of Ethiopia the country is divided in to four (4) regions based on rainfall types. They are (i) Region B: mono modal type-1 (ii) Region D: Mono modal type-2 (iii) Region A: Bimodal type-1; and (iv) Region C: Bimodal type-2 (NMSA, 1996).

When the rainfall occurs in one continuous period of time in a year, this is termed as mono modal and when this occurs in two discontinuous periods in a year, this is termed as bimodal. Again, each of these are divided in to type1 or 2 based on the time of occurrence of the continuous period/s or by the prominence of rainy period.

Mono modal type-1: Dominates by a single maxima rainfall pattern
Mono modal type-2 /Diffused pattern/: Irregular rainfall pattern (does not have well defined rainfall pattern
Bimodal type-1: Characterized by quasi-double maximum peak in August
Bimodal type-2: Dominates by double maxima rainfall pattern with peak during April and October

In a more comprehensive manner the Ethiopia climate seasons could be classified in three seasons. These are given as Bega; which is generally the dry season that covers the period from October to January, Belg: Refer to a small rain season that covers the period from mid-February to mid-May and Kiremt: Refer to the main rainy season that cover the period from June to September. About 50 to 90 Percent of the main annual rainfall occurs in Kiremet season over the principal cropping Zone. In Bega season, the rainfall varies between 10 to

400 mm; this is about 25 to 600 mm in Belg season and about 10 to 1200 mm in kiremt season (NMSA, 1996).

Quality of rainfall data can be think of at least six categories (E.J.Schiller and B.G Latham, 1996).

- ✓ No numerical data available, but of course local people knows quite well the seasonality of precipitation and which crops will grow (with what sort of water-stress failure rate);
- ✓ There is no numerical data, but RWH has been practised for long enough locally for people to have a feel for what is an adequate tank size;
- ✓ Only annual average rainfall is available, probably at a somewhat distant recording point, plus local knowledge of seasonality;
- ✓ Monthly rainfall, average over at least 4 years, can be obtained;
- ✓ Actual monthly rainfall records for at least 4 years, and preferably 7-10 years, are available for the site or for a location sufficiently nearby to give confidence or allow some systematic correction to be applied;
- ✓ Daily rainfall data for a relevant location and lasting at least 4 years is available; daily data is adequate for all design methods except perhaps the optimisation of Gutters for which rainfall intensity data is useful.

Thus, in the planning of DRWH/RWH reliable Rainfall data are required. This information can be obtained from the Government Methodological Office or Agency, the Ministry of Agriculture, University, Airports. In our country the NMSA provides this information at reasonable cost for private sector and NGOs and without payment for researchers from Universities.

2.6.1.2. Demand

For technical judgment the next most important element is the demand. The demands imposed on the system depend on water use. In the hh, water is used for various purposes such as for drinking, clearing, cooking and washing. In rural part of our country per capita safe water demean is estimated to be ‘’between’’ 15 to 25 l/c/d (MoWR, 2002).

However for special cases where the supply is much more less than the normal requirement, demand could be cut down to a specific purpose like for drinking and cooking and the amount to be 10 l/c/d and for school children the demand could be taken as 5 l/c/d.

The volume of water needed per person vary from one area to another; water demand in general depends on:

- ✓ The range of use or purposes;
- ✓ The number of people to be served;
- ✓ Climate, religion, culture, living standard (socio-economic condition) and
- ✓ Availability and complexity of developing the water resources etc

Once the supply (Roof runoff) and the average per capita demand of the hh or group people is fixed the next step is the decision making criteria i.e. estimating the total demand and compare it with the supply. This is could be demonstrated roughly as follows:

If the roof area of a residential building is 25 m^2 and the annual average precipitation of the locality is 1200 mm, then rudimentary maximum supply over a period of a year would be about 30 m^3. On the other hand the total annual safe water demand could also be estimated to be 25 m^3; based on 10 l/c/d (drinking and cooking only) and average household number to be 7 persons.

If supply exceeds demand, then the rainwater harvesting system is feasible from supply-demand point of view. If the supply is less than the demand the possible solutions would be either increasing the catchment area (may be difficult under practical condition) or reducing the demand (reduce the purpose of the harvested water like use the water for drinking and cooking purpose only; as demonstrated in the above example and balance the total demand from other source/s.

2.6.1.3. Economics

DRWH must be economically justifiable or feasible to the hh or user community. Investment cost of proposed DRWH system must be evaluated and compared with the cost of alternative water supply improvements. It has been discussed that DRWH is a feasible option if other conventional sources are not feasible option

Cost of renovation of building in general or only the catchment (roof) depends on the local price of building materials and associated storage requirement. The system may be economically justifiable but it must also be affordable to the hh or users community.

The tank forms the largest single cost in DRWH system and in higher capacity system it will dominate totally, accounting for 90 Percent of the total system cost. In smaller capacities low cost systems, the tank will be command about 70 Percent of the system cost. It is therefore vital to get this component rightly. Tanks can be made cheaper by reducing either the size of the tank, the quality of material used or increasing the fraction of hh contribution either money or time in production (T.H.Thomas, 2003).

The selection of the tank size involves the right play of a number of variables, some are easily measurable and others are more difficult to quantify. The most important to a water supply organization are the cost, coverage and service delivery.

Selecting a thank design with too high cost will have several ramification. Like:

- ✓ There will be low service coverage
- ✓ The technology will not be replicated, as it is too expensive
- ✓ Full cost recovery will prove impossible

In general, we might say a RWH system is “economically viable’’ if the benefit of harvesting is greater than the cost. There are various ways of making the comparison; of these the payback time is fairly easy for a water agency to use as in a test for economic viability, because it can compare with whatever is the “acceptable” upper limit on payback time used by that agency for other water investment of comparable risk.

The use of Roof water harvesting is to be widespread in a region where the demand is acute; financing for the tanks should be available from the community and NGOs. In some special cases or arrangement capital can be made available in the form of a revolving fund.

2.6.1.4. Social

Once it has been tentatively established that it is technically and economically feasible to construct DRWH the next step involves social and economical assessment. This stage is critical to the success of the system.

The DRWH planner must determine the extent of community needs- this must be done in light of traditional practices within the community. The role of women and children in carrying water and amount of time spent in this activity should be examined critically.

Gender roles and status not only determines the opportunity to participate in Roof water harvesting imitations but also influence the way in which the benefit of DRWH are realized. Women are the main beneficiaries yet this traditional lack of control over hh resources associated with Roof water harvesting, this limits role in decision making in the home, and their limited access to information and credit stand in the way of them being able to achieve these benefit.

The engineer should collect information on existing catchment technologies and discuss with the community the usefulness of water supplies by a Roof water system. Users should be informed for the playability of rainwater. The community need for communal versus individual catchment system should be evaluated.

Learning the local indigenous knowledge or skill, local available construction material and experience that can be used in Roof water harvesting system are very critical elements for designing of low cost DRWH system where the sustainability is quite assured. The use of PRA as a tool for collecting information from the community has to be well exercised to probe more and more information.

Eventually, the community members will decide if they are willing to participate in stages of the project i.e. in terms of the amount of time to work with, labour and money hhs are willing to commit to the project.

2.6.1.5. Health

The ultimate goal of provision of safe and adequate water supply is to improve the quality of life of the community as a whole; so designing DRWH should be made in multi-disciplinary approaches. Thus the outcome shall address all the pertinent problems of the community in sustainable fashion.

Assessing the sanitation and hygiene practices of the community is very essential on the design of the system to attain the envisaged impacts of the project or the system. For this baseline health survey has to be carried out to identify the area of sanitation and hygiene education promotion.

In general water, potable, from any source has to be handled properly or hygienically from the source up to use in house.

2.7. Rainwater Harvesting Techniques

There are two main techniques of rainwater harvesting:

- ✓ Storage of rainwater on surface for future use; and
- ✓ Recharge to ground water

The storage of rainwater on surface is a traditional technique and structures used were surfaces and underground tanks, ponds, check dams, weir etc. while recharge to ground water is a new concept of rainwater harvesting (Directorate of town panchayats, 2007).

The structures generally used for groundwater recharging are:

Pits: - Recharge pits are construed for recharging the shallow aquifer. These are constructed 1 to 2 m, wide and 3 m deep which are back filled with boulders, gravels, coarse sand;

Trenches: These are constructed when the permeable strata is available at shallow depth. Trench may be 0.5 to 1m wide, 1 to 1.5 m deep and 10 to 20 m long depending up on availability of water. These are back filled with filter materials;

Dug wells: Existing dug wells may be utilized as recharge structure and water should pass through filter media before putting into dug well;

Hand Pumps: The existing hand pump may be used for recharging the shallow/deep aquifer, if the availability of water is limited. Water should pass through filter media before diverting into hand pumps;

Recharge wells: Recharge wells of 100 to 300 mm diameter are generally constructed for recharging the deeper aquifers and water is passed through filter media to avoid choking of recharge wells;

Recharge Shafts: For recharging the shallow aquifer which are located below clayey surface, recharge shafts of 0.5 to 3 m diameter and 10 to 15 m deep are constructed and back filled with boulders, gravel and coarse sand;

Lateral Shaft with bore wells: For recharging the upper as well deeper aquifers lateral shafts of 1.5 to 2 m wide and 10 to 30 m long depending upon availability of water with one or two bore wells are constructed. The lateral shafts are back filled with boulders, gravel and coarse sand.

Spreading techniques: - When permeable strata start from top then this technique is used. Spread the water in streams by making check dams, bunds, cement plugs, gabion structures or percolation pond may be constructed.

CHAPTER THREE

3.1. STANDARD DESIGN CRITERIA AND APPROCHES

There are various categories of DRWH system arrangements. The following sub-sections shall discuss each of the major components of DRWH system and the standard design parameters.

3.1.1. Catchments

Basically, there are two types of rainwater harvesting schemes; those designated for agriculture use and those designated for domestic water supply. DRWH systems can roughly be broken down in to four primary processes and three treatment processes (Warwick University, 2005).

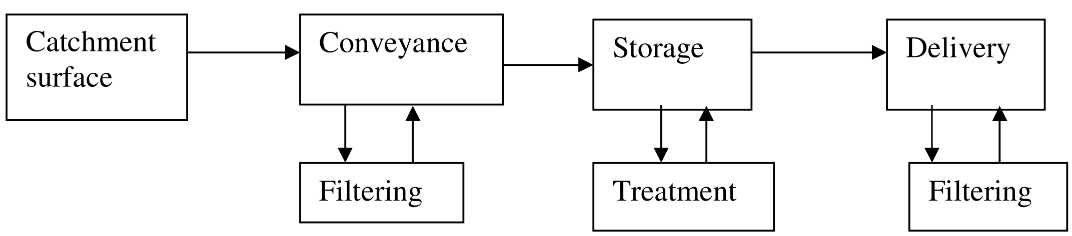

Figure 3.1: Primary Processes of DRWH System (Adopted from Warwick University, 2005)

There is a considerable range in complexity of DRWH systems. Where the simplest may be the use of any form of catchment or roof regardless the quality and size of the Roof for instances the use of a banana leaf as a means of conveyance to unknown volume of storage material be from plastic ,earth, clay pot or any. On the contrary, the most complex or sophisticated system might be with automatic treatment at each stage of the process, electronic monitoring and dual reticulation systems.

Typical hh or community level DRWH system in developing countries, like us, comprises corrugated iron sheet Roof as a catchment, Steel Gutter or down pipes as conveyance structure and Barrel or Ferro cement tank as storage with varying capacity.

RWH for agricultural use require large catchment areas and in this case use of ground surface storage is the obvious choice. On the other hand, rainwater for human consumption should be cleaner than water for agricultural use and roofs are obvious choices of catchment surface as their elevation protect it from contamination, which are common to surface water and treatment is needed as a prerequisite for their development as potable water supply. Ground catchments are prone to contamination by human and animal faecal matter, rotting vegetation, Agricultural inputs etc.

In general catchment determines the quantity and quality of water to be harvested. Types of catchment could broadly classify as Roofs (GI sheet, Asbestoses, thatched etc), Ground (earth soil) and Rock. GI sheet Roofs are fare best due to their relative smoothness and the sterilizing effect of the metal Roof heating under the sun Galvanize steel is not inherently resistant to corrosion but it is available with rust resistant coating such as Zincalum and other materials (David A Cunliffee, 1998).

Asbestos roof material (used on older home) should not be part of a system to provide drinking water. Similarly cementitious (concrete tile and fiber-cement shingles) and clay tile are not recommended because they can support mold, bacteria and algae growth and more difficult to clean (FloTrue International corp (2005).

The total rainfall amount or depth can't be fully trapped from a catchment, which ever the type may be, to the storage thank or reservoir. There are losses that are mostly due to infiltration, wetting the surface and splashing due to either wind effect or size of the Gutter and /or down pipes. Loss associated with adsorption and wetting of surfaces accounts about 2mm per month or 12mm per year (Martin, T.J (1980).

These losses are usually represented by a Run-off coefficient, a number between zero and one. A good impermeable Roof as corrugated iron sheet will deliver almost all rainwater fall on it. Ground catchment has a lower runoff coefficient as rain infiltrates in the pores of the soil and joins the ground water.

Table 3-1: Runoff Coefficient and Characteristics of Different Roof Types

No	Type	Runoff coefficient	Note
1.	GI Sheets	> 0.9	• Excellent quality water, surface is smooth and high temperature helps to sterilize bacteria
2.	Tile (Glazed)	0.6 to 0.9	• Good quality for glazed tiles • Unglazed harbor mould • Contamination can exist in tile joints
3.	Asbestos	0.8 to 0.9	• New sheets give good water quality • No evidence of carcinogenic effects by ingestion (Campbell, 1993) • Slight pours so reduce runoff coefficient and older Roof harbor moulds and even moss
4.	Organic (Thatch, Cadjan)	0.2	• Poor quality water (>200 FC/100ml) • Little first flush effect • High turbidity due to dissolved organic material which does not settle

Sources: Warwick University, 2005

As one can see from the above table, the poor performance of organic Roofs would seem to preclude them from the use for rainwater harvesting system. Nevertheless, organic Roof could be used for secondary purposes and discouraged to use for domestic purposes.

Various techniques have been used to improve thatch Roof to use for domestic water supply like polythene sheeting however, the sheeting tends to degrade in sunlight quickly and could only be used for only one season. The use of thatch Roofs for domestic water supply or as secondary source (watering livestock or gardening and the like) is not as such practiced in many developing country. The reason could be cost of the polythene sheet is very expensive including Guttering and other accessories.

As discussed before ground catchment has a much lower runoff coefficient than Roofs (0.1 to 0.3), however they are usually provide much larger catchment area. If it is superimpose with paved (rock, or concrete pavement) yield will be maximized as the runoff coefficient improves to 0.6 to 0.7 (Warwick University, 2005).

3.1.2. Gutter

The purpose of the Gutter is to convey the rainwater from the Roof to the storage tank directly or to the down pipes and then finally to the tank. The chance of significant losses of rainwater would increase as the conveyance system from roof to the tank is longer i.e. in some arrangements water is conveyed from roof by gutter and then from gutter to down pipes and then to collection box at the foot of each down pipe and then from collection boxes to tank by pipe system.

The usual Gutter material in developing countries is galvanized sheet metal with triangular (V-shape), rectangular or semi-circle in shape. There are variety of types of gutter in the world such as prefabricated plastic, Aluminium, Steel, Wood and Bamboo, half pipes, Flexible guttering. The selection of the type of the Gutter mainly depends on the cost, difficulty in mounting as well to some extent water quality (Peter Morgan, 1998).

Plastic gutter are less available in developing countries but in countries where industrial bases are good like Mexico, India and Sir Lanka, it is readily available at reasonable cost. Aluminium Gutters are non-corrosive but too expensive. Steel Gutter is relatively non-corrosive and very common in Africa. Steel Gutter produced in workshops are usually square in shape and the cost of theses Gutters is 2 to 3 times a similar Gutter produced on-site (Warwick University, 2005).

On site, Gutters are usual V-shaped. The shape is quite efficient but practices indicate that it has a tendency to block with debris; mounting V-shape Gutter is difficult as it is fixed just under the Roof edge. Rectangular Gutters can be easily fixed on fascia board, which is fixed on the rafter, but the problem is that fascia board might be missed and the distance from the Roof edge is random (Nissen-Petersen & Lee, 1990).

It is uncommon to use wooden planks and bamboo as gutter but in theory or in literature, it is possible to use being it is too cheap or no cost to the community (Agarwall & Narain, 1997 (Parcely & Cullis, 1996).

The problem with bamboo Gutter is durability, it decay and as well, linkage is possible. The porous media of bamboo forms an ideal environment for accumulation of bacteria that might be eventually washed in to the storage tank.

Half and flexible PVC pipes are normally coasty and are not as such durable due to brittle after degradation by UV (Hapugoda,1999).

The flow performance of a gutter varies along its length resulting in a spatially varying flow; however for a long gutter it can be approximated by the usual manning formula. Using this formula an idea of the actual size of gutter need can be developed for any gutter profile (Warwick University, 2005).

Table 3-2: Typical Gutter sizes

Sources	**Section**	**Roof size (m^2)**	**Slope (%)**	**Cross Sectional Area (cm^2)**
(Hermann & Hassen, 1996	Square	40 – 100	0.3 – 0.5	70
	Half Round	40 – 60	0.3 – 0.5	63
(Nissen-petersen & Lee, 1990	45^0 Triangle	Not Specified	1.0	113
(Edwards et al.1984	Not specified	Not specified	0.8 - 1.0	70 - 80

Heggen (1989) under took a detail theoretical analysis of the hydraulic performance of gutters. The various factors affecting a gutter's capacity to carry runoff from the Roof to the tank were examined. These included the gutter's length, cross-sectional area, shape, roughness and slope. As a general guideline to gutter dimension for catchment areas of different sizes, a useful rule of thumb is to make sure that there is at least 1cm^2 of gutter cross-section for every 1m^2 of Roof area (Hasse, 1989).

To avoid overflow during torrential down pours, it take sense to provide a greater gutter capacity. A 10 cm * 10 cm gutter with a cross-sectional area of 100 cm^2 can be used for Roof areas measuring up to about 100 m^2 under most rainfall regimes. For large Roofs/public Roofs, such as at schools the 14 cm * 14 cm V-shape is suitable from Roof section up to 50 m long and 8m wide.

Gutter should have sufficient and continuous fall to downpipes to prevent poling of water which could increase accumulation of materials, lead to algal growth and possibly provide a site for mosquito breeding. A fall of 1:100 to 1:500 should be sufficient (David A Cunliffe, 1998).

The result of Heggen's analysis revel a number of interesting insights, which are worth consideration when undertaking gutter design; these included:

- ✓ Increasing slope from 0.01 to 0.03 (1:100 to 3:100) increased potential water flow by between 20 and 100 percent- this effect was specially prominent for smaller gutter size;
- ✓ Semi-circular gutters were the most efficient at conveying water;
- ✓ The rule of thumb of 1 cm^2 of gutter cross-section per 1m^2 of roof catchment area seems to apply under realistic conditions i.e. a 20 m-long gutter on a 100 m^2 Roof (20m * 5m) subjected to a storm with rainfall intensity of 20 mm/hr

3.1.3. Down pipes

Down pipes are produced from different material; steel pipe or rolled sheet metal and PVC are the most common types. Down pipe cross-sections are sometimes smaller than those of the gutter as it is assumed that since they are normally vertical, water will pass through them faster than through Gutters. In Roof catchment systems, however down pipes should have similar dimensions to Gutters. This is because the down pipes are often not vertical and act as channel to convey water from the end of the Gutter in to tanks.

Suggested sizes of down pipes are given against the Roof area feeding the down pipe. These sizes are big enough for a pipe whose length is not more than six times its drop (where drop is the change in height from the pipe entry to the water level in tank). For down pipes laid very flat, whose length is more than six times their drop, the next larger size is recommended.

If tanks inlet filter is provided, then the drop should be measured to the top of the filter, not the water surface in the tank. In any case it is wise to provide a screen above the pipe entry to prevent twigs and leaves from entering it (T.H. Thomas, 2003).

Table 3-3: Recommended Size of Down Pipe

Gutter width /top width(mm)	Roof area served by one gutter (m^2)	Recommended down pipe size (mm outside diameter)
55	13	20
60	17	25
65	21	25
70	25	32
75	29	32
80	34	32
85	40	40
90	46	40
95	54	40
100	66	40

3.1.4. Jars/Tanks/storage/reservoirs

As discussed in section 2.2 water resources in general and rainwater in particular has to be managed comprehensively for sustainable development. Rainfall is a natural phenomena and it is difficult to predict exactly when shall it fallen or it is not falling when it is needed.

Therefore, we required to build or make ready some form of storage structure to trap and save the seasonal rainfall for various purposes in future. The amount of rainwater to be harvested will depend on the amount (depth), distribution and intensity of rainfall and the available of and type catchment area. On the other hand it depends on the various utilities of the harvested water and the number of members of the hh or user group.

DRWH tank must be relatively watertight (say, leakage of less than 5 Percent of the daily abstraction) and hold the required volume at the desired quality (T.H. Thomas (ed), 2003).

Other requirements include:

- ✓ The ability to with stand erosion or damage to excess input of rainwater;
- ✓ Exclusion of vermin and access to mosquito breeding;
- ✓ Exclusion of light so that algae do not grow and larva growth;
- ✓ Sufficient ventilation to prevent an aerobic decomposition of any washed in matter;
- ✓ Easy access for clearing;
- ✓ Sufficient strength to withstand wear and tear and an predictable natural forces;
- ✓ No hazard for fallen of children in to the tank and
- ✓ Not giving undesirable test

There are a number of different methods for sizing tanks; from a simple to a complex or sophistication option depending on the system component or size and skill of practitioner.

In general, there are two categories of construction of tanks/reservoirs for DRWH system:

1. Surface or above ground-tanks with various shapes; it is most common for DRWH system;
2. Sub-surface or underground tanks; common for ground catchment system and are constructed with various shapes; circular, cylindrical, Half sphere, cube or any.

Table 3-4: Pros and Cons of Above and Underground Storage

Description	Pros	Cons
Aboveground	✓ Allow for easy inspection for cracks or leakage; ✓ Water extraction can be done by gravity and Tap; ✓ Can be raised above ground level to increase water pressure	✓ Required spaces; ✓ Generally more expensive; ✓ More easily damaged; ✓ Prone to attack from weather; ✓ Failure can be dangerous
Underground	✓ Surrounding round gives support allowing lower wall thickness and thus lower costs; ✓ More difficult to empty by leaving tap on; ✓ Require little or no space above ground; ✓ Unobtrusive; ✓ Water is cooler; ✓ Some users prefer it because ''it's like a well''	✓ Water extraction is more problematic; often requiring a pump, a long pipe to a downhill location or steps; ✓ Leaks or failures are difficult to detect; ✓ Possible contamination of the tank from groundwater or floodwaters; ✓ The structure can be damaged by tree roots or rising groundwater; ✓ If tank is left uncovered children (and careless adults) can fall in possibly drowning; ✓ If tank is left uncovered animals can fall in contaminating the water; ✓ Heavy vehicles driving over a cistern can also cause damage; ✓ Cannot be easily drained for cleaning

Sources: T.H. Thomas, 2003

Usually, the main calculation in designing a DRWH system will be to size the water tank correctly to give adequate storage capacity. The storage requirement will be determined by a number of interrelated factors. These include:

- ✓ Local rainfall data and weather patterns
- ✓ Roof (or other) collection area / more technically catchments;
- ✓ Runoff coefficient; and
- ✓ Users number and consumption rates

There are a number of different methods for sizing system components. These methods vary in complexity and sophistication. Some are readily carried out by relatively inexperienced first-time practitioners; others required computer software and trained engineers who understand how to use this software The choice of the method uses to design system components will depend largely on the size and sophistication of the system and its component, availability of tool (like computer) and kill and education level of the practitioner. Generally there are three different methods for sizing tanks (Warwick University, 2005).

Mehtod-1: Demand side approach/ Dry season demand versus supply

A very simple method is to calculate the largest storage requirement based on the consumption rate and occupancy of the building/catchment. This approach considers the length of dry period as a design constraint. The tank is designed so that it accommodates the hh/beneficiary during the dry season. The length of dry period can be estimated by;

- ✓ Asking farmers/community about the longest drought they remember
- ✓ By estimating from official weather data the number of consecutive dry month per year

Storage requirement, $St = (Ca * T) / D$; where Ca = annual consumption, T = Longest average dry period and D = Number of days in a year

This simple method assumes sufficient rainfall and catchment area which is adequate, and is therefore only applicable in areas where this situation. However, it does not take in to account variations in annual rainfall patterns. It is a method for acquiring rough estimate of thanks size.

Method –2: Supply side approach/ Mass curve technique/

In low Rainfall area or areas where rainfall is of uneven distribution more care has to be taken to size the storage property. During some months of the year there may be an excess of water, which at other times there will be a deficits. If there is sufficient water throughout the year to meet the demand, then sufficient storage will be required to bridge the period of scarcity. In general storage is very expensive; this should be done carefully to avoid unnecessary expenses.

This method is more accurate of sizing a tank involves an analysis of data using the mass curve technique. Successful use of the technique requires (input data):

- About 10 years monthly rainfall data of the project area or any nearby area with similar rainfall pattern;
- Choice appropriate runoff coefficient that accounts for the losses in relation to the type of the roof/catchment/ type;
- Actually measured roof area;
- Number of targeted user community or household members; and
- Average daily per capita water demand depending on pre specified purposes

While the output of the method yield maximum tank or reservoir capacity that caters the targeted community through the year.

Mehtod-3: Computer Model

There are several computer-based programs for calculating tank size quite accurately, of such programs ''SimTanka'' which has been written by an Indian organization called Ajit Foundation is available free of charge world wide web. The Ajit foundation is a registered non-profit volunteer organization with its main office in Jaipur, India and its community resource centre.

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SimTanka is a software program for simulating performance of rainwater harvesting systems with covered water storage tank. The idea of a computer simulation; is to predict the performance of rainwater harvesting systems based on mathematical model of the actual system. In particular SimTanka simulates the fluctuating rainfall on which the rainwater harvesting system is dependent.

The result of the simulation allows you to design a rainwater harvesting system that will meet demands reliable, that is, it allows you to find the minimum catchment area and the smallest possible storage tank that will meet your demand with probability of up on to 95 Percent in spite of the fluctuation in the rainfall.

SimTanka requires at least 15 years of monthly rainfall records for the place at which the rainwater harvesting system is located. If you do not have the rainfall record for the place then the rainfall record from the nearest place which has the same pattern of rainfall can be use (Ajit Foundation, 1997)

Thus, successful use of the technique requires (input data):

- Minimum of 15 years monthly rainfall data of the project area or any nearby area with similar rainfall pattern;
- Choice appropriate runoff coefficient that accounts for the losses in relation to the type of the roof/catchment/ type;

- Actually measured roof area;
- Number of targeted user community or household members;
- Average daily per capita water demand depending on pre specified purposes; and
- Level of confidence of the reservoir meet the demand; which is 75 to 95 percent

While the output of the method yield optimum tank or reservoir capacity that caters the targeted community through the year or required roof area that meet predetermined demand.

3.1.5. Other auxiliary components

3.1.5.1. First flush

During periods of no rain, dust, Bird droppings, dead plant matter and Rodent and other nuisance will accumulate on the Roof top. These materials are washed off with the first rain and may contaminate the water in the tank. If we did not provide means to exclude the entry of such materials the quality of the water will be deteriorate (Sileshi, 1998

Contamination can be avoided by diverting the first 5 litres of rain for small roofs and 20-25 litres of rain for medium roof, from the tank. Flush traps can be use to prevent the first flush from reaching the tank (David A Cunliffe, 1998).

There are two completely independent variables that make each storm event unique: intensity and duration. Studies have shown that intensity is the critical wash off factor for most storm event. Based on these facts there are two most popular and generally used, first-flush device types: The ''Constant-Volume Containers'' or "Manual fixed volume" and ''First-Flush Valves'' or "Fixed mass and flow rate (Flo True International corp, 2004).

Constant Volume First Flush Containers

Generally speaking there are three main configurations of Constant Volume First Flush containers. These are:

- ✓ Homemade pipe diverter (vertical pipes that hold a small volume of water, the bottom end is capped by a threaded plug that is used to drain it between rains);
- ✓ Roof washer Box (made of Fiberglas) and supported by a metal stand and
- ✓ Diversion Tank (typically made of Fiberglas, polypropylene, or metal)

The constant–volume first-flush containers works depends on the capacity of the devices when the rain begins to fall, regardless of the rain intensity, then the excess rainwater is

conveyed to the storage vessel or tank. They work on the theory that, if they are sized correctly (for example: 1 gallon capacity per 100 sq.ft. of the Roof area), then the rainwater that is sent to the storage vessel will be essentially free of contaminants.

The constant-volume method is the simplest and widely recommended (Lee & Visscher, 1992, Gould & Nissen-Petersen, 1999), it does, however rely on the user both being home and prepared to go out into the rain to operate the devices much reducing its usefulness.

The major pitfall of constant-volume Container is that when rainfall is a low intensity (which is the general pattern) it is likely that a constant-volume container will substantially fill with clean water because wash off does not occur effectively at lower intensities. Then, when more intense rains begin, undesirable contaminants from roof and gutter can wash into the clean water storage vessel. Moreover it is manually operated system after each rain and hence if we didn’t clean after each rain the contamination would be continued.

First-Flush Valves

There are two types of First-Flush Valves that are commercially available. These are:

- ✓ Valve Kit (the workings of the valve are installed into a standard PVC Tee); and
- ✓ Tee Valve (the workings of the valve are integral to PVC Tee)

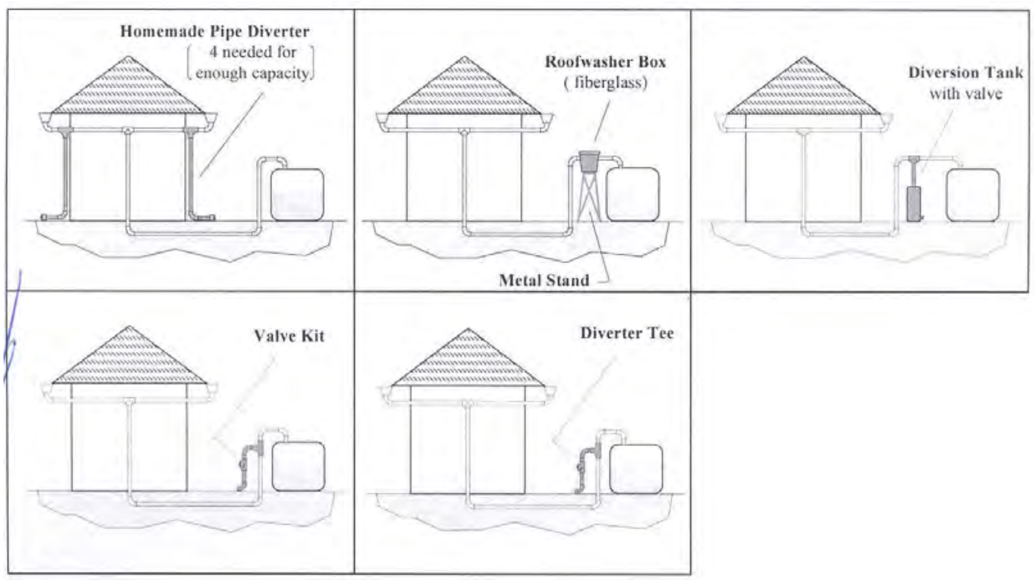


Figure 3-2: Different Arrangements of First Flush Trap (Adopted from FloTrue International Corp, 2004)

First-flush valves unlike constant-volume containers they are sensitive to the rate of the rainwater flow. It works in such a way that when the rainwater flow rate reaches a designed minimum a spring-suspended hollow internal container (i.e. valve ball) located inside the devise begins to slowly fill with water. Then, when the valve ball has filled the increased weight causes it to contact a valve seat and stop the water flow. The excess rainwater is then conveyed to the storage vessel.

First-flush valves, on the other hand, dump contaminated water and debris to the ground or into a second tank. There are two primary advantages as a result. First, contaminated water is not likely to mix with clean water going into the storage vessel. Second, these devices do not

typically needed to be manually cleaned or emptied in order to prepare for the next rain. Hence, since valves dump rather than fill they can keep the water in the storage vessel cleaner (no mixing) and do not require constant cleaning in order to keep potent blooms of bacterial from becoming a potential health hazard.

3.1.5.2. Filters

Filters are another possible solution to keeping sediment and contaminants out of the storage tank. A filter unit is chamber filled with filtering media such as fibre, coarse sand, and Gravel layers to remove debris and dirt from water before it enters the storage tank. Charcoal can be added for additional filtration (Warwick University, 2007).

There are various types and combination of filter such as Charcoal water filter (10 cm gravel layer, 10 cm charcoal layer, 25 cm sand layer and 25 cm gravel layer), Sand filter (20 cm gravel layer,30 cm sand layer and 20 cm gravel layer); Dewas filter (PVC pipe 140 mm in diameter and 1.2 m long; three chamber pebbles first layer 2-6 mm, second layer slightly larger than the first and the third layer 12-20 cm pebbles); VARUN, Horizontal roughing filter and slow sand filter, Filter channel. The Germany manufactures products of WISY and MALLBETON filters are also available (Warwick University, 2007).

Depending on the scale of the DRWH the provision of filter ranges from the conventional standard techniques of filtration i.e. slow sand filter and rapid sand filter could be used. However for small community or hh DRWH the use of coarse grade sand and gravel chamber fixed at the inlet of the reservoir could be used to remove the larger particles including leaves, dead animals etc

A typically community sand filter will have a thickness of 20 cm coarse gravel; 30 cm fine sand and 20 gravel layer (Rainwater harvesting technology, 2007).

3.1.5.3. Splash Guard

Splash guard consists of a long strip of sheet metal and bent at angel and hung over the edge of the Roof to ensure all runoff for the Roof enters the gutter. The splash guard is nailed on to the Roof and the lower half is hung vertically down from the edge of the Roof. Splash Guards can easily manufactured on site form a sheet of metal.

During torrential downpours, large quantities of runoff can be lost due to gutter overflow and spillage. This is particularly a problem on long Roofs where, due to the slope of the gutter, it may hang many centimetres below the eaves of the Roof. To overcome this problem, advices known as a splash-guard, which was originally produced in Kenya, can be incorporated on corrugated Iron Roofs (Nissen-petersen, 1992).

Splash guard consists of long strip of sheet metal 30 cm wide, bent at angel and hung over the edge of the Roof by 2-3 cm to ensure that all runoff for the Roof enters the gutter. The splash guard is nailed on to the Roof and the lower half is hung vertically down from the edge of the Roof. This is easily manufactured on sit from sheet metal.

3.1.5.4. Distribution Point/Water Points

Depending on the prevailing topographic condition types of distribution point or facilities varies from scheme to scheme. Mostly there are two common arrangements of distribution points. The first arrangement is based on the relative position and type of the rainwater conveyance system up to the tank and the second one is based on the size of the tank.

For small hh water tanks, out let (a Tap) is fixed on the wall of the tank and most of the time they are above the prevailing ground level. Whereas, for big water reservoirs the out lets are normally apart from the tank and constructed above or below the prevailing ground level, depending on the available head to insure gravity flow from the tank to the distribution point.

Existing practice teaches us for smaller water tanks up to a capacity of 10 m^3 a tap fixed on the wall of the tank is quite satisfactory while for reservoir capacity bigger than theses value we could use the conventional standard water point above ground level with 4 to 6 faucets.

Figure 3-3: Typical underground (with two taps) and above ground (four taps) water Points

3.1.5.5. Soakaways /Percolating pit

Sockaways or percolating pits are used to absorb drainage water at water collection point or water points in order to avoid drainage problem. Absences of this facility causes soil erosion or create favourable environment for mosquito breeding.

Practical observation shows us that a pit excavated to 60 cm * 60cm * 60-100 cm (depth) quite sufficient for DRWH system. The excavated pit will be filled with crushed stone and river sand to facilitate easily drainage (Rainwaterharvest, 2007)

CHAPTER FOUR

4. CONSTRUCTION MATERIALS, MAINTENANCE AND REPAIR

One of the advantages of promoting DRWH is its simplicity for construction and does not required as such a qualified engineer. Provision of on job training for the local community or local masons on the method of construction of tanks and gutter manufacturing are found quite satisfactory.

Most of the construction materials for DRWH system are available in local markets or shops the difficulty is how to cut down the investment cost of the various component of DRWH system?

Information gathered from practitioners indicates that DRWH is not a cheaper option and its initial investment cost is very expensive. In addition to this, most of them also agreed tanks or reservoir and their construction formwork contribute the major portion of the total investment cost of the system.

4.1. Construction material

4.1.1. Tank/Reservoir

As most of civil engineering works site selection is one of the most important construction requirement for reservoirs or tanks in DRWH. If reservoirs are to be constructed above ground (as most the common case for DRWH) the reservoir should be founded on firm foundation or soil material. In case where underground reservoir or tanks are preferred due to head problem for gravity flow the effect of tree roots and maximum water table fluctuation should have been serious consideration on the structure stability.

The storage reservoir is usually the most expensive part of the system so the design and construction needs due attention to achieve a durable product. The tank must be constructed in such a way that it is durable and water tight, and that the collected water does not become contaminate.

Worldwide, the variety of Roof water tank is enormous. There are thousands of ways to constructing DRWH systems and most well tried methods found in good texts and manuals will, if followed properly, give a satisfactory result. The most common construction material or kinds rainwater harvesting tanks are steel, concrete and Ferro cement, Fiberglas and plastic tanks (T.H.Thomas, 2003).

Concrete and Ferro cement tanks are strong and long lasting and can be installed underground. New tanks may impart tastes and may leach lime thereby increasing the PH of water. Accordingly theses thanks may need to be flushed before use.

Fiberglas thanks suitable for the collection of rainwater are available. These thanks are manufactured with a food-grade coating on their interior surface. The coating is cured before the tanks are offered for sale. The tank should be also being manufactured in a manner to prevent the entry of light which could encourage algal growth.

Material economics can be made on water tanks by considering the geometry of surface area to volume. Idealized tank shapes are spherical; cylindrical; half Sphere and cube. The aspect ratio can also have an effect on the cost of the tank. Practical cost of construction of Ferro cement reservoirs (above ground) in various parts of our country reported to be 700 to 1250 Birr /m^3 (Girma, 2006). Refer Annex 6-1: Detail stapes of construction of a 40 m^3 Ferro cement reservoir; Water Action experience.

4.1.2. Gutter, Splash guard and Down pipes

For effective operation of DRWH system, a well designed and carefully constructed Gutter system is crucial. About 90 Percent or more of the rainwater collected on the roof will be drained to the storage if the gutter, Splash guard and down pipe system is properly fitted and maintained (Jo Smet, 2003).

Common materials for gutter system are metal and plastic; in most countries these are available in the village shops. But also cement-based products, bamboo and wood can be used; these have had a variable rate of success and have in some cases reduced confidences in DRWH system.

With high intensity rains rainwater may shoot over the conventional gutter, resulting in a low production; splash guards can prevent this spillage. Gutter and down pipes need to be thoroughly inspected; repairs and cleaning should be conducted at least once in a year; just before the beginning of the rainy season. Common problems of Gutter are:

- ✓ Capacity
- ✓ Slope
- ✓ Mounting and
- ✓ Clearing from debris for V-shape Gutters as it is fixed by wire with the splashguard or the rafter.

4.1.3. First flush and filter

The first rain drain the dust, bird droppings, leaves etc. that lie on the roof surface. In practice, preparation and cleaning of the roof surface before the first rains hardly ever happens. To prevent theses pollutants and contaminants getting into the storage tank, the first rainwater containing the debris must therefore be diverted or flushed. Many techniques have been introduced but most fail in practice because of lack of proper operation and maintenance; then theses first flush solutions are just by passed. Permanent systems needing less care are the best.

Screens to retain larger debris such as leaves can be installed in the down pipe or at the tank inlet. The same concern applies to collection of rain runoff from a hard surface. Here the preparations before the first rain are easier and simple gravel-sand filters can be installed at the entrance of the storage tank.

Practical experience and observations during the survey shows that wire mesh filters get corroded in a short time period and become non-functional. The use of plastic material is much better than steel or iron for longer time serves. In addition to this frequent diverting of the first flush may loosen the joints (welded points) gutter and finally lead to failure of the whole system.

4.1.4. Distribution point

Any types of the convectional water points could be used as a distribution point for DRWH. Distribution point shall be constructed from masonry or concrete or mosaic whichever is cheaper, durable and with good astatically value.

Practical experience shows that the most common type of DRWH distribution point is isolated masonry underground water point for tanks above 10 m^3 capacity and for tank less than this capacity a faucet is fixed on the wall of the tank or jar at a convenient direction and position.

4.2. Maintenance, Repair and Cleaning Arrangement

The primary focus of maintenance procedures should be kept in mind that all components of DRWH must be clean that enables to minimise the risk of contamination i.e. either entering or retained in conveyance and/ storage tanks.

Regular inspection and clearing of catchment, gutters, filters, and tanks reduces the likelihood of contamination. Water from other sources should not be mixed with that in the tank.

4.2.1. Catchment system

The catchment system that comprises the roof; gutter and down pipes should be inspected before every rainy season or end of the dry season. The catchment area should be kept clear of debris falling onto the catchment area. Overhanging branches also provide access to the roof for rodents, cats and possums and can provide rooting points for birds. The roof should be washed clean once or twice a year and in particular should be cleaned towards the end of dry season (T.H Thomas, 2003).

Similarly Gutter and down pipes need to be inspected more frequently as compared to roof and other components of DRWH system. The incidence of blockage of gutter and down pipes with every rainy season is common phenomena, where the building is close to road side or overhanging branches. So inspecting and clearing of leaves and other wanted materials like pieces of plastic bags blow with wind must be removed regularly.

Moreover, gutter supports posts at overhanging sections need to be a durable material like steel material like pipe or any arrangement and slope need to be checked to avoid lose of the expected rainwater.

4.2.2. Tank

Reservoirs or tanks should be examined for the accumulation of sludge every 2-3 years, or if sediment/ or turbidity is reported by the users community in the collected water. Depending on the type of tank construction (above and underground) tank desludging become from simple to complex. For above ground tanks that are provided with wash out, the effort required to cleanup tanks would be very simple, which is a matter of opening the get valve/drain plug/, where as for the underground tanks it is relatively complex. The clearing operation for underground tanks would be either manual cleaning or pumping out the sludge. Care should be taken not to disturb protective film on the surfaces of steel tanks (David A Cunliffe, 1998).

In general it is very important to check the structural condition of the tank before choosing the method of clearing. Harsh clearing methods may totally damaged old tanks or may accelerate deterioration under good condition tanks.

Where cleaning necessitates entering the tank, care should be taken to ensure adequate ventilation is provided and an additional person is in attendance. Advice on working in confidence spaces should be available from occupational, health, safety and welfare authorities.

Organic material removed from the tank may be disposed of in the garden by spreading and digging into garden beds to improve soil fertility.

4.2.3. Collection Chambers/Manholes

In a system where collection chambers or manholes being components of a DRWH system each chamber should be inspected from the existence of contaminates such as plant leaves; bird droppings, small dead animals, spiders, rodents etc. Cracked walls and poor sealing of the cover slab should be rectified before the occurrence of any contaminants in the system.

4.2.4. Disinfections

Regular disinfections of rainwater held in domestic tanks is not considered necessary in most cases and is generally only recommended as a remedial action. As discussed earlier community distinguish or characterize the quality of drinking water either in terms of test, odour or colour. In some instances in absence of any of the physical tests defects the water might cause illness. Especially for those part of user community or members of an hh with lower immune responses, such as very young or old person, cancer patients, people with diabetes, organ transplants or those who are HIV positive, boiling the water before consumption should be considered.

Rainwater can be disinfected by heating and holding at rolling boiling for one minute or more. This will kill any harmful bacteria, viruses or protozoa including Giardia and cryptosporidium (WHO, 1994)

Chlorination is also another method of improving the quality of the harvested water. Chlorination is most appropriately used to treat rainwater if contamination is suspected due to the rainwater being coloured or selling. Chlorination is effective against harmful bacteria and many viruses but it has limited effect against protozoa. When chlorine is added to water, it reacts with organic matter and other impurities in the water and the amount of chlorine required for disinfections will depended on the concentrations of impurities. In general, concentrations will be low in rainwater.

As a general guide, the addition of 40 ml of liquid sodium hypochlorite (12.5% available chlorine) per 1000 litter or 7 gm of granular calcium hypochlorite (75% available Chlorine) per 1000 litres of water will give a reasonable assurance of effective disinfection. Both of these methods will provide chlorine does of approximately 5mg/litter (David A Cunliffe, 1998).

Handling and checking of the amount of residual chlorine should be monitored or handled by professionals than layman. Free chlorine residual of 0.5mg per litre after a contact time of 30 minutes is desirable (David A Cunliffe, 1998).

4.2.6. Inlet screens and first flush/bypass devices

Inlet screens and first flush devices should be cleaned regularly and kept in good repair.

CHAPTER FIVE

5. DATA ANALAYSIS

The field survey is carried out from April 25 to 30, 2007. Minjar and Shenkora woreda is mainly rural area and well known of its subsistence agricultural products. Teff; wheat and different types of beans are the major substance crops grown in the woreda. Information obtained from the community indicate the woreda is food sufficient and has not been received any Food Aid from government or NGO.

On the contrary the woreda is known of its poor surface and sub-surface water resource potential. The most common sources of water supply in the woreda both for human being and livestock watering are ponds. Whereas the most common source of safe water supply for human being is deep well. Normally wells are drilled up to a depth of 300 m and the yield is also discouraging in most of the cases. This has been ascertained by the attempt made by Water Aid Ethiopia in 1996 and the regional water Bureau in different times.

The challenge of providing safe water supply to the community through deep well drilling was manifested during the survey. The Amhara region water Bureau has been financed by JICA to improve the safe water supply of the woreda via drilling of 11 wells in the woreda. During the survey the regional water bureau drilling crew staffs that came from Kombolcha branch office were under drilling of a deep well which is located about 200 m away of one of the DRWH scheme (Chele Gebreal Church DRWH). The well site is specifically located between Baynessgan and Woldeyohanness Village; N-08^0 56.087 and E-039^0 32.145 and elevation 1683m amsl.

The well was drilled to a depth of 248 m. As per the information obtained from the drilling crew (including the hydrogeologest) the formation is ash after 100 m and is not changed up to 248 meters and this formation judge by the professionals as a none water bearing aquifer, the crew decided and abandoned the well

Figure 5-1: Drilling Crew sealing the well and water problem in Arerti town (the woreda town)

The above opportunity strongly justifies the problem statement of the study i.e. how it is difficult to solve the safe water supply problem in the woreda through drilling of deep wells and Roof water harvesting is one of the technologically option and appropriate technology in the woreda. Following section shall discuss the analysis or findings from each of the schemes.

5.1 Sama Senbet DRWH Schemes

5.1.1 Back ground information

The DRWH schemes implemented in Sama Senbet PA is planned to serve a total of 1400 people and the project was commenced from February 1997 to February 1998, The project was mainly financed by OXFAM UK (an international NGO) (K.Yezichalem and A.Eshetu, 1998).

The total project cost was estimated to be Birr 548,936.74. Accordingly the cost sharing among the project stakeholders was as follows:

OXFAM UK	Birr 532,893.87 (97 percent)
Water Action	Birr 10,665.43 (1.9 percent)
Community (in Labour)	Birr 6,377.44 (1.15 percent)
Total	Birr 548,936.74

Originally the project had no software components but on the course of implementation the implementing body, Water Action, recommend sanitation and hygiene education to be a component of the project to meet the envisaged objectives of the project. Thus the project is re-formulated in such a way that the hardware part includes construction of various components of the DRWH system where as the software part includes provision of hygiene and sanitation education and community developments activities.

5.1.2. Objective

- ✓ Improve the health status of the targeted communities through provision of safe water;
- ✓ Reduce the time and energy unduly wasted by women and children in fetching water so that they will have more time for other important activities;
- ✓ Minimize mortality and morbidity hazards on children who are by comparison more vulnerable to health problems than adults and
- ✓ Develop the skill of the communities to be served by the project

5.1.3. Project Activities /Outputs/

- ✓ Construction of Four 40 m^3 Ferro cement Reservoirs and one 75 m^3 Masonry Ferro cement Reservoir to store the harvested rainwater from four blocks of Sama Senbet primary second cycle school Roof areas;
- ✓ Construction of two masonry ferro cement reservoirs with a capacity of 100 m^3 and 150 m^3 he harvested rainwater from the Roof area of Senbe Church;
- ✓ Construction of one 150 m^3 Masonry Ferro cement Reservoir to harvest rainwater from the Roof area of Tekelehaymanot Church and
- ✓ Construction includes fixing of a total of 200 m Gutters and splash guard, Concrete (70 m) and PVC pipe (670 m length and dia 25-150mm) and construction of water points.

5.1.4. Design criteria

The following design criteria, data and assumptions were employed during the planning exercises of the two schemes:

(a) Design criteria

- ✓ Mean annual rainfall 900 mm;
- ✓ Effective yield from Roof catchment 75 percent of the annual mean precipitation;
- ✓ Losses due to leakage; evaporation; wind effect etc. 25 Percent of the mean annual rainfall;
- ✓ Average daily per capita water demand
    - o 5 litres for students;
    - o 10 litres for community (drinking and cooking purpose only) and
    - o 20 litres for teachers and their families

(b). Available roof area and beneficiaries

- ✓ Estimated Roof area of Sama senbet (Sabbath) Church 300 m^2;
- ✓ Estimated Roof area of Teklehimanot Church 536 m^2;
- ✓ Total Roof area of School blocks 685 m^2;
- ✓ Total number of beneficiaries are 1400 inhabitants
    - o 800 people to be supplied from the church scheme and
    - o 540 pupils and 60 teachers (including their family) from the schools scheme

5.1.5. Summary of the Analysis

The following section shall discuss the analysis carried out for each of the schemes i.e. the school and church schemes.

5.1.5.1. School Scheme

The geographic location of the school system is N-08^0 47.146 and E-039^0 19.792 and the elevation is about 2116m amsl.

5.1.5.1.1. Beneficiary

Discussions made with school community (Teachers) indicate that currently the total number of beneficiary community that has been using the harvested is about 63 i.e. 33 Teachers; DAs 6; Health extension workers 3; Guards 2 and Teachers and Guards family 19.

The school community has established a consumption rate of 10 to 15 Jerikans (250 to 375 litres) per month for bachelors and 35 to 40 Jerikans (875 to1000 litres) per month for couples. Depending on the amount of water harvested the demand is adjusted to have the water through the year. The school community use the water for Drinking, Cooking and cloth washing. The cost of water or water tariff established is 10 cents per 20 to 25 litres or on average 10 cents per 23 litres.

5.1.5.1.2. Reservoirs Types and existing condition

Based on the available roof area, demand and supply analysis four 40 m^3 Ferro cement and one 75 m^3 Masonry Ferro cement Reservoirs are constructed with in the school compound. Of the four Ferro cement reservoirs one is not total functional. The major problem noted with Ferro cement reservoirs in the school compound is foundation. For instance the non functional 40 m^3 Ferro cement reservoir has been maintained by Water Action to solve the high rate percolation through the reservoir bottom floor. The problem was solved temporarily but during the survey it becomes very serious and the reservoir is out of use.

Minor cracks are observed on the walls of the Ferro cement tanks but it is only oozing of stored water and has trivial effect on the storage. Regarding the 75 m^3 reservoir; the major problem is cracks on the pavement around the reservoir and the out let of the over flow pipe is fully buried in the ground and hence the reservoir roof slab experience uplift pressure this result separation of the wall and top tie beam of the reservoir. As per the discussion with the school community (tap attendant and teachers) significant water is lost through this section when the reservoir is full.

Another defect observed with the reservoir is that the get valve fixed at the out let is not functional and hence water is controlled by the get valve fixed at the water point only.

Wire mesh filter was fixed at the inlet of all of the reservoirs but during the survey it was observed that all are corroded and damaged. Due to this the rainwater inters in to the reservoirs without any checking that might contribute to the overall contamination of the harvested water in the reservoirs. Sunlight could enter through the inlet to the reservoir and hence the possibility of the development of Algae is very high.

5.1.5.1.3. Gutter and Splash Guard

All the roofs of the school has fixed with Gutter and splash guard that are manufactured on site. The Gutters are v-shapes/Triangular with size 13 cm depth and 14 cm top width and the splash guards are 20 cm width. The problem observed with gutters is slope. The gutters have no uniform slope and also the wooden support is getting decayed especially at the end tip that connects to the reservoir inlet. The wooden post requires major maintenance preferably replacing by durable material. The opportunity to see the insides of the gutter is difficult however as per the information collected from the teachers clearing has not been done so far, since construction.

5.1.5.1.4. Down pipes

All reservoirs constructed in the school compound does not requires down pipe as the water directly conveyed from the roof to the inlet via the v-shaped Gutters.

5.1.5.1.5. Distribution points

The distribution point of the system is masonry underground water point with three faucets. The water point is constructed below the existing ground level to have a good gravity flow from the tanks. The water point lacks drainage and the retaining wall and the stair case requires major maintenance.

5.1.5.1.6. Water quality

Quality of water directly determines the drinking water security of a community. The criteria used by the user community in all of the schemes are colour; taste; presences of worms; odour. The community perceptions of drinking water are governed by these factors and accordingly they found that rainwater is found to be a good quality as compared to the pond water, which is the most common sources of water supply in the woreda.

To verify the quality of the harvested water samples are collected and physical and biological tests have been carried out by an authorized institution. The test is conducted in WWDSE laboratory services. A sample is taken from the 75 m^3 masonry Ferro cement reservoir and output of the lab analysis shows that the PH is 7.09, Turbidity is trace conductivity 75 μS/cm and faecal coliform is nil.

Table 5-1: Summary of Water Quality Test Result; School scheme

Date of Sampling	Location	Source of water	No of sample	PH	Turbidity (NTU)	Conductivity (µS/cm)	Faecal coli forms counts/100 ml
27-04-2007	Minjar and Shenkora Woreda	School 75 m^3 reservoir	1	7.09	Trace	75	Nil

5.1.5.2. Church Scheme

The geographic location of the church system is N-08^0 46.423 and E-039^0 19.475 and the elevation is 2088m amsl.

5.1.5.2.1. Beneficiary

Discussions made with the Tap attendant (as well the Guard of the Churches) indicate that it is difficult to estimate the exact number of beneficiaries from the church scheme. However he pointed out that there are about 100 peoples (aged and a few are disables) that lives in the Monastery and regularly uses the sources. These people collect 20 to 25 litres of the harvested water twice in a week; on Wednesday and Friday only.

The other beneficiaries are the community that lives within or a way of the vicinity of the project area. The consumption is very irregular and they collect significant amount of water every Sunday in relation to the [4]SENBETE. Under normal condition the community collect water from the surrounding ponds but when the pond water is finished they collect water from the DRWH system in relation the SENBETE only. Except the 100 people living in the monastery no one is allowed to use the water except in relation to the religious rituals.

Depending the amount of water harvested the supply is adjusted to have water throughout a year, at least for these living in the monastery. People living in the church monastery use the water for Drinking, Cooking and Cloth washing.

5.1.5.2.2. Structural or Build Type and Existing Condition

[4] SENBETE is one of the orthodox church followers religious rituals conducted every Sunday

In general the exiting structural condition of both of the churches is at Good condition. The wall of the senbet church is of stone and that of Tekelhaimanot church is cement plastered mud and wood.

5.1.5.2.3. Reservoirs Types and Condition

Based on the output of the demand and supply analysis three masonry Ferro cement reservoirs are constructed with in the churches compound. Of these reservoirs two are 150 m^3 and the reaming one has a capacity of is 100 m^3. The 100 m^3 and one of the 150 m^3 reservoir are planned to store rainwater harvested from Senbet Roof catchment while the other 150 m^3 reservoir is planned to store water from Tekelhaymanot church roof catchment.

Based on the information obtained from tap attendant the 100 m^3 reservoir has foundation problem i.e. significant amount of water is percolating through the foundation and the reservoir does not give service. The 150 m^3 reservoir constructed to store water from Tekelehymanot church is not also functional because about 40 to 60 percent of the Gutter (which was fixed during the construction of the building) is damaged.

None of the system components are maintained after the construction completed and handed over to the community. So, out of the three reservoirs constructed in the church compound only one (150 m^3 reservoir) is functional. During the survey the other two reservoirs (150 and 100 m^3) have no water.

Regarding clearing of reservoirs the tap attendant reported that functional 150 m^3 reservoir is cleaned at the beginning of every wet season.

5.1.5.2.4. Gutter and Down pipes

All the roof of the church building has fixed with Gutter and down pipes during the construction of the buildings (not by the project). The Gutters are semi-circle in shapes. The problem with gutters and down pipes is that they are not designed for the purpose and the capacity and slope is not checked during planning and design of the system. As mentioned earlier about 40 to 60 percent of the gutters of the Tekelhaymanot church are damaged or loosely connected with the down pipes so significant amount of water is lost before the rainwater enters in to the manholes. Moreover Wire mesh filter was fixed at the inlet pipes that connect collection chambers (manhole) that are constructed at the foot of each down pipe but during the survey all are corroded and damaged. So that water inters in to the reservoirs without any proof.

The opportunity to see the insides of the gutter is difficult and as per the information collected from the tap attendant clearing has not been done so far. So there is a high opportunity of accumulation of contaminants in the gutters.

5.1.5.2.5. Collection Chambers/or Manholes

Masonry box type collection chambers with 30 to 40 cm wall thickens are constructed at the foot of each of the down pipes and the chambers are enter connected with 4 inch drainage PVC pipes to convey the water from one box to the next and final to the reservoirs.

The major observed problem with the collection chambers is that most of the cover slabs are not sealed to prevent entry of lizard and other insects. Thus most of the chambers are not clear i.e. sediments, plants leaves and nest of spider and other worms are also seen on the floor. Chambers has not been cleaned after construction.

5.1.5.2.6. Distribution points

The distribution points of the systems are two water points each with three faucets each. The water points are above prevailing ground level. A few of the taps are not functional. The water points are fenced by the local community using local materials and by planting small shallow rooted plants around.

5.1.5.2.7 Water Quality

Quality of water directly determines the drinking water security of a community. The criteria used by the user community in all of the schemes are colour; Taste; presences of worms; odour. The community perceptions of drinking water are governed by these factors.

To verify the quality of the harvested water two samples are collected and physical and biological tests have been carried out by an authorized institution. The test is conducted in WWDSE laboratory services. A sample is taken from the functional 150 m^3 masonry Ferro cement reservoir.

Output of the lab analysis shows that the PH is 7.18, Turbidity is 6 NTU slightly more than the recommended, conductivity 78 μS/cm and the total coli form is found to be 20/100ml where as the faecal coli form is nil.

Table 5-1: Summary of Water Quality Test Result; Church Scheme

Date of Sampling	Location	Source of water	No of sample	PH	Turbidity (NTU)	Conductivity/Hardness (µS/cm)	Faecal coli forms counts/100 ml
27-04-2007	Minjar and Shenkora Woreda	Senbet Church 150 m^3 Reservoir	1	7.18	6	78	Nil

5.2. Minjar and Shenkora Woreda Low Land PA's Roof Water Harvesting; Sanitation and Hygiene Education Project

5.2.1 Back ground information

The DRWH schemes implemented in Chele and Kiticha are planned to serve about 1218 people and was commenced from January to June 2003 (Water Action, 2001). The project was mainly financed by the ESRDF and partly by the community and Water Action. The total project cost was estimated to be Birr 500,000.00 Accordingly the cost sharing among the project stakeholders were as follows: -

✓ Community (in kind)	Birr 58,116.00
✓ ESRDF	Birr 389,883.92
✓ Water Action	Birr 52,000.00
Total	**Birr 500,000.00**

The project was designed to have both the software and hardware components. The hardware part includes the construction of various components of the DRWH and TPLs where as the software part includes provision of hygiene and sanitation education and community developments activities.

5.2.2. Objective

Short-term Objectives

- ✓ Reduce the drudgery of women and children by providing water at closer vicinity for 1218 needy communities;

- ✓ Improve the health status of the community by providing safe drinking water and through the provision of environmental sanitation and hygiene education intervention.

Long-term Objective

- ✓ Improve the quality of life of the people within the project area;
- ✓ Strengthen the skill of the community to use and manage their local available resources;
- ✓ Contribute to the national development plan

5.2.3. Project Activities/outputs

General Items

- ✓ Mobilization of man power and construction equipments;
- ✓ 21 Km access rod clearing;
- ✓ Study and design;
- ✓ One store and camping and
- ✓ Vehicle rent, Water Action project management and office related costs

Water Supply

The major activities in this component are:

- ✓ Supply and fixing of V shaped Galvanized iron sheet gutter;
- ✓ Supply and fixing of splash guard and ordinary down pipes;
- ✓ Supply and lay of Gs and PVC pipes;
- ✓ Construction of two 10 m^3 capacity Ferro cement reservoirs, with its tap stand;
- ✓ Construction of one 40 m^3 capacity Ferro cement reservoirs, with its tap stand;
- ✓ Construction of one 100 m^3 capacity Ferro masonry cement reservoirs, with its tap stand;
- ✓ Construction of one 150 m^3 capacity Ferro masonry cement reservoirs, with its tap stand and

- ✓ Construction of collection, intake Boxes and sock away pits

Sanitation and Hygiene Education

The major activities in this component are: -

- ✓ Health base line survey and analysis in 30 hhs;
- ✓ Provision of school, individual and mass health education to 1260 peoples;
- ✓ Construction of six hh demonstration Pit latrines;
- ✓ Provision of orientation for 13 government staffs and
- ✓ Provision of Training for six Village hygiene promoters/communicators (VHC's)

Community Development

The major activities in this component are: -

- ✓ Establishment of village level water and sanitation committees at the two Keble's;
- ✓ Establishment of woreda steering committee;
- ✓ Provision of water technician training for six members of the communities;
- ✓ Provision of orientation program for 36 WatSan committees and
- ✓ Provision of one set tools and spare parts

5.2.4. Design criteria

The following design criteria, data, criteria, and assumptions were used in the preparation and design of the water supply system:

(a) Design criteria

- ✓ Mean annual rainfall is considered 800 mm;

- ✓ Losses due to leakage, evaporation, wind effect etc. is considered to be 25 percent of mean annual rainfall;
- ✓ Effective run-off yield from roof catchments is considered 75 percent of the annual mean precipitation;
- ✓ Average daily per capita water demand
    - o 10 litres for beneficiary community;
    - o 5 litres for school Children

(b). Available roof area and beneficiarie

- ✓ Estimated roof area Chele scheme
    - o Gebreal Church 254 m^2; School blocks 80 m^2; Teachers residential block 25 m^2; Private house 28 $m^2$and
- ✓ Estimated roof area Kiticha Scheme
    - o School with three blocks 288 m^2, Two teachers residential block 26 m^2 and 80 m^2 and DA house 24 m^2
- ✓ Total number of beneficiary Chele scheme are 541 people
    - o 300 people from church scheme;
    - o 31 teachers and government workers and about 200 students; and
    - o Private House 10 people;
- ✓ Total number of beneficiaries Kiticha scheme are 684 people
    - o 280 people from school scheme (including teachers and their families) and number of pupils 400;
    - o 4 government staffs

5.2.5. Summary of the Analysis

The geographic location of Chele PA DRWH Schemes constructed in the school compound are found in N-08^0 55.118 and E-039^0 31.638 and that of the Chele Gebrale Church is N-08^0 55.327 and E-039^0 31.658. Similarly the Kiticha kebele DRWH School schemes are located is N-08^0 51.691 and E-039^0 29.840 and that of the DA house is N-08^0 51.539 and E-039^0 29.849.

5.2.5.1. Beneficiary

Discussions made with school community (Teachers) in Chele primary second cycle school indicate that the total population that has been used the harvested water are is estimated to be 24 Teachers; students 2 (Sports boys); DAs 3; Health extension workers 2 and 2 Guards with their family. Similarly the current number of beneficiary in Kiticha primary second cycle school are 11 Teachers and 3 DAs.

The school community has established a consumption rate of 200 litres per month. However the supply depend on the amount of water harvested i.e. the demand is adjusted to have water through the year. The school community use the water for Drinking and Cooking (about 60 percent) and for cloth washing. The water tariff is 20 cents per 20 to 25 litres or 10 Birr per m^3.

5.2.5.2. Structural or Build Type and Existing Condition

Chele School was constructed in 1981/82 with three blocks; two are teaching blocks. The schools are constructed with wood and mud wall. Since the school is constructed 26 to 27 years before the blocks are at poor condition. Walls are started collapsing and hence gutter lack support.

Figure 5-2: 40 m^3 Ferro cement reservoir fixed with a nearly damaged school block (Chele School)

Kiticha School was constructed in 1998/99 with Four Block; two are teaching blocks and the remaining are residential blocks for the teachers. The teaching blocks are constructed with Hollow Block and are at good condition while the residential buildings are of mud and wood block and at fair condition.

Figure 5-3: 150 m^3 Masonry and 10 m^3 Ferro Cement Reservoir In Kiticha primary Second cycle School

5.2.5.3. Reservoirs Types and Condition

Based on the available roof area and the supply-demand analysis two 10 m^3 Ferro cement; one 40 m^3 Ferro cement and one 100 m^3 Masonry Ferro cement Reservoirs are constructed in Chele. The 40 m^3 and one of the 10 m^3 Ferro cement reservoir are constructed in the school compound. Whereas the other 10 m^3 Ferro cement Reservoir and the 75 m^3 masonry Ferro cement reservoir is constructed in private house compound and Chele Saint Geberial church compound respectively.

All of the reservoirs are functional however the Fencing of the 75 m^3 reservoir is fully damage and the reservoir is easily accessed by animals and children. Pavement around the reservoir and cover slab of valve box is damaged. The reservoir has never been filled and it serves only 6 to 8 days only during the dry period.

The get vale fixed to control the realise of the stored water from the 40 m^3 reservoir is damaged as a result the school community collects water by inserting 3-4 m long flexible plastic pipes or hosepipe in to the reservoir through the inlet opening at the top. This contribute serious contamination of the stored due to poor handling of the hosepipe i.e. the pipe is thrown away everywhere after and before use.

Similarly three reservoirs are constructed in kiticha primary second cycle school compound; one 150 m^3 masonry reservoir and two Ferro cement reservoirs with a capacity of 40 and 10 m^3. The 150 and 40 m^3 reservoirs store water harvested from teaching blocks where as the 10 m^3 Ferro cement reservoir store water from teacher's residential building.

As per the information obtained from the user community wire mesh filter was fixed at the inlet of all of the reservoirs but during the survey it was observed that all are corroded and damaged. Due to this the rainwater inters in to the reservoirs without any proof that might contribute to the overall contamination of the harvested water.

5.2.5.4. Gutter and Splash Guard

All the roof catchments in Chele and Kiticha DRWH Schemes are fixed with Gutter and majority of the roofs have no splash guard. The Gutters are Rectangular in shape with size 13 cm width and 14 cm depth. The problem with gutters is slope. The gutters have no uniform slope and also the wooden support is getting decayed that requires maintenance, preferably replacement by durable posts. The opportunity to see the insides of the gutter is difficult and as per the information collected from the use community; none of the schemes Gutter have been cleared since construction.

5.2.5.5. Down pipes

All reservoirs constructed in the school and private compound does not requires down pipe as the water directly conveyed from the roof to the reservoir inlet via Gutters; whereas the Church systems have a number of down pipes and are at good condition.

5.2.5.6. Collection Chambers

The school systems does not required down pipe as the rainwater conveyed from the roof directly in to the reservoirs by Gutters. But the collection cambers for Church system requires maintenance. The chambers covers slabs are not sealed and filter wires are also damaged due to corrosion. As a result small dead animals and various solid wastes are observed in the chambers that cause serious contamination of the harvested water.

5.2.5.7. Distribution points

The distribution point of the 10 m^3 reservoirs system is a Faucet fixed at the bottom of the tanks and is functional. The distribution point for the 40 m^3 and the 75 m^3 reservoir are underground masonry water point with three faucets. Out of the three Faucets only one is functional.

Un underground water point with three taps is constructed to deliver the stored water from the 150 and 40 m reservoirs. Based on the information obtained from the teachers and the tap attendant the pipe line from the collection chamber to the water point is clogged and hence the water point is not functional. The school community collect water at the collection box by dipping that expose the collected water for contamination.

5.2.5.8. Water quality

Quality of water directly determines the drinking water security of a community. The criteria used by the user community in all of the schemes are colour; Taste; presences of worms; odour. The community perceptions of drinking water are governed by these factors.

To verify the quality of the harvested water two samples are taken from Kiticha kebele DRWH systems and three a sample from Chele system. The samples physical and biological tests have been carried out by an authorized institution. The test is conducted in WWDSE laboratory services and Output of the analysis shows that the water is safe for consumption as per the WHO standard

Table 5-3: Summary of Water Quality Test Results from Kiticha and Chele Kebele Schemes

Date of Sampling	Location	Source of water	No of sample	PH	Turbidity (NTU)	Conductivity (µS/cm)	Faecal coli forms counts/100 ml
27-04-2007	Minjar and Shenkora	Kiticha 150 m^3 Reservoir (School)	1	6.98	Trace	70	Not tested
27-04-2007	Minjar and Shenkora	Kiticha 10 m^3 Reservoir (DA house)	1	6.89	Trace	76	Nil
27-04-2007	Minjar and Shenkora	Chele 10 m^3 Reservoir (School)	1	7.63	5.0	61	Not tested
27-04-2007	Minjar and Shenkora	Chele 10 m^3 Reservoir (HH)	1	7.55	3.0	81	Not tested
27-04-2007	Minjar and Shenkora	Chele 40 m^3 Reservoir (School)	1	7.12	4.0	95	Nil

CHAPTER SIX

6. RESULT

This chapter shall discuss the major technical performances of the schemes in terms of tank capacity and water quality as established in the methodology of the study. Moreover the section shall brief discuses other performance elements like social, institutional and continuity of services to have a full picture of the problems associated with sustainable services delivery.

6.1. Technical issues

6.1.1. Tank size

One of the major indictor to measure the technical performance of DRWH scheme or system is the tanks size or the amount of water secured or made available for the user community with in the specified duration.

In this regard detail analysis is carried out to examine the capacity of the existing tanks in relation to the available roof areas and the number of targeted beneficiaries. As discussed in the literature review there are basically three approaches to determine the capacity of DRWH tanks/reservoirs. The approach followed in the design project document is the same for the two schemes and it is a combination of the two methods i.e. **Method-1** Demand side approach and **Method-2** supply side approach. The advantage and disadvantage of each of the methods including **Method-3** (computer Model) has been discussed in the literature review.

Based on the design criteria established a total of 992 m^3 of rainwater can be collected from the church and the school roof catchments of the Sama Senbet scheme. Similarly the demand is estimated to be about 3898 m^3 per annum. This shows a net deficit of about 2,900 m^3 per annum or the deficit is about 3 times less than the demand of the targeted community

Table 6-1: Sama Senbet DRWH Supply and Demand

No	Scheme	Roof area (m^2)	Amount of Rainwater Harvested (m3/year)	Total Demand (m^3/Year)	Deficit (m^3/Year)
A.	Churches				
1.	Senbet	300	202.5		
2.	Tekelehaymanot	536	361.8		
	Sub total	836	564.3	2920	2355.7
B.	School				
1.	Residential Block	91	61.43		
2.	Administrative Office	90	60.75		
3.	Teaching Blocks				
3.1.	Block-A	285	192.4		
3.2.	Block-B	168	113.4		
	Sub total	634	427.98	978	672.2
	Total	**1,470**	**992.28**	**3898**	**2,905.72**

Regarding the Chele and kiticha scheme the analysis result shows that a total of 495.3 m^3 of rainwater can be collected from the church and the school schemes per annum and the demand is estimated to be 3039.5 m^3 per annum. This also shows that a net deficit of about 2544.6 m^3 per annum.

Table 6-2: Minjar and Shenkora Woreda Low Land DRWH

No	Scheme	Roof area (m^2)	Amount of Rainwater Harvested (m^3/year)	Total Demand (m^3/Year)	Deficit (m^3/Year)
A.	***Chele site***			0	
1.	Chele Gebreal	254	152.4	1095	-942.6
2.	School	80	48	472	-424
3.	Private House	28	16.5	36.5	-20
	Sub total	**254**	**216.9**	**1603.5**	**-1413.6**

No	Scheme	Roof area (m^2)	Amount of Rainwater Harvested (m^3/year)	Total Demand (m^3/Year)	Deficit (m^3/Year)
B.	***Kiticha Site***				
1.	Kiticha School Block (A-C)	440	264	1422	-1158
2.	Kiticha DA House	24	14.4	14.4	-
	Sub total	464	278.4	1436.4	-1158
	Total	**718**	**495.3**	**3039.4**	**-2544.6**

Information gathered from the user community and tap attendants shows that under very serious controlled supply the harvested water shall serve from a few day to a couple of months in a given year. For instance the Sama senbet school DRWH system which is originally designed to provide safe water to school children and teachers lasts within 3 to 4 months while giving service only for school teachers. The same holds true for Chele 100 m^3 masonry Ferro cement reservoir which is planned to provide safe water for about 300 people shall serve only 2 to 3 days during the dry season; where all the ponds water used up.

To verify the findings the study has tested the reservoirs capacity of each of tanks with the help of the most recommended methods or techniques i.e. The Mass curve and the SimTanka software. Outputs of the analysis made with these methods shows that the tanks are designed and constructed beyond the annual expected runoff harvested and never meet the demand of the targeted number of beneficiaries in any of the months of a given year. For instance three masonry Ferro cement reservoirs with a total capacity of 350 m^3 are constructed to store rainwater collected from the roof of Senbet and Tecklehimanot churches (total roof area 836 m^2). According to the project document 800 people will have safe water from theses scheme through a given year at a supply of 10 l/c/d (for drinking and cooking only).However output of the mass curve analysis shows that the system can supply only for 80 people (10 percent of the target) at a supply of 10 l/c/d and the required reservoir capacity to be about 160 m^3 only.

Similarly using SimTanka software the system can serve for 80 people at 10 l/c/d with optimum tank size of about 184+/-25 m^3 at 95 percent of the time demand meet in each month and 100 percent of the time the tank will be able to meet the demand.

Thus result shows that the two approaches gives nearly equal size of tanks; even the upper limit of the optimum tank size obtained by applying SimTanka software is about 140 m^3 less than actually constructed capacities.

Related with this further discussion were made with the tap attendant and reported that out of the three reservoirs one of the 100 m^3 masonry Ferro cement has never been stored water due to foundation problem. Moreover the other 100 m^3 reservoir is not also giving services due to damage of the gutters (Teklehimanot Church). So, the 150 m^3 reservoir is the only functional tank. Out of these discussions and the result obtained, tank size, by the above two methods one could learn that it might not be either due to foundation or gutter problem but the available catchment could supply only the functional 150 m^3 reservoir. Actually this conclusion might need some detail work on ground like foundation seepage test, recording storage in each season and the like. (Refer Annex -7-1: different scenario and tank capacity using mass curve technique and SimTanka software).

Further analysis is carried out to see the relationship between tank capacity and roof area; a linear relationship with coefficient of correlation 1 is found. So the equation shall be applied for the design purposes in the same area or similar areas with somewhat identical rainfall pattern. Moreover tank size and cost relationship for circular ferro cement reservoirs has been also examined and is found that a linear relationship with coefficient of correlation 0.892.
Please note that the relationship is developed based on the prevailing cost during the projects implementation, so it need further work in relation to the current cost escalation in the country.

Figure 6-1: Roof area Vs tank capacity

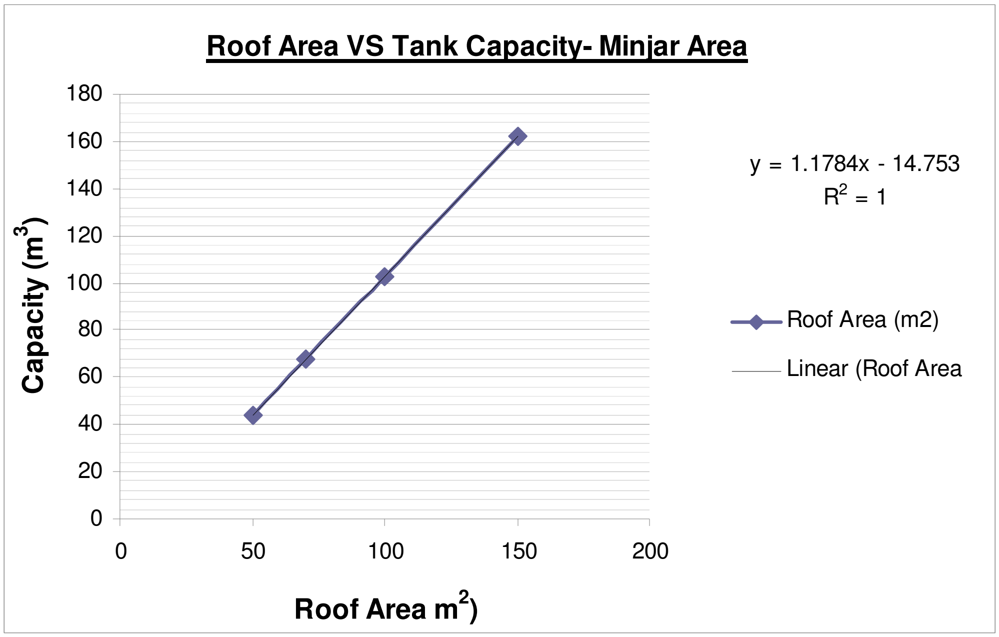
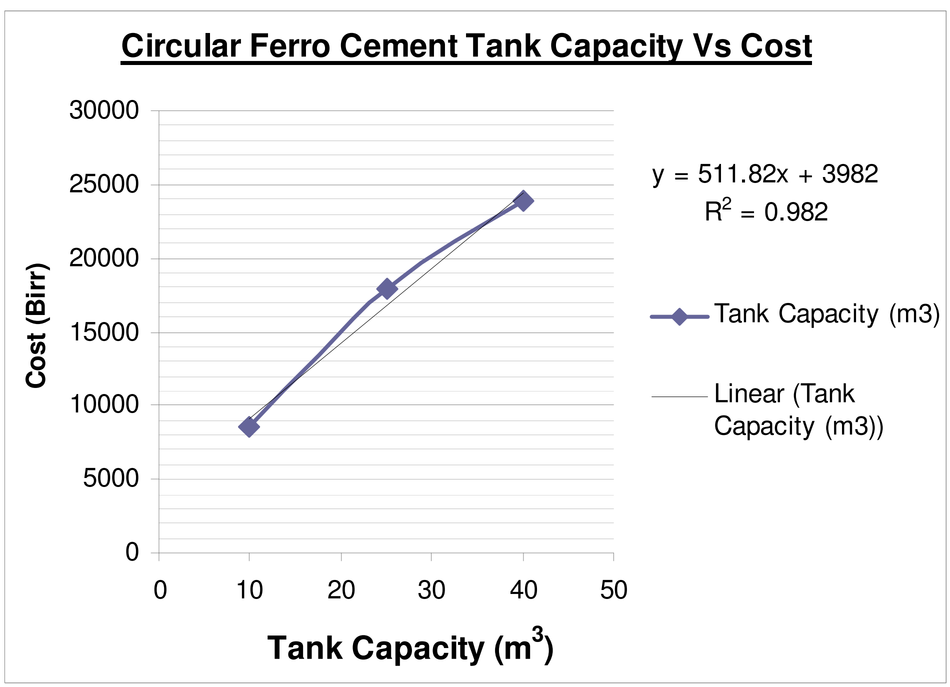


Figure 6-2: Tank capacity Vs cost



6.1.2 Quality of Water

Quality of water is one of the basic parameter that affects the performance of DRWH system. The field survey and discussion made with the community show that water collected from the schemes has good quality except some turbidity.

To verify the physical observation six (6) water samples were collected and physical and biological tests were conducted by an authorized institution. The samples are tested in the WWDSE laboratory service. Output of the lab result shows Turbidity ranges from Trace to 6 NTU; Electrical conductivity is from 61 to 95 µs/cm; PH ranges from 6.89 to 7.63 and faecal coli form per 100 ml is nil.

The lab result shows that the harvested water, from all of the schemes, is safe for drinking except a little improvement required to drop the level of turbidity of the $150m^3$ reservoir constructed at sama senbet church.

6.1.3. Social issues

Information gather from the project proposals and field survey reviles that the community was actively participated in all the stages of the project cycle. Most of the schemes are designed to provide supplementary safe water for drinking and cooking purpose only. However due lack of awareness the community, in Minjar and Shenkora people uses the water for cloth washing and other purposes. This last the water for shorter period which is much below the planned duration.

Studies have reviled that women and children are more vulnerable in the use of unsafe water. Accordingly one of the specific objectives of the DRWH implemented in the study area is to contribute in solving this problem. Nevertheless in all of the schemes school children's are note benefited from the services i.e. teachers and the woreda development extension workers are the major beneficiary of the schemes. In general the DRWH schemes implemented in school compounds missed one of the major targeted beneficiary i.e. the school children.

6.1.4 Institutional issues

Water Action has established water committees and water management board who are responsible for the overall management of the schemes. For the day to day activities of the scheme i.e. water distribution, maintenances and provision of hygiene and sanitation education trained VHCs are responsibly. In addition to theses water action has produced Amharic version scheme management by law. The bylaw shows that the woreda water desk and the zone water department shall provide the necessary technical support to the water management board to insure sustainable services of the schemes.

Income obtained by selling water to the user community is considered to be the major sources of income that shall be used for O and M of the schemes. Moreover water revenues to be installed in a local bank or micro-finance institution. As per the discussion made with the community most of the community does not now about the money they paid for the water and various committees have been changed to manage the schemes.

In any case the schemes lack institutional value and it could be said that the schemes have no owner in general. Discussion made with the Minjar and Shenkora woreda water desk indicate that the woreda has not give attention to the schemes that is more attention is given to big schemes like the deep well and other sources. This shows that the level of awareness is not only the problem of the user community but the responsible sector woreda office.

Discussions with the community also indicate that they do not know whom to communicate for maintenance and disinfections of the system. Even school teachers have this problem.

In general speaking unless otherwise the institutional problems of the schemes are solved in a very short period of time all of the schemes will not be exist or functional.

6.1.5. Continuity of service

There are a number of factors that affects the continuity or sustainable service of a water supply schemes. Among other includes needy community, community participation (in all stage of the project), institutionalising of the system, awareness creation, institutional by law etc.

In this respect Water Action has established water committees and water management board in each of the woreda DRWH schemes who are responsible for the overall management of the schemes. Trained VHCs are responsible for day to day activities of the scheme such as water distribution, maintenances and provision of hygiene and sanitation education. In addition to theses the organization has produced an Amharic version scheme management bylaw. The bylaw shows that the woreda water desk and the zone water department shall provide the necessary technical support to the water management board to insure sustainable services of the schemes.

Income obtained by selling water to the user community is considered to be the major sources of money that shall be used for O and M of the schemes. Moreover water revenues to be installed in a local bank or micro-finance institution. As per the discussion made with the community most of the community does not now about the money they paid for the water and various committees have been changed to manage the schemes.

In any case the schemes lack institutional value and it could be said that the schemes have no owner in general. Discussion made with the Minjar and Shenkora woreda water desk indicate that the woreda has not been giving attention to these schemes, which means more attention is given to big schemes like the deep well, river intake and other sources. This shows that the level of awareness is not only the problem of the user community but the responsible sector woreda office.

Discussions with the community also indicate that they do not know whom to communicate for maintenance and disinfections of the system; even school teachers have this problem.

CHAPTER SEVEN

7. CONCLUSSION AND RECOMMENDATIONS

7.1. Conclusion

The purpose of this research is to carry out the technical performance evaluation of DRWH schemes implemented by Water Action in Minjar and Shenkora Woreda. The research output will contribute to improve the level of services and promotion of DRWH technology in the effort made to improve the low level national safe water supply and sanitation coverage; wherever the technology is a feasible option.

The promotion of DRWH as an appropriate technological option requires a number of innovative approaches to cut down the investment cost. Most practitioners agreed that DRWH is an expensive technological option if it is designed as sole sources of safe water supply whereas a best option if it is a supplementary source both in the rural as well urban dwellers. The use of DRWH significantly decreases the monthly water fee for urban dwellers, where the price of water is expected to be significant.

One could learn from the projects document that the planning exercise is conducted with full and active participation of the user community. The community has involved in all cycles of the projects. However, finding of the study shows that the institutional set up of all of the schemes requires closed attention i.e. the overall scheme management set up need to be further diagnosis, it could be dared to say that currently schemes has no owner. Poor relationship between the user community and the water management committee and the woreda water desk are the major problem noted during the survey.

Information obtained from the community reveal that water revenue has not been used for operation and maintenance of the schemes. Moreover water revenue has kept at the hand of the committee this is unfair financial income management system.

Field observation and discussion with the user community indicate that proper operation and regular maintenances are an ignored aspect in most of the schemes. Gutters are started to fail; distribution boxes are getting damaging; nearly all filter are corroded and out of use; wooden Gutter supports are decayed etc. Damage of Gutter system results significant loss of water due to splashing out of high intensity rainfall and reservoir filling time to be longer; eventually the harvested water may not satisfy the demand.

Some of the design approaches of the major components of DRWH system need to be re-considered. During the survey it is noted that most of the reservoirs never experience over flow or not full. This shows that the demand is much more than the supply. For instance employing the mass curve technique and SimTanka software prove that the existing Sama Senbet Church reservoir shall serve only 10 percent of the targeted community.

DRWH is known more for its social and qualitative benefits than quantitative or tangible benefit and may fail a comparative advantage test where other sources of water are plentiful or the development technique is relatively chipper or simple.

An effort on optimizing the investment cost of any type of water supply and sanitation project requires a wise engineering consideration. Nevertheless considering cost only may lead to poor judgment and might have some danger. For instance most of the distribution points or water points of the observed schemes are constructed underground to attain gravitational flow from reservoir to the distribution point; in shorter pipe length. However, the approach enable to cut down cost of pipe work the distribution points lacks sufficient drainage system that result stagnant water. Thus, the underground distribution points create a favourable environment for mosquito and other insects breeding.

Site identification of potential roof catchment needs to focus on the existing condition of the building. Most of the schemes are dependent on mud and wood wall buildings or houses that are constructed more than 10 years, on a minimum. A specific site in Minjar and Shenkora woreda DRWH scheme implemented in Chele primary second cycle school is close to fail, which is attached to a 40 m^3 Ferro cement reservoir that cost more than 50,000 Birr. The useful life the school block has gone before implementing the scheme. So during the design or planning exercises it is wise to consider the cost of renovation of the buildings and future site plan changes.

One of the specific objectives of the projects is improving the health situation of the user community; more specifically it benefits children and women as they are vulnerable for water borne and water related diseases. However in all schemes constructed in school compounds has never been giving services to school children. During the field survey it is observed that school children bring water to school for dinking during their stays in the school. This is purely conflict-ridden to the specific objective of the projects.

Moreover Sanitation and Hygiene education and community development are two of the major components of projects. As compared to the water development almost nothing is found on the ground on the promotion of hygiene and sanitation i.e. trained village health communicators and care takers are not providing the expected services to the community.

One of the parameter to evaluate the performance of water supply project is quality of water. In this regard most of the schemes have not been disinfected since construction. During the survey it is observed that dead animal, small insects and their egg and plant leave has been seen in collection chambers and Gutters. However the physiochemical and Biological laboratory water quality test result shows that the water is safe for drinking. All samples Faecal Coli form is nil; Turbidity is Trace to 6 NTU (only one sample has this value); PH values ranges 6.89 to 7.63.

It may be amazing that the result of the laboratory water quality analysis and the field observations are quite contradictory. The reason on good water quality is that if rainwater is stored for a longer period of time contaminates will be cleared naturally by the bacteriological process and the water keeps it quality.

The survey findings and questionnaires feedback from practitioners shows that DRWH is a simple technological option; reliable and controllable sources; gives chemically and bacteriological low risk water; significantly reduced the drudgery of safe water collection for the rural community and has potential of significant financial savings in urban areas. With all these benefits a little has been done on the promotion and implementation of DRWH to solve the very problem of safe water supply both in the rural and urban part of our country.

The ultimate sources of fresh water is rain however information gap among community, water professionals, policy makers, international financers and donors (are more interested for large scale projects and programs) are some of the reasons for the low level promotion and implementation of DRWH. For instance the Ethiopian water resources management policy didn't point out anything about rainwater harvesting. Target established in the national water sectored development program indicate that the national safe water supply coverage to be 76 percent by the end of 2016. So, It would be a challenging task to the ministry to achieve its plan without considering one of the simplest and affordable technological option; DRWH system.

To realize the effect of DRWH on the provision of safe water supply in the country on could work out the following rough estimate: the national WMS 2004 show that about 483,545 hhs in Addis Ababa live in corrugated iron sheet roof buildings and out of these about 155,387 hhs live in two rooms. So, if we assume the smallest house unit size to be 4m * 4 m ($16m^2$) annual about 4.4 million cubic meter of water can be harvested. and could be used to improve the level of safe water coverage of the city.

Recently, the government have started promoting and investing significant amount of money on rainwater harvesting for crop production and domestic water supply proposes, which is an encouraging step to attain the target.

7.2. Recommendation

- ✓ The study recommend that water revenue, whatever the mount may be, should be installed in a local bank or credit and saving association. The very purpose of the money should be to use for future operation and maintenance of the schemes. In some cases the money might be so small and requires subsidizing from other water development schemes with in the same area.

- ✓ Field observation and discussion made with the user community indicate that O and M of schemes is an ignored aspect. So capacity building through refresher training to the community, the WatSan committee and the village health communicators/care takers/ are very important steps to sustain the schemes.

- ✓ Lack of standardization is one of the gaps observed in the most of the schemes. For instance some of the schemes lack splash guard, in some schemes gutters are rectangular in shape and in others they are triangular. So it is recommended to use triangular or semi-circle gutter as their hydraulic efficiency is high. Triangular gutters are very simple if gutters are manufactured on site.

- ✓ Many research outputs show that provision of first flush devices is found very important to improve the quality of harvested water. Information obtained from the community shows that they are aware of the importance of the devices but the operation is difficult. This is because the first 2-3 minute rainwater is expected to be diverted manually i.e. diverting the gutter from the inlet. But at the start of the rain it might be rare case where by people to be at home or might be at slept. Especially for communal schemes like church, mosque and schools availability of gutter operator during the start of the rain is impractical. So for such small community water supply scheme the use of a constant volume first flush device is recommended.

- ✓ The other important component of DRWH scheme is the filter. Nearly all of the reservoirs and conveyance pipes had been fixed with wire mash filter. But during the survey it is observed that all of the filters are damaged due to corrosion. So the study recommends using plastic filters or sand filters to improve the services age of the filter material.

- ✓ The woreda water desk, which is one of the responsible governmental institution need to closely follow up the DRWH schemes and provide the necessary technical and financial support to the water management committee or board. Discussion made with the woreda water desk shows that they are giving more support for large scale water schemes like boreholes than the DRWH schemes. So it is recommended to build the capacity of the woreda water desk staffs through provision of technical training on promotion of DRWH technology.

- ✓ Some of the design approach and criteria exercised for these schemes needs to be re-considered. For instance tank sizes, which is the most important and expensive facility in the promotion of DRWH system are determined based on an average annual rainfall that does not consider the rainfall patter. The method is used only for preliminary works and gives a size that does not fit with the demand. So the research recommend to use either the most popular method the mass curve technique or the SIMTANKA software (freely available) to determine the optimal size of tanks or reservoirs. SIMATNKA requires 15 years rainfall data and of course mass curve also requires 7 to 10 years rainfall data. So depending on the availability of data we can use one of the two methods. The mass curve does not require sophisticated software a hand calculator is quite satisfactory.

- ✓ The study also recommends the use of HEC-HMS to estimate the runoff from roof catchment that enables to determine the capacity of Gutter and down pipes.

- ✓ DRWH is known more for its social and qualitative benefits than quantitative or tangible benefit and may fail a comparative advantage test where other sources of water are plentiful or the development technique is relatively chipper or simple.

- ✓ Site identification or identification of potential roof catchment needs to focus on the existing condition of the building in general. We can say the building is the head work for

DRWH system, so failure of the building is totally to mean failure of the system or the services rendered. So during the planning design it is wise to consider cost of renovation of the building.

- ✓ Based on the field observation and feedback collected from practitioners the research recommend promotion of hh and institutional (school) DRWH are more sustainable than communal schemes in various ways. The most common advantage of hh DRWH schemes is that hhs will be directly responsibility for O and M of the scheme and the closeness of the water at get develops confidences and reliability on the water management and use.

- ✓ The promotion of DRWH in general is not a cheap option but in areas where both surface and subsurface water resources potential is poor in terms of quantity and it will be a best option. DRWH could be made a cheapest option if promoter has used innovative knowledge to cut down cost of construction of the various components of the system.

- ✓ Awareness creation for water professionals, policy makers, international financers and donors through workshops, meetings , publications such as brochures and the like are very important works to be under taken to improve the promotion of DRWH in the effort made to improve the low level safe water supply of the country. In these regard the ERHA has been made a number of effort but should have been strengthen.

- ✓ Future study should consider larger sample size, geography representation, climate, culture, religion and other parameters that affect the water demand and supply situation. Moreover the study should also need to consider other technical performances elements that are not considered in this study such as social aspect and financial viability.

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APPENDIXES

Appendix 1-1: Geographic position of DRWH Schemes

No	Description	GPS Location	Elevation meters amsl)	Remarks
1	**Minjar and Shenkora Woreda Schemes**			
1.1.	Chele Kebele, Hh 10 m^3 Ferro Cement Reservoir	N-08^0 55.022'	1719	
		E-039^0 31.619'		
1.2.	Chele Kebele, 40 m^3 School Ferro Cement Reservoir	N-08^0 55.156'	1721	
		E-039^0 31.630'		
1.3	Chele Kebele, Gebrail Church 75 m^3 Masonry Ferro cement Reservoir	N-08^0 55.418'		
		E-039^0 31.787'	1711	
1.4.	Chele Kebele the abandoned New Deep well	N-08^0 56.087'	1683	
		E-039^0 32.145'		
1.5.	Chele Kebele , School 10 m^3 Ferro Cement Reservoir	N-08^0 55.118'	1721	
		E-039^0 31.638'		
1.6	Kiticha Kebele, School 40 m^3 Ferro Cement Reservoir	N-08^0 51.691'	1693	
		E-039^0 29.84'		
1.7.	Kiticha Kebele, School 150 m^3 Masonry Ferro Cement Reservoir	N-08^0 51.70'	1695	
		E-039^0 29.825'		
1.8	Kiticha Kebele, DA House 10 m^3 Ferro Cement Reservoir	N-08^0 51.539'	1699	
		E-039^0 29.849'		
1.9	Sama Kebele, School 40 m^3 Ferro Cement and 75 m^3 Masonry Ferro Cement Reservoirs	N-08^0 47.146'	2116	
		E-039^0 19.792'		
1.10	Sama Kebele, Senbet (Sabbath) Church 100 and 150 m^3 Masonry Ferro Cement Reservoirs	N-08^0 46.423'	2088	
		E-039^0 19.475'		

Appendix 1-2: Mean Monthly Rainfall, Modjo station

Element: Monthly Rainfall (mm)
Region: Shoa
Station: Modjo

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1986	0.0	56.2	34.0	59.2	32.7	182.2	132.2	65.1	72.6	3.1	0.0	0.0
1987	0.0	22.8	377.9	75.7	200.3	8.9	154.3	233.6	53.3	14.5	0.0	0.0
1988	20.5	4.5	6.8	29.7	10.7	124.8	255.4	300.5	243.3	62.8	0.0	0.0
1989	0.0	14.9	125.1	84.9	0.2	77.0	175.5	385.3	116.4	22.5	0.0	1.8
1990	0.0	131.1	48.2	54.6	x	20.6	291.8	228.9	125.4	0.4	0.0	0.0
1991	0.0	31.1	147.1	4.3	13.8	55.2	329.9	205.0	92.2	0.0	0.0	0.0
1992	41.2	5.4	9.9	48.5	18.0	86.2	182.9	287.0	82.9	27.4	10.7	1.9
1993	2.0	19.5	0.0	82.5	73.0	59.6	286.5	216.6	82.1	5.4	0.0	0.0
1994	x	x	22.6	39.7	x	87.2	251.0	117.5	127.3	0.0	40.1	2.5
1995	x	44.6	37.0	60.5	31.4	32.7	180.8	143.7	70.9	2.5	0.0	0.0
1996	x	0.0	97.5	72.2	127.0	214.9	221.3	220.9	79.8	0.0	3.0	0.0
1997	30.4	0.0	37.6	16.8	16.1	130.6	216.1	158.6	77.8	55.3	21.0	0.0
1998	32.3	7.6	50.7	46.0	46.0	112.1	161.3	274.8	149.0	154.1	0.0	0.0
1999	x	0.0	18.4	0.0	4.2	90.9	541.5	362.0	67.4	87.4	0.0	x
2000	0.0	0.0	12.0	10.1	33.2	128.0	285.9	230.8	114.1	12.6	25.4	0.0
2001	0.0	28.5	79.4	22.5	111.0	131.5	184.7	175.6	54.9	0.0	0.0	0.0
2002	0.0	0.0	8.9	13.7	6.5	62.4	193.5	168.2	90.2	0.0	0.0	14.7
2003	40.6	55.9	74.9	84.3	23.2	129.0	393.2	148.6	96.1	0.0	0.0	14.3
2004	12.5	0.0	99.3	114.6	9.8	x	393.8	211.2	123.7	99.1	32.4	x
2005	x	19.1	160.5	149.6	201.4	200.6	320.6	296.1	143.4	7.3	10.9	0.0
2006	1.6	38.5	90.5	61.6	19.2	108.1	344.4	x	x	24.9	x	x

Appendix 1-3: Mean Monthly Maximum and Minimum Temperature, Modjo Station

Appendix 1-3-1: Mean Monthly Maximum Temperature, Modjo Station

Element Monthly Maximum Temperature (C^0)
Region: Shoa
Station: Modjo

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1986	28.0	30.4	x	x	29.7	26.5	25.3	25.3	26.0	27.6	26.6	26.5
1987	27.2	28.7	28.5	28.5	27.9	27.8	27.0	25.7	28.1	28.9	28.7	28.3
1988	28.1	30.1	31.3	30.0	31.5	28.3	23.8	24.4	25.0	28.2	27.3	27.1
1989	27.0	30.0	30.1	27.5	31.3	28.6	24.2	24.7	25.3	27.6	28.0	27.5
1990	28.2	27.8	28.3	29.2	x	29.3	25.1	24.5	25.9	27.4	28.0	26.5
1991	29.4	29.0	29.7	30.0	31.3	30.7	24.5	24.3	26.3	28.4	27.6	27.5
1992	28.0	29.0	31.6	31.8	32.2	29.9	24.8	23.5	25.7	27.1	27.2	27.9
1993	27.8	27.5	31.6	29.8	29.3	28.6	26.7	25.9	26.2	28.6	28.7	28.5
1994	x	x	32.0	31.8	33.0	28.4	24.8	23.9	25.2	27.2	26.5	26.2
1995	27.9	29.2	29.1	29.1	30.7	30.0	24.5	24.8	26.0	27.9	28.2	28.2
1996	x	28.7	29.1	29.9	29.9	29.3	26.6	24.9	26.9	27.5	27.5	27.2
1997	28.0	28.5	30.9	29.1	30.7	28.6	25.2	26.3	28.1	28.5	27.5	28.6
1998	29.2	30.4	31.1	32.0	31.9	32.3	26.9	24.5	25.7	27.0	26.7	27.0
1999	x	30.8	30.5	31.0	30.9	30.0	29.4	28.9	28.8	28.6	29.3	x
2000	28.5	29.7	30.9	30.6	30.6	20.3	24.3	23.7	26.4	27.5	28.4	28.2
2001	28.1	29.6	29.5	30.9	30.1	28.3	26.3	26.0	27.8	29.7	29.5	29.6
2002	29.2	30.0	29.4	29.9	30.5	29.4	28.1	27.5	28.8	28.4	29.3	27.7
2003	28.6	29.3	29.9	29.6	32.1	30.0	25.5	26.8	29.4	30.3	28.9	27.6
2004	29.2	29.4	30.2	31.1	33	x	27.4	29.1	30.3	29.4	30.5	x
2005	x	x	31.7	32.5	31.7	31.6	27.3	28.1	28.1	30.1	28.4	28.1
2006	30.2	31.7	30.9	30.2	32.9	30.7	27.9	x	x	31.2	x	x

Appendix 1-3-2: Mean Monthly Minimum Temperature, Modjo Station

Element: Monthly Minimum Temperature (C^0)
Region: Shoa
Station: Modjo

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1986	6.3	13.6	x	x	14.4	14.7	13.3	8.7	7.7	4.2	4.2	10.5
1987	11.4	11.3	15.3	13.9	14.5	15.0	15.1	14.7	14.6	13.1	10.3	10.3
1988	11.9	14.5	14.8	15.3	15.4	14.2	15.3	14.7	14.2	11.5	7.3	9.9
1989	8.6	11.7	x	x	x	x	x	x	x	x	x	11.9
1990	10.4	14.1	13.1	13.3	x	12.9	13.9	14.1	13.2	10.4	9.6	7.5
1991	11.0	13.6	14.5	14.3	14.2	14.0	14.4	13.9	13.1	11.8	8.7	10.1
1992	11.5	12.7	14.7	14.3	13.6	13.1	13.5	13.9	11.9	10.4	10.6	11.3
1993	11.0	11.5	11.3	13.8	13.9	13.5	13.9	13.9	13.2	12.2	9.5	8.6
1994	x	x	13.7	14.5	15.1	13.0	15.2	14.7	14.0	11.0	9.7	9.3
1995	8.4	12.6	14.2	15.2	14.8	14.0	14.5	14.8	14.0	13.6	10.4	11.4
1996	x	11.0	13.3	13.3	13.5	13.2	15.0	14.4	13.0	10.2	10.0	8.1
1997	11.5	9.7	14.6	13.3	13.4	15.1	14.6	14.6	12.6	11.7	13.3	9.0
1998	11.5	11.1	12.6	13.8	13.1	13.0	14.0	15.4	14.5	13.0	8.4	6.8
1999	x	11.9	14.2	13.1	12.5	12.7	12.9	12.7	12.9	12.7	13.3	x
2000	9.4	10.1	13.3	14.7	14.7	13.6	14.4	13.9	13.4	11.7	9.5	7.7
2001	7.7	10.3	12.6	13.1	13.9	13.6	13.5	14.0	12.4	10.7	10.4	7.0
2002	9.0	8.7	12.3	12.6	12.4	12.9	14.0	14.5	12.3	10.6	9.2	9.4
2003	9.7	10.7	10.8	13.7	13.4	12.4	8.7	8.5	10.0	8.0	9.6	6.1
2004	9.0	9.3	10.2	11.1	12.9	x	6.9	7.6	9.2	8.6	6.9	x
2005	x	x	11.1	12.0	10.8	9.9	7.1	6.5	6.8	7.1	6.8	4.8
2006	8.1	11.1	10	9.9	12.3	9.2	7.4	x	x	11.2	x	x

Appendix 1-4: Questionnaire

Addis Ababa University
Questionnaires To Conduct Technical Performance Evaluation Of Domestic Roof Water Harvesting Schemes (DRWHS)
(The Case Of Water Action; Indigenous NGO):

(Field findings to be collected by researcher)

Section I: Water Supply

I. General Information:

Project Name: ____________________________________

Region: ____________________________________

Zone: ____________________________________

Woreda: ____________________________________

II. Population Information:

1. Type of service: Communal ☐ Hh Institutional ☐ Other ☐
2. Number of users Hhs/People/ __________________

III. Structural Situation:

1. When was the building/house/ constructed?______________________
2. Existing condition of the house/store/school/church etc:

Good ☐ Fair (Star damage of wall, Roof, foundation) ☐ Poor (Close to damage) ☐

3. Type of the indwelling/water harvesting building and its roofing:

Hollow block wall with CIS roof _______ Mud block wall and CIS roof______

Mud block wall and thatched roof _____________CIS wall and roof ___________

4.When was the scheme constructed and start giving services?________________

5.What is the estimated/available/ capacity of tank or Reservoir?______________

6. Is the scheme/in general/ functional? Yes ☐ No ☐ If No, please specify the estimated date and reason____

7. Is there any crack on the wall, roof and bottom slab of the tank/reservoir?

Yes ☐ No ☐

On the Wall ☐ On the Roof ☐ On Bottom Slab ☐ All

If yes, how do you classify the case? Minor crack ☐ Major crack ☐ It does not store water for longer ☐

7. What is your assessment on the existing condition of the down pipes?

Good ☐ Fair (loss connection and Star leakage) ☐ Poor (doesn't lead water to ☐ ık)

8. What is your assessment on the existing condition of the collection chambers?

Good ☐ Fair (minor crack, damaged cover slab) ☐ Poor (Major crack, damaged cover slab and leakage) ☐

9. Is the scheme or the facility maintained before? Yes ☐ No ☐ If yes, when and by whom?____

Section II: Sanitation:

1. Is there any contamination of the Roof catchments area? (Example Plants, Birds dropping, foliage, dust etc) Yes ☐ No ☐

2. Are the Gutters, which collect water from the roof dirty? Yes ☐ No ☐

3. Is there any defect at the tank intake? (Example lack of filter) yes ☐ No ☐

4. Is there any other point of entry water to the Reservoir/tank which is not properly covered? Yes ☐ ☐

5. Is there any defect on the roof (top of the tank) which could let in water in to the tank? Yes ☐ No ☐

6. Is the tap leaking or otherwise defective? Yes ☐ No ☐ , If yes, how do people collect water from the tank?______________________________________

7. Is the soak away pit under the tap non functional or dirty? Yes ☐ No ☐

8. Is the water collection point has adequate drainage? Yes ☐ No ☐ , If Yes, describe the situation?____

9. Is there any sources of pollution around the reservoir/tank or water collection areas? Yes ☐ No ☐ , if yeas indicate the type?__________________________

Section II: Water Quality:

1. Are people using the Water? Yes ☐ No ☐ If No, Specify the reason____

2. Is the harvested water has odour? Yes ☐ No ☐ If Yes, What do people expected the causes of the smell____

3. Is the harvested water has colour? Yes☐ No ☐ If Yes, What do people expected the causes of the colour____

4. Is there any water quality tests conducted after the facilities are put in place?

Yes ☐No ☐ If yes, When and by whom ___________________________________

Section II: Quality of services:

1. Is the scheme serves peoples/ population/ that were not considered in the design or in the plan? Yes ☐ No ☐ If yes; please specify the number of hhs

____

2. Is there any new water supply scheme implemented in the project area that shall contribute the provision access for the potable water supply? Yes No ☐ ☐

Please describe the type and when it is constructed __________________________

____

3. Describe about the water abstraction method like how much, when and average amount and the like.

____

____

____

4. How long the harvested water in the tank serves the beneficiaries? Number of days or weeks or months in a year:____

5. What is/are the alternative source of domestic water supply for the people/beneficiary / right after the water in the reservoir or the tank depleted?

____

____

6. Had it been happen that the reservoir/tank are full and overflow?________________

7. Is there any duplication of such effort either at hh or institutionally level?

If yes, by whom (institution) and how many are there?_______________________

____

Interviewer by _____________________________________

Signature: ______ Date _____________________

Addis Ababa University

Technical Performance Evaluation Of Domestic Roof Water Harvesting Schemes (DRWHS)

(Views and comments collected from practitioners)

1. How do you define domestic roof water harvesting (RDWH)?
2. Why Roof water harvesting?
3. Do you believe that a little has been done on the promotion of roof water harvesting? If yes, what are your assessments for the major problems on the promotion of roof water harvesting? Please describe in detail.
4. Is DRWH a cheaper option? Please describe your opinion.
5. What is your assessment on the cost of implementation of DRWHS as compared number of beneficiaries it serves? If available can you indicate schemes type by component and cost?
6. Is the communal or hh DRWH technical are efficient or sustainable, and why?
7. Have you been heard any information about the quality/negative/ of the harvested water?
8. Please include any information based on your practical experiences

Appendix 4-1: Water Quality Lab Result

Appendix 6-1: Construction Stapes of 40 m^3 Ferro Cement Reservoir

The following stapes of construction of 40 m^3 Ferro Cement Reservoir is adopted from the practical experience of Water Action. The construction steps assume that all pre works are done during the planning phase or the study.

1. Chose a suitable site on a firm ground, clear the top vegetative soil to remove plant roost;
2. Make a circle with diameter 6 m and mark the centre of the circle with a peg;
3. Mark the wall foundation trench by attaching a tape measure to the centre peg, trace out a radius of 2.5 m then excavate foundation trench with size 30 by 30 cm and a trench for any pipe work;
4. Place the pre prepared concrete mix of 1:2.5:5 (by volume) in the foundation trench. Please note that the concrete should be well compacted for maximum density and finished off with a level surface (the use of concrete vibrate is advisable to avoid segregation);
5. Cast twenty-four pieces of angle Iron (30 x 30 x 4 mm) vertically with a length of 2.3 m meter each into the wet foundation at 65 cm centre to centre spacing and to the full foundation depth (30 cm). The angel Irons must be placed in truly vertical position (check with sprit level) and should be supported until the concrete sets as they will determine the shape of the tank; the concrete should be given several days (7 to 14 days) to harden before the walls are started to construct;
6. Wrap straight galvanized steel wire (Black iron) around the ring of the vertical angle iron supports at 5 cm spacing starting from the bottom up to the full height of the tank. At each angel iron each strand of wire should tied with soft iron wire. Three extra strands are wrapped around the top of the tank;
7. Place the roof reinforcement of 8 mm diameter at 32.5 cm centre to centre spacing around the top of the tank and fasten to the angle iron and hoop wire (before the walls are plastered) leaving on access hatch at the centre;
8. Bend down the roads on the angle iron and hoop wires to form a canopy, then tie temporarily to a prop erected in the centre of the tank this will leave an opening for the access hatch;
9. Fasten formwork sheeting(plywood or flat galvanized iron) inside the ring of angle iron supports and tie to them with soft iron wire;

10. Trowel 1 cm thick mortar on to the out side of the tank, gives 24 hours to harden and apply a second coat and finish with a plasters steel flat;
11. Strip the formwork
12. Apply a third mortar layer 1 cm thick to the inside part of the tank;
13. Trawl a fourth layer on to the inside of the tank and finish with a plasterers steel float;
14. Cover the tank and allow to cure;
15. Round a 4 mm diameter wire in a spiral fashion over the top of the tank at 10 cm centre to centre spacing and tie to each radial reinforcement bar with soft iron tie wire;
16. Leave loose one section of the reinforcement to allow the sheet formwork of the walls to be lifted out;
17. Trowel 3 cm mortar layer on to the top and finish with plasters steel float;
18. Cover the tank and allow to cure and refer table bellow for estimated materials requirement for the construction on a 40 m^3 Ferro cement reservoir

Table --Construction materials required to construct 40 m^3 Ferro Cement Reservoir.

No	Description	Unit	Quantity	Unit Price	Total Price (Birr)
1	Sand	m^3	10	100	1,000.00
2	Cement (Portland Cement or equivalent)	Qt.	40	350	14,000.00
3	Gravel (03)	m^3	4	85	340.00
4	Stone	m^3	7	35	245.00
5	Reinforcement Bar				-
5.1	Dia 40 mm	Kg	110	10	1,100.00
5.2	Dia 8 mm	Kg	190	10	1,900.00
6	Black wire	Kg	8	4	32.00
7	Corrugated Iron sheet or play wood) for formwork	m^2	36	50	1,800.00
8	Angle Iron (30x 30 x 4 mm)	m	84	15	1,260.00
9	Timber	m^2	3	60	180.00
10	Equalities	Ls	-		200.00
11	Sack	m^2	34	10	340.00
12	Others	Ls	-		800.00
Total					**23,197.00**

Appendix 7-1: Different Scenario and Tank Capacity Determined using Mass Curve Technique and SimTanka Software