ANALYSIS OF RAINWATER HARVESTING SYSTEM IN KATSINA STATE, NIGERIA

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Declaration

This is to certify that the work presented in this thesis is the outcome of the investigation carried out by Abdullahi Aminu Lawal under the supervision of Prof. Dr. Rezaul Karim in the department of Civil and Environmental Engineering Department (CEE), Islamic University of Technology (IUT), Gazipur, Bangladesh. It is hereby declared that this thesis/report or any part of it has not been submitted elsewhere for the award of any Degree of Diploma.

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Dedication

To my Family, Engr. Umar B. Imam and Engr. Murtala A. U.

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Acknowledgement

All the praises and thanks be to Allah Almighty who granted mes an opportunity to complete my thesis work successfully.

First and foremost I would like to express my deepest gratitude to my supervisor Prof. Dr Rezaul Karim for his excellent guidance caring, patience, motivation, enthusiasm and immense knowledge.

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Last but by no means the least my sincere thanks to my family who supported me throughout all my studies.

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Abstract

Water is an essential resource for all life on the planet. Of the water resources on earth only three percent of it is fresh and two thirds of the freshwater is locked up in ice caps and glaciers. Of the remaining one percent, a fifth is in remote, inaccessible areas and much seasonal rainfall in monsoonal deluges and floods cannot easily be used. At present only about 0.08 percent of all the world’s fresh water is exploited by mankind in ever increasing demand for sanitation, drinking, manufacturing, leisure and agriculture. The available freshwater exploited is under stress due to increase in population and climate change. Water supply systems in many cities of the world are under stress. To tackle this problem, water authorities are adopting several measures including demand management and identifying alternative water sources such as rainwater harvesting.

Rainwater Harvesting System (RHS) could be the best among the various technologies to augment freshwater resources in order to reduce the scarcity of safe water. Rainwater and its utilization could be an environmentally sound solution, which can avoid many environmental problems often caused by conventional large-scale projects using centralized approaches.

The importance of roof rainwater harvesting as strategy to meet domestic water demand and to reduce run-off in built-up areas is growing worldwide. Indicators that measure the performance of rainwater harvesting systems have been developed. One such indicator is reliability, which is dependent on the rainfall and water consumption patterns, tank size and effective roof area. The application of an appropriate rainwater harvesting technology can make possible the utilization of rainwater as a valuable and, in many cases, necessary water resource. Rainwater harvesting has been practiced since antiquity, and in most developing countries, is becoming essential owing to the temporal and spatial variability of rainfall. Rainwater harvesting is necessary in areas having significant rainfall but lacking any kind of conventional, centralized government supply system, and also in areas where good quality fresh surface water or groundwater is lacking. Rainwater Harvesting System (RWHS) is basically a simple, technically feasible and socially acceptable system to store and use rainwater for drinking purpose

Excel model that accounts for tank inflow and outflow and computes system reliability based on monthly rainfall data, effective roof area, monthly water consumption and tank size was developed. The model uses monthly rainfall data and parameters to calculate the reliability and

demand satisfaction of a given rainwater harvesting system, and output includes a graph of the system's storage tank level over the simulation time period.

Water demand is proportional to the storage capacity and hence the catchment area, the storage volume (liter) was determined for varying demand (liter per capita per day) for 5 number household and available roof area (m2) of 10, 15, 20, 30, 40 and 50 respectively. Storage may be tank or cistern, because the available polyethylene tanks in the market are 500, 1000, 1500, 2000, 3000, 4000 and 5000 liters which are the most common and easiest to clean and connect to the piping system.

The rooftop area was multiplied by the annual rainfall and runoff coefficient to obtain the amount of water store Based on the results, a nomograph for reliability of 66.67% was developed. The nomograph was used to optimally size rainwater harvesting systems where the storage found to be 1000L. The higher the reliability, the greater the investment costs in water storage and roof area. , it is observed that the maximum reliability of the system is only 66.67%.

Therefore, the water from supply main has to be used to fulfill the demand. The reliability can be increased by increasing the roof area and storage. Depending on the needs of your household, that can be significant amount of water to augment your water supply.

Chapter I

1 INTRODUCTION

With increasing population and changing climate regime, water supply systems in many cities of the world are under stress. To tackle this problem, water authorities are adopting several measures including demand management and identifying alternative water sources such as storm water harvesting, grey water and wastewater reuse and desalination. Among all the alternative water sources, storm water harvesting perhaps has received the most attention. Despite positive outcome from many studies, there remains a general community reluctance to adopt storm water harvesting on a wider scale. Part of the reason for this reluctance can be attributed to lack of information about the effectiveness of a storm water harvesting system and the optimum storage size required to satisfy the performance requirements under the specific site conditions and proper in depth understanding of the effectiveness of any proposed on-site storm water harvesting system is often lacking.

The world's total water supply of about 332.5 million cubic miles (about 1,385 million cubic kilometers) of water, over 96 percent is saline. And, of the total freshwater, over 68 percent is locked up in ice and glaciers. Another 30 percent of freshwater is in the ground. Thus, rivers and lakes that supply fresh surface water for human uses only constitute about 22,300 cubic miles (93,100 cubic kilometers), which is about 0.27 percent of total water, yet rivers are the source of most of the water people use. It is estimated that the average person in developed countries uses 500-800 litres of water per day, compared to 60-150 litres per day in developing countries. When individuals lack household access to water, they must purchase it from another source.

During the past decade, considerable techniques have been developed for designing and optimizing of rainwater harvesting systems such as water balance simulation (Fewkes and Butler, 2000; Villarreal and Dixon, 2005, Khastagir, 2009, Pandey et. al, 2011), probabilistic methods (Lee et al., 2000; Guo and Baetz, 2007) and hydrological approach (Kim et al, 2009).

For instance, simple water balance model was employed for estimating the rainwater storage in an on-farm reservoir (OFR) system (Pandey et. al, 2011). The simulation shows that as the OFR size increases, the rainwater storage in the OFR reduces. A hydrological analysis of rainwater harvesting facilities was conducted using a model based on the Identification of unit Hydrographs And Component flows from Rainfall, Evaporation and Streamflow data (IHACRES) (Kim et al, 2009). Using this model, the rainfall, rainfall loss, inflow to the storage tank, tank storage volume, overflow from the tank, and rainwater consumption data were simulated to evaluate the hydrological characteristics of the rainwater harvesting facilities. Recently, Campisano (2012) used a dimensionless methodology to determine the optimal size of rainwater harvesting tanks based on the results of daily water balance simulations for 17 rainfall gauging stations in Sicily (Italy).

Rainwater harvesting consists of a wide range of technologies used to collect, store and provide water with the particular aim of meeting demand for water by humans and/or human activities. The application of an appropriate rainwater harvesting technology can make possible the utilization of rainwater as a valuable and, in many cases, necessary water resource. Rainwater harvesting has been practiced since antiquity, and in most developing countries, is becoming essential owing to the temporal and spatial variability of rainfall. Rainwater harvesting is necessary in areas having significant rainfall but lacking any kind of conventional, centralized government supply system, and also in areas where good quality fresh surface water or groundwater is lacking. Rainwater Harvesting System (RWHS) is basically a simple, technically feasible and socially acceptable system to store and use rainwater for drinking purpose. The ultimate goal of rainwater harvesting is to store water (in a tank/reservoir) during the rainy season so that you can use it when needed most during the summer. Most important of all, there are many financial models to suit developing and developed countries. What is most needed is the moral acceptance of the technology and the political will to implement the systems. Rainwater Harvesting sums up all the techniques and methods that are involved in the capturing, diversion and storage of rainwater. RWH augments the amount of disposable water, especially in the dry season as it can be stored. RWH refers to many different techniques; some of them use methods to collect water from ex-field areas, some of them increase the efficiency of the fallen rain by conserving soil moisture.

RWH is ecologically, socio-culturally and economically sustainable (RELMA 2005:5). It is ecologically sustainable because there is no exploitation of natural resources and it does not pose any threat to the environment, either. It is socio-culturally sustainable because the lessened pressure on stream flow water makes a contribution to a healthy co-existence of stakeholders within one and the same watershed. Apart from that, in a spatially smaller context, communities that apply RWH can be encouraged to work together and help each other (e.g. while constructing the community pond, supporting each other financially in a so-called *“merry-go-round” scheme8*, managing the fair splitting of the collected water, etc.). It is economically sustainable because investments are relatively cheap and a successful appliance of the technique enhances the disposable time for earning an extra income. Furthermore, higher yields that surmount the own needs of a household can be sold – provided that there is access to markets. For example, women in Sri Lanka whose households had applied a micro-irrigation technique and attained bigger yields could receive revenue from selling their products (IWMI 2006:5). That is why it makes sense to consider RWH in the context of sustainable development. Yet, in geography, what theories are suitable or common that uses sustainability as a research concept? The conceptualization of sustainable development ought to include the three mentioned sub-domains economic, socio-cultural and ecological sustainability, as well as an actor-centred approach (WIESMANN 1998). Apart from the difficulty that every actor-centred study displays a unique case, there is the problem of where to draw the line in consideration of the study‟s systemic boundary. WIESMANN & MESSERLI (2007:132) call the latter *systemic trap of sustainability*. In a model that claims to picture reality as close as possible, many more variables have an impact on a certain case and it would be impossible to incorporate them all or to understand every (reciprocal) effect they might have.

Rainwater has traditionally been a security in areas where water has been scarce. In our region, Rajasthan, Gujarat, various areas in Pakistan, India and Sri Lanka are located in dry zone areas with 500-600 mm of rainfall or less a year. People have survived by collecting rainwater and accommodating their agricultural patterns and crops to suit the available rain and reduce evaporation. In Rajasthan, *kundis*, are unique structures which look like huge concrete saucers on the landscape. These are used for collecting rainwater to meet the needs of the local people and animals. Similarly, in the karstic central areas of Jamaica cemented catchment areas were constructed to collect the rain and lead it into community tanks. Rainwater can be used to meet part of domestic water demand including both potable and non-potable. In urban areas, at a household level, rainwater can be used for flushing toilets, watering gardens and washing floor and these uses are known as non-potable. While in rural areas, it becomes the main source of water for potable uses which include drinking, bathing, and cooking. In rural areas it is recommended to treat the collected rainwater prior to use particularly if it is intended to be used for drinking.

A simplified rainwater harvesting system consists of a storage tank which is usually connected to a rooftop through a pipe. Rooftops are constructed from various types of materials such as concrete slab, plastic corrugated sheets, metal corrugated sheets, corrugated cement tiles and corrugated clay tiles. The collection areas of rainwater harvesting systems are building's roof. The size of the roof varies from one type of building to another. Small roof size or catchment usually found in houses and large size is found in super markets and airports. The size of catchment has a direct influence on the collected rainwater volume from a catchment. Also, the intensity of the rainfall is another factor affecting the collected volume of rainwater. Many rainwater harvesting systems were installed in many countries including Malaysia but the main concern is the reliability of these systems. The reliability mainly depends on collected rainwater volume and related to the nature of water consumption (for potable and non potable uses).

1.1 Scope

This research aims to assess the possibility of meeting a part of the growing residential drinking water demand in Katsina State with alternative sources of water using rain water tanks. The study plans to develop a tool to determine the optimum size of a customized rainwater tank by investigating the reliability of the tank to meet the demand based on the geographic location of the state, the area draining to the tank (catchment) and the number of occupants in the house.

1.2 Objectives

The objectives of this research are to:

Analyze the satisfaction of the rainwater harvesting system

Analyze the reliability of rainwater harvesting system based on; Catchment, pattern of rainfall and intensity, water demand and capacity tank

To determine the optimum storage tank for the rainwater harvesting system

Chapter II

2 LITERATURE REVIEW

2.1 The Study Area

Nigeria has the potential to become Africa's largest economy and a major player in the global economy by virtue of its rich human and material resource endowment. The surface water resources potential is estimated at about 267.3 billion cubic metres of water per annum while the ground water resources potential is about 51.9 billion cubic metres of water per annum, whilst the country is also awash with oil, gas and other mineral resources. The country is implementing a National Economic Empowerment and Development Strategy (NEEDS), which encapsulates an objective assessment of her past, present situation and hopes for a better future. Thus, under NEEDS, priority is to be given to agriculture, especially improvement in the productivity of peasant farmers, and the continuing investment in water resources is not just only to provide water to the people as a social service, but to also provide water for irrigation to further enhance agricultural productivity. Also emphasis will now shift to developing small dams as a more cost effective way of utilizing water resources for irrigation in the country and rain water harvesting for irrigation agriculture was to be promoted where surface and underground water is not readily available.

Countries like Canada are using ten to twenty times more water than is necessary to meet basic human needs. In developing countries, 20 to 30 litres of water per person per day are considered adequate for basic human needs. In Canada, they generally use that amount of water in one or two flushes of the toilet! The chart below lists the amount of water that is required for domestic purposes, according to the World Health Organization.

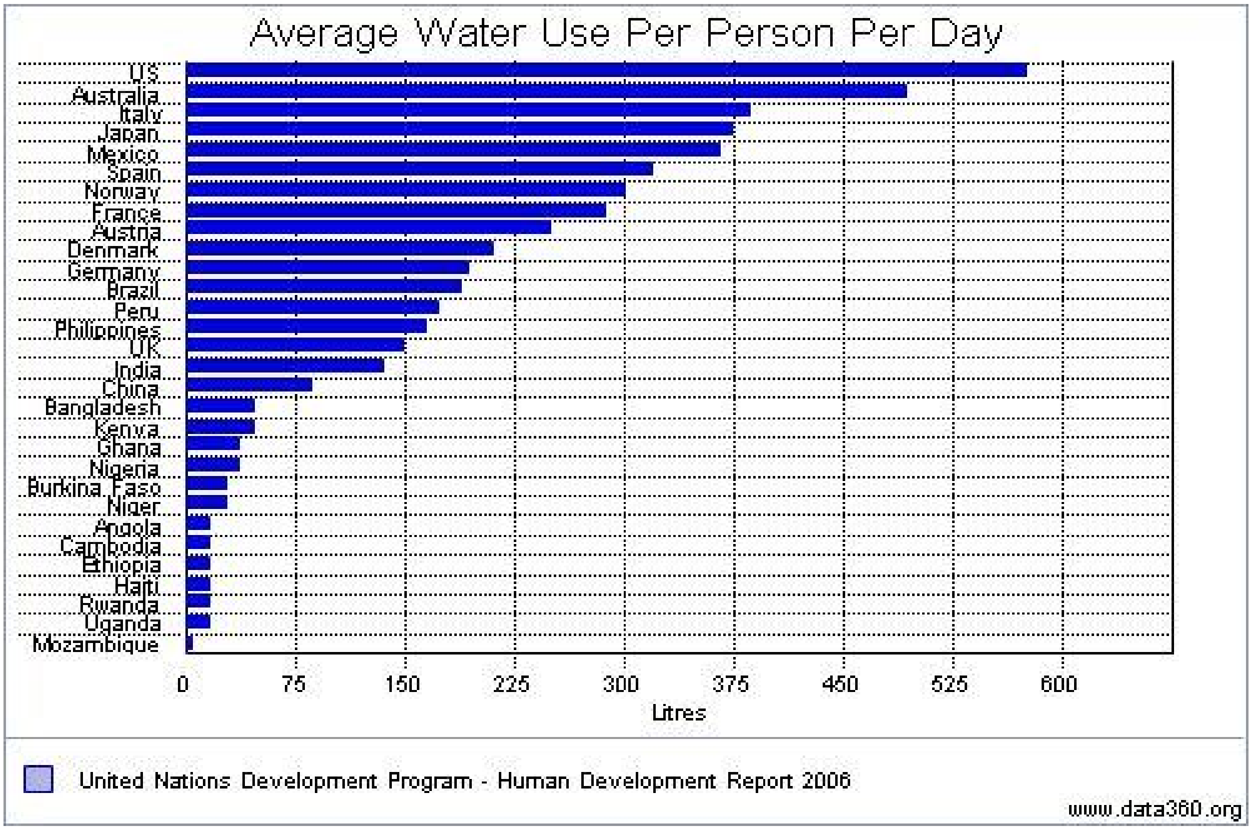


Figure 2-1: Average Water Usage

In Nigeria Dams and reservoirs are used for irrigation, water supply, hydro-electric power generation or some combination. They are of particular importance in the north of the country, where rainfall is low. The table 2 lists some of the larger ones.

Katsina is located on latitude 13°01’ N and longitude 07°41’ N. It has an average rainfall of 623 mm. Water supply in Katsina state is sourced through the damming of rivers and digging of wells and boreholes that reach subsurface or underground water sources. Existing dams include Ajiwa Dam (supplying DutsimMa town and environs), Malurnfashi dam (supplying Malurnfashi town and environs), Jibia Dam (supplying Jibia town and environs), and Mairuwa Dam (supplying Funtua town and environs).

Based on estimates of requirements of lactating women who engage in moderate physical activity in above-average temperatures, a minimum of 7.5 litres per capita per day will meet the requirements of most people under most conditions. This water needs to be of a quality that represents a tolerable level of risk. However, in an emergency situation, a minimum of 15 litres is required. A higher quantity of about 20 litres per capita per day should be assured to take care of basic hygiene needs and basic food hygiene. Laundry/bathing might require higher amounts unless carried out at source.

Katsina State is located in the North-Western region of Nigeria, Bordering Niger republic, Kaduna, Kano and Jigawa States on latitude 13°01’ N and longitude 07°41’ N. Katsina State has 34 LGs and has an average rainfall of 623 mm. Generally, the climate varies considerably according to months and seasons (as in table2-1). They are a cool dry (harmattan) season from December to February; a hot dry season from March to May; a warm wet season from June to September; and a less marked season after rains during the months of October to November, characterised by decreasing rainfall and gradual lowering of temperature.

Katsina state suffers from what is known as economic water scarcity. This occurs when scarcity is not physical, because resources are abundant or at least sufficient to supply the population’s demands but the economic issues, lack of infrastructure, investment and poor governance water is not delivered to citizens. Figure (2-2) Is map representing the different cases of scarcity and abundance in the world, it can be seen that Katsina’s water scarcity is economic. It is more efficient to collect rainwater than to fetch surface water or groundwater since the source is direct because rainwater feeds both groundwater and surface water.

A rainwater harvesting system designed considering average annual rainfall will not provide much benefit for a critical dry period. Similarly, a rainwater harvesting design for a particular region will not be similar for rainwater harvesting design in other regions. Rainwater harvesting system can solve the most pressing issues water by collection and store rainwater from roofs for future use. It can also be used to overcome water shortage by fully utilized rainwater during rainfall and used water utility

To understand the issues prompting the interest in rainwater catchment systems, terms and key concepts must first be explained. A pervious surface is a surface that can absorb water and is synonymous with soil surfaces, either bare or vegetated. In a natural system West of the Cascades, rainfall that reaches the ground is absorbed by duff, a thick layer of decomposing organic matter, and organic soils which gradually feed the underlying water table. The groundwater feeds the streams later in the season when the water level drops to the level of the ground water. Thus, the forest naturally processes the rainfall, providing the

water needs for the flora and fauna (Booth 1991). During intense storm events, the volume of the water saturates the soils and sends the rainwater over the soil and into the nearest stream. These infrequent events cause a dramatic increase in the volume entering the stream, causing erosion and movement of material in the streams such as boulders and woody debris. After this event, the stream will recover and become replenished and return to a similar state (Booth 1991). Impervious surfaces, common in urban environments, will not absorb water. Some examples include concrete, asphalt, metal, and brick. These materials are used to make roads, highways, parking lots, roofs, and sidewalks. An estimated 60% of impervious surfaces are associated with transportation and the remaining 40% related to rooftops (OPWD 1994). As the impervious surface increases, the amount of water leaving a site and entering the nearest stream increases. With the introduction of more impervious cover to the watershed, the frequency of floods to the stream increases and does not allow for the stream to return to its

normal non-flood state. The stream is continually impacted by this force of water, which causes erosion of the sides of the channel (channel expansion) and the down-cutting of the stream bed (channel incision). Both of these actions cause an increase in sediments that enter into the stream, decre sing the overall health of the stream, including a reduction in aquatic organisms living in the stream (Booth 1991). As the impervious surface increases the amount of water leaving a site increases. By collecting and storing rainwater, water that would otherwise be lost can be stored. This is one of the great advantages of RWH, especially in consideration of climate change: people can rely on a greater amount of disposable water without exploiting ground water or stream flow water. In this context, RWH can help to reduce the conflict potential between different actors within a watershed

The amelioration of access to clean water and the amount of disposable water have many positive side effects. As LEHMANN et al. (2010) point out, the adoption of RWH “makes some significant contributions to achieving the Millennium Development Goals.” The 8 MDGs that were formulated in the year 2000 by agents of the UNO, World Bank, OECD and several NGOs are: eradicate extreme poverty and hunger; achieve universal primary education; promote gender equality and empower women; reduce child mortality; improve maternal health; combat HIV/AIDS, Malaria and other severe diseases; ensure environmental sustainability; and develop a global partnership for development. LEHMANN et al. (2010) explain how RWH can help to reach these goals: the availability of water saves energy and time, thus labour and money, since water does not have to be carried to households from distant sources. While the harvested water leads to more reliable and greater yields, the members of the households can use their saved time to go about other work, therefore generating more income. RWH at schools improves hygiene and nutrition and pupils can spend more time learning, as they do not need to carry water to the school before preparing meals. “Women are usually in charge of the household water supply” (LEHMANN et al. 2010:3). RWH empowers women because it gives them the possibility to get paid work where the presence of local markets allows it. Either way, RWH provides them with more time at their disposal, which can be invested in other activities. Therefore, their status as a decision-making actor in the household increases. Properly stored rainwater provides households with safe and hygienic water and therefore reduces the risk of infection and child mortality and helps combat other severe diseases. In 2004, the WHO estimated that poor waterquality “is responsible for the deaths of 1.8 million people every year. Furthermore, the quality and quantity of water at home also affects maternal health. Environmental sustainability and can provide access to safe drinking water without threatening natural water sources.

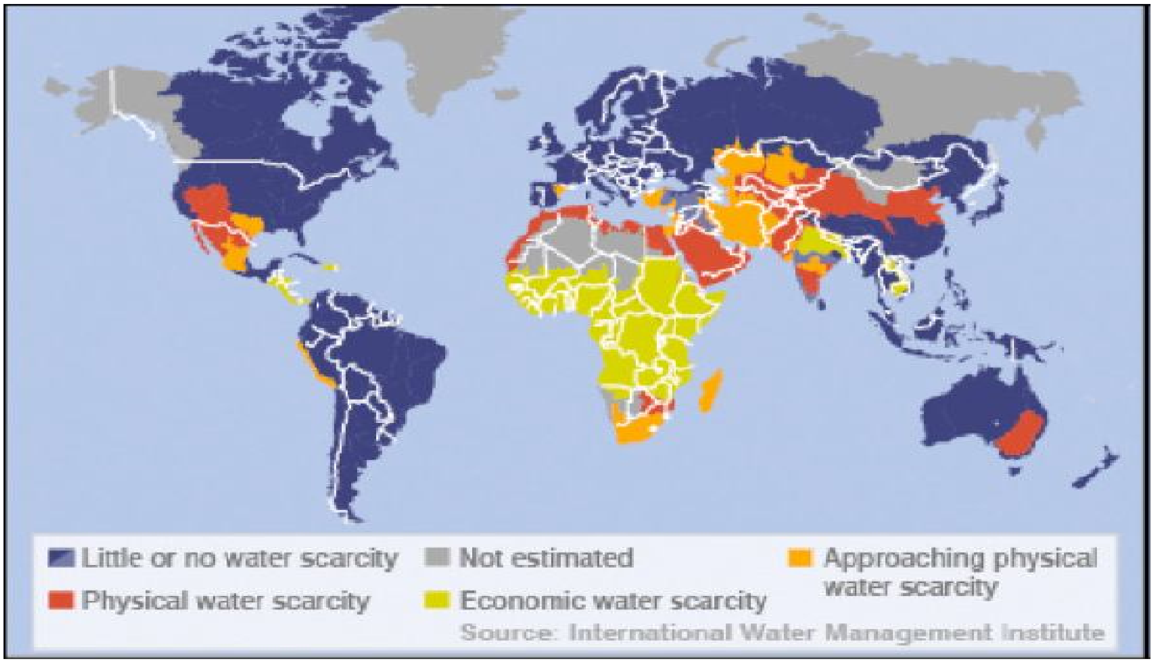


Figure 2-2: World Water Availability

Figure 2-3: Study Area

Figure 2-4: Study Area

Components

Catchment

Transportation

First flush

Storage

Catchement Area: The surface that receives rainfall directly is the catchment of rainwater harvesting system. It may be terrace, courtyard, or paved or unpaved open ground. The terrace may be flat RCC/stone roof or sloping roof. Therefore the catchment is the area, which actually contributes rainwater to the harvesting system. The catchment area is the surface on which the rain that will be collected falls. While this Guide focuses on roofs as catchment areas, channeled gullies along driveways or swales in yards can also serve as catchment areas, collecting and then directing the rain to a French drain or bermed detention area. Rainwater harvested from catchment surfaces along the ground, because of the increased risk of contamination, should only be used for lawn watering. For in-home use, the roofs of buildings are the primary catchment areas, which, in rural settings, can include outbuildings such as barns and sheds. A "rain barn" is a term describing an open sided shed designed with a large roof area for catchment, with the cisterns placed inside along with other farm implements. The roof area is the length in metres (L) multiplied by the within meters (W). The measurements needed to calculate the roof collection area, in meters squared (m2). The effective collection area is equal to the area of roof or hard standing that can be reasonably used to collect rainfall (in plan). This may not equal the entire roof area, as the arrangement of down pipes or location of different roof areas may not allow the entire roof to be used. The total rainwater collection area of a property can include both roof water run-off and hard standing infiltration into sustainable Drainage System (SUDS), where demand is greater than the roof area alone can supply. The quality of run-off water should be good enough not to need extra treatment other than an oil trap (if a driveway is used). An area likely to be heavily contaminated with animal faeces is therefore not suitable. Even if rainwater is not collected for non-potable use, PPS25 advocates that SUDS should be considered. SUDS can improve the quality of run-off water and reduce peak storm flows. This allows rainwater to be returned to the environment at an appropriate quality and flow rate for replenishing ground and surface water supplies. The size of a roof catchment area is the building's footprint under the roof. The catchment surface is limited to the area of roof which is guttered. To calculate the size of your catchment area, multiply the length times the width of the guttered area.

Transportation: Rainwater from rooftop should be carried through down take water pipes or drains to storage/harvesting system. Water pipes should be UV resistant (ISI HDPE/PVC pipes) of required capacity. Water from sloping roofs could be caught through gutters and down take pipe. At terraces, mouth of the each drain should have wire mesh to restrict floating material. Conveyance systems are required to transfer the rainwater collected on the rooftops to the storage tanks. This is usually accomplished by making connections to one or more down-pipes connected to the rooftop gutters. When selecting a conveyance system, consideration should be given to the fact that, when it first starts to rain, dirt and debris from the rooftop and gutters will be washed into the down-pipe. Thus, the relatively clean water will only be available some time later in the storm. There are several possible choices to selectively collect clean water for the storage tanks. The most common is the down-pipe flap. With this flap it is possible to direct the first flush of water flow through the down-pipe, while later rainfall is diverted into a storage tank. When it starts to rain, the flap is left in the closed position, directing water to the down-pipe, and, later, opened when relatively clean water can be collected. A great disadvantage of using this type of conveyance control system is the necessity to observe the runoff quality and manually operate the flap. An alternative approach would be to automate the opening of the flap as described below.

First flush: First flush is a device used to flush off the water received in first shower. The first shower of rains needs to be flushed-off to avoid contaminating storable/rechargeable water by the probable contaminants of the atmosphere and the catchment roof. It will also help in cleaning of silt and other material deposited on roof during dry seasons Provisions of first rain separator should be made at outlet of each drainpipe.

Storage: In this method rain water collected from the roof of the building is diverted to a storage tank. The storage tank has to be designed according to the water requirements, rainfall and catchment availability. Each drainpipe should have mesh filter at mouth and first flush device followed by filtration system before connecting to the storage tank. It is advisable that each tank should have excess water over flow system. Tanks vary in size from a small water butt to large underground tanks that contain many thousands of liters of water. A wide range of water butts are now available, made from a wide range of materials, from re-used, wooden wine barrels to imitation boulders and of course the familiar green plastic model. In the UK, larger tanks tend to be constructed from Glass Reinforced Plastic, Polyethylene or Concrete. Different tank materials suit different installations, and advice should be sought from a reputable rainwater harvesting supplier. It will moderate the water temperature, reducing bacterial growth in summer and frost damage in winter. The tank should also be shielded from direct sunlight, to avoid overheating and the development of algae. Usually the best solution is to house the tank underground. As the tank is often the most expensive part of a rainwater system, costs can be reduced by carefully considering how large it needs to be. The size of a rainwater holding tank must match the demand for water with its availability as closely as possible. The tank size chosen should be a balance between cost, storage capacity, and the need to enable an overflow at least twice a year, to flush out floating debris. A rule of thumb for household water use is to size the tank at 5% of the annual rainwater supply, or of the annual demand, using the lowest figure of the two. Industrial / commercial premises may need to make more detailed calculations. The tank size is calculated from the collection area, drainage coefficient, filter efficiency and rainfall.

Tank size (liters) = effective collection area x drainage coefficient x filter efficiency x annual rainfall x 0.75

Excess water could be diverted to recharge system. Water from storage tank can be used for secondary purposes such as washing and gardening etc. This is the most cost effective way of rainwater harvesting. The main advantage of collecting and using the rainwater during rainy season is not only to save water from conventional sources, but also to save energy incurred on transportation and distribution of water at the doorstep. This also conserves groundwater, if it is being extracted to meet the demand when rains are on.

Climate data for Katsina

Today there is no doubt that the environmental health of the planet is in a critical state. The most vital resource, water, is becoming inaccessible for many people and it is obvious that old patterns of its management must be changed.

At the same time, many centuries ago, mankind's wisdom has foreseen how to go through critical situations. When dramatic climate change had transformed flourishing landscapes into deserts; man has started to collect the precious raindrops. Thanks to this, he made possible the existence of many permanent settlements in arid areas. Today, in the new conditions of emergency, many good and willing people do not know where to start from to improve the water situation in the world. There is no single answer to this question, and here, we will summarize the most urgent measures which, according to us, should be taken.

1. As the IPCC recommended in its AR4 Synthesis Report, rainwater harvesting, water storage and conservation techniques should be expanded. They are considered as the most efficient tools for climate adaptation in the Water Sector. A large campaigning promotion among citizens should make this "old style" practice known and used by everyone.

2. A corresponding policy, institutional reforms and financial support should frame the return to the holistic way of treating the hydrologic resource, rain. In a few states and regions in the world, there are already existing regulations and a legislative basis facilitating the wide spreading of Rainwater Harvesting. The IRHA will address an appeal to political leaders to support the introduction of the necessary legislative and regulatory framework for sustaining rainwater harvesting practices in the water policy of their governments.

3. The most important work at grassroots level should be done in schools. On the one hand, we are aiming at forging the consciousness and habits of the future citizens. On the other hand, we wish to transform the project site, a school in a village or in a town, in a platform for work with the population. The successful implementation of rainwater harvesting and sanitation program in a school will be the best way to access to people's consciousness and to mobilize to start to work for their selves. Training local masons to build up simple rainwater harvesting systems for villagers will provide them with a job and will enhance the access to water for many. Holocene (11 kyr BP to present) climate fluctuations, including large spatial variation in Holocene monsoon and temperature over India are now well-resolved from various climate change proxies. A somewhat coherent, although unresolved, picture that emerges for India is as follows: as the aridity increased in the region as is evident from palaeo climatic studies, people intensified rainwater harvesting as is seen from archaeological and historical evidences. Folk sayings such as capture rain where it falls may have originated in response to the increased aridity in the Indian region over the last few millennia. Such climate fluctuations may have given rise to traditional village tanks, ponds and earthen embankments numbering more than 1.5 million that still harvest rainwater in 660,000 villages in India and encourage growth of vegetation in commons and agro-ecosystems.(Deep Narayan Pandey, et al, CURRENT SCIENCE, VOL. 85, NO. 1, 10 JULY 2003) Indeed, a specific emphasis through the long sweep of history on management of rainwater harvesting systems in ancient texts, such as *Rigveda* (1500 BC),*Atharva Veda* (800 BC), Kautily as *Arthasastra* (300 BC), Varahamihir as *Brihatsamhita* (AD 550), and Kalhan as *Rajatarangini* (AD 11481150) may

document adaptation to fluctuating climate. There is other evidence of climate change rainwater harvesting hypothesis. Majority of palaces and forts (perhaps all) constructed during the 1318th century developed elaborate water-harvesting systems. Addressing water problem holds the promise in future for a world compounded by climate change, growing population and decreasing water-impounding area of traditional tanks due to urbanization. We will have to take into account the large-scale, natural climate variations as well as human-induced climate change in the management of natural, social and economic systems. Alternative to ecologically damaging, socially intrusive and capital-intensive water management projects that fail to deliver their desired benefits, it would be useful investing in decentralized facilities, efficient technologies and policies, and human capital to improve overall productivity rather than to find new sources of water supply. Such efforts would need to be encouraged with innovative policy regimes that concurrently promote rainwater harvesting.

Table 2-1: Climate Data

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Average high °C (°F)	23 (73)	27 (81)	31 (87)	33 (92)	33 (92)	32 (89)	28 (83)	27 (81)	29 (84)	29 (85)	27 (80)	24 (75)	28.6 (83.5)
Average low °C (°F)	21 (70)	22 (72)	27 (80)	30 (86)	29 (85)	29 (85)	26 (79)	24 (76)	26 (78)	26 (79)	23 (73)	19 (67)	25.3 (78)
Precipitation cm (inches)	0 (0)	0 (0)	0 (0)	1 (0.2)	5 (1.8)	8 (3.2)	18 (6.9)	26 (10.1)	12 (4.6)	1 (0.3)	0 (0)	0 (0)	69

2.2 The Need for RHW in Katsina State

Providing water is never free; the water needs to be collected, stored, treated and distributed. Providing too much water is a waste of money, taking too much water from a limited source may deprive people elsewhere of water and have adverse environmental and health impacts. As different sectors of society use water for different purposes: drinking, cooking, washing, producing manufactured goods, growing food, producing and using energy, and other domestic or industrial purposes. The water required for each of these activities varies with climatic conditions, life style, culture, tradition, diet, technology, and wealth. Changes in climate and pollution are reducing portable raw water. While the resources available to cater for the demand are shrinking, the potentials for large-scale water resources development in developing and poor countries are overshadowed by financial constraints and other factors. This leads to an emerging interest in improving safe water access through small-scale water projects at the household, village and local levels to arrest the problems posed by water crisis in our local environment. For many rural households which do not have access to clean drinking water, tapping the clouds instead of the water pipes has become a significant way of supplementing access to safe water supply.

The objectives of any water-supply system are: *(a)* to supply safe and wholesome water to the users, whether these constitute a family, a group of families, or a community; *(b)* to supply water in adequate quantity; and (c) to make water readily available to the users, in order to encourage personal and household hygiene. Even if plenty of water is provided, there may be other limits to its use, such as the time taken for people to travel and queue to get it. If people take more than 30 minutes to collect water, the amount they will collect will reduce. The amount of storage facilities available is also important. Washing facilities near the water points reduce the need to transport water which reduces the cost of supply and difficulties to the users. The situation is critical in developing countries as the gap between the water demand and the

supply has been continuously widening. This has led to an increased emphasis on the optimal management of the available resources. Rigorous planning and management of water resources is required for long term sustainable resource development. The need for optimal management of existing water resource systems as well as the optimal development of the new ones is now universally acknowledged. Water resource systems are an important part of the infra-structure.

Distribution of Water on Globe every country, particularly the developing ones. In addition to the basic purpose of supporting life, they serve a multitude of water uses such as the water supply, hydropower generation, recreation, irrigation, flood control, navigation and wild life maintenance. India is likely to experience “water stresses” from this year i.e. 2007 onwards. It will be pertinent to shift the thrust of the policies from “water development to sustain water development”. Half a century back, the high level of sub soil water was a major problem of Delhi – the Government had an exclusive division to install large number of tube-wells to compound the water to Yamuna to lower the ground water level. Today the problem is exactly the opposite. The water table has gone down to such as extent that we are desperately trying to recharge the aquifers.

Human interference with the environment has made rains more irregular, since the natural cycle, is disturbed. The quantity of rainfall is becoming erratic, reduced and uncertain. Hence, a need for conservation is felt much more than ever before. The rise of urban development, amenities, and luxury is driving to high per-capita consumption of water. It is therefore necessary to conserve and augment the renewable natural ground water resources as a last chance for survival, realizing that natural resources are not unlimited if they are exploited beyond certain limits. A vital element of this shift in strategy is the increasing importance of water harvesting and artificial recharge of ground water. With industrialization, urbanization and rising living standards, non-agriculture uses of water are increasing exponentially. The rapid developments of cities and population explosion in urban areas have, led to the depletion of available surface water resources. Now, the available water resources are at far then distance, from the cities, forcing the municipal corporation to spend higher capital expenditure and longer time for planning and execution for the conveyance of water. This has also resulted into over exploitation of surface sources like wells for drinking and industrial use, resulting in the dropping of water levels and drying up of bore wells or sea-water intrusion because of the imbalance of inflow and outflow. Several MDGs are closely related to water for health and sanitation. The MDG Target 7C aims to halve water supply deficits, presenting a formidable challenge for investment and social and technical alignment.

However, the amounts of water necessary to reduce water supply deficits are in many cases available. In addition, the use of domestic water is not necessarily consumptive, as the water can be cleaned and re-used. Quantifying minimum water requirements to meet basic human needs has resulted in vastly disparate estimates. Annual per capita water needs range between 18 m3 and 49 m3, suggesting that approximately 0.1 to 0.3 km3 is required for basic water consumption, sanitation and societal uses by the global population. It is important to note that water for domestic, public and commercial use in many cases is returned to stream flow locally. Return flows are reduced by consumptive losses, and often result in diminished water quality, increased health risks amongst downstream users and degraded habitats. Relatively larger amounts of water are used to generate the ecosystem services needed to ensure provisioning of basic supplies of food, fodder and fibers. Just to meet the food requirements of a balanced diet, approximately 1,300-1,800 m3 of water per person are consumed per year. This translates to 8,800-12,200 km3 for a world population of 6.7 billion in 2008/2009. The water used for food production, whether irrigated or rain fed, is consumptive; i.e., at a local site, water will be incorporated into foodstuffs, evaporated from the land surface or otherwise non-retrievable for further use downstream. In comparison with amounts of water needed for domestic, public and commercial purposes, the projected needs for additional water to meet MDG target on hunger (MDG 1C) suggest additional withdrawals of water for both rain fed and irrigated agriculture to meet the target through 2015. Today, rainfed and irrigated agriculture appropriate 7,700 km3 of freshwater globally to provide food (CA, 2007). Of this, approximately 2,600 km3 is direct withdrawals for irrigation purposes. To meet the MDG Hunger goal, an additional volume of 1,850 to 2,200 km3 of water needs to be appropriated annually, based upon current agricultural practices and assuming balanced diets (SEI, 2005). To feed all a reasonable diet by 2050 may require almost doubling of today’s water resources. With renewable accessible freshwater globally limited to 12,500 km3, it is a great challenge facing humanity. The consumptive use of water for crops and vegetation to provide other biomass goods such as timber, fibers for clothing, wood for energy etc. is not included in the above numbers. A third dimension is the sustainable management of resources. This is mainly addressed in MDG 7 (Target 7a: Integrate sustainable natural resource strategies in national policies). This target can be interpreted as seeking to ensure sustainable use and safeguarding of water resources. Such safeguarding could include the management of water for other uses, for example, for ecosystem services, including provision of minimal environmental flows necessary for maintenance of aquatic organisms and their habitats. Accounting for the provision of minimum environmental flows in major river basins suggests that water stress is even more imminent than when estimated based on renewable water resources solely for human use (Smakthin *et al.*, 2004; Fig. 2.4). These estimates suggest that, already, 1.1 billion people are living in severely water stressed basins (0.9<Water Stress Index<1), and an additional 700 million people live in moderately stressed river basins (0.6<Water Stress Index<0.9). Clearly, further consumptive use of water or increased pollution may seriously affect ecosystem health, as well as human wellbeing and potential for development. Despite the fact that England and Wales appear to have plenty of rain, our growing population and the changing climate mean that our water resources are under pressure. The large number of new houses to be built over the next few years will increase the competition for available water between the environment and people, especially in the south-east of England which has been designated an area of water stress. Reducing demand for mains water can help to reconcile these competing needs. One way of reducing demand is to use a rainwater harvesting system to provide water for domestic uses that do not require water treated to drinking water quality. Rainwater harvesting systems can be installed in both new and existing buildings, and the resulting water used for all purposes except drinking (unless treatment to a potable quality is provided). There are no agreed water quality standards for rainwater use in England and Wales. If properly collected, stored and only used for non-potable purposes such as toilet flushing, harvested rainwater need not undergo any additional treatment such as chemical disinfection. Washing machines can also be fed by rainwater without disinfection, but occasionally color and odor may cause a problem if the quality of the collected water is poor. When rainwater is used to supply a garden tap or rain water butt, care needs to be taken to ensure that the water cannot be accidentally drunk.

The potential savings that can be made from rainwater harvesting depend on both the demand for non-potable water and the amount of rainwater that can be supplied, which depends on the roof area available for collection and the amount of local rainfall. Savings achieved by rainwater harvesting systems will be greater in larger buildings, such as industrial/commercial buildings and schools, due to their larger roof areas and potentially greater demand for non-potable water. In addition to the pressures on water resources, there are concerns over rainwater drainage from urban areas. Adverse impacts on flood risk and water quality mean that our existing approach to rainwater drainage systems will have to change. In England, Planning Policy Statement 25 (PPS25) on development and flood risk requires that planning authorities consider the effects of surface water drainage. This will result in increasingly strict controls on runoff from sites. The Environment Agency is promoting the use of sustainable Drainage Systems (SUDS), including rainwater harvesting, to retain and control surface water. The need to reduce storm water discharge rates may therefore be an incentive for choosing rainwater harvesting systems. Rainwater harvesting systems are not yet common in England and Wales, for two main reasons:

- The high cost of the systems compared to the low cost of water.
- Concern that the quality of the water may pose a health risk.

Additionally, only metered customers (all industrial and commercial customers and around 30% of domestic properties) will benefit financially by using these systems. The majority of domestic customers, who don't pay for water by volume, have no immediate financial incentive to install rainwater harvesting systems

Rainwater is the source of all our water, it fills rivers, aquifers and lakes, from where it is abstracted by water companies for the public water supply. Before mains water is distributed, it is treated to make it safe for human consumption. While stringent standards guard the potable water quality in the UK3, there are no standards for the quality of non-potable water. Defra intend to produce appropriate standards for non-potable water to overcome the concerns about potential health hazards and bolster public confidence in using non-potable water. The cost and practicality of long-term water quality monitoring of rainwater systems is a problem. One possible solution is to ensure that system design and installation standards prevent problems from occurring, rather than undertaking continuous water quality monitoring. Best practice guidelines are currently in progress through a number of routes.

2.3 Advantage and Disadvantages

When considering the possibility of using rainwater catchment systems for domestic supply, it is important to consider both the advantages and disadvantages and to compare these with other available options. RWH is a popular household option as the water source is close by, convenient and requires a minimum of energy to collect. An advantage for household systems is that users themselves maintain systems without the need to rely on other members of 'the community. Since almost all roofing material is acceptable for collecting water for household purposes, worldwide many RWH systems have been implemented successfully. However, RWH has some disadvantages. The main disadvantage of RWH is that one can never be sure how much rain will fall. Other disadvantages, like the relatively high investment costs and the importance

of maintenance, can largely be overcome through proper design, ownership and by using as much locally available material as possible to ensure sustainability (and cost recovery). The involvement of the local private sector and local authorities and control their can facilitate up scaling of RWH. Given the fact that rainfall is unevenly distributed between years, as well as within rainy seasons, storing rainwater is a key component of water management. The water can be stored in storages of different construction Check dam in village of Dotad Jhabua and dimensions; for example, large reservoirs with large catchments and small tanks and ponds with small catchments, or use of natural or artificial groundwater

Recharge to store water in the soil. There is evidence to show that village-scale rainwater harvesting will yield much more water for consumptive use than large or medium dams, making the latter a wasteful way of providing water, especially in dry areas. In the Negev desert where rainfall is only 105mm annually, it was found that more water is collected if the land is broken up into many small catchments, as opposed to a single large catchment (Agarwal,2001). This is because small watersheds provide an amount of harvested water per hectare which is much higher than that collected over large watersheds, as evaporation and loss of water from small puddles and depressions is avoided. As much as 75% of the water that could be collected in a small catchment is lost at the larger scale. It is important to recognize that the non harvested water does not necessarily go to waste, as it is returned to the water cycle from the landscape (Ruf,1998). Several other studies conducted by the Central Soil and Water Conservation Research Institute in Agra, Bellary and Kota, and another study conducted in the high rainfall region of Shillong, have all found that smaller watersheds yield higher amounts of water per hectare of catchment area. To put it simply, this means that in a drought-prone area where water is scarce, 10 tiny dams, each with a catchment of 1 ha, will collect Check dam Prasad more water than one larger dam with a catchment of 10 ha. However, critics have suggested that the benefits

of smaller rainwater harvesting systems versus large scale downstream implementation is mostly an effect of different scale and project implementation, and lack of consideration of (negative) externalities (Batchelor et al., 2003). There is scientific evidence that even withdrawal of water by rainwater harvesting can have depleting effects, if the water is for consumptive uses such as irrigation. Evapotranspiration of plants (crops, trees, other vegetation) is an absolute loss of water, which potentially can affect downstream flows of water if used upstream excessively.

2.4 Availability of Surface and Ground Water Resources in Katsina state

Groundwater is the water located beneath the ground surface in soil pore spaces and in the fractures of geologic formations. A formation of rock or soil is called an aquifer when it can yield a usable quantity of water. The depth at which soil pore spaces become fully saturated with water is called the water table. Groundwater is recharged from the surface. Sometimes it flows to rivers supplementing its water The natural discharge of ground water often occurs at springs, or it can form oasis or wetlands. Groundwater is also often withdrawn for agricultural, municipal and industrial use by constructing and operating extraction wells. Groundwater is naturally replenished by the surface water from precipitation, streams, and rivers when this recharge reaches the water table. It is estimated that the volume of groundwater is fifty times that of surface freshwater; the icecaps and glaciers are the only larger sources of fresh water on earth. Groundwater makes up about twenty percent of the world's fresh water supply, which is about0.61 percent of the entire world's water supply. A comparison of water levels from 1960 to 2001 shows that the water levels in major parts of Delhi are steadily declining because of over-exploitation. During 1960, the ground water level was by and large within 4 to 5 meters, and in some parts even water logged conditions existed. During 1960-2001, the water levels have declined by 2- 6 m. in most part of the alluvial areas. The decline of 8-20 m. has been recorded in south-west district and in south district it has been 8-30 m. If this trend continues it is predicted that water scarcity will become a major problem in the near future.

The combined effect of this altered hydrology has led to more frequent and severe flooding in the metropolitan area and nearby surface water resources such as river and lakes during rainy seasons. The water level goes too low during Dry periods thus significantly affecting the buffering capacity of the aquifer. An aquifer is a subterranean geologic unit (or layer) of permeable material (like sand and gravel) that is capable of providing usable quantities of water to a well. Aquifers can be confined or unconfined. A confined aquifer has a low permeability confining layer (an aquitard), such as clay, above it that restricts the upward and downward movement of the water. If a confined aquifer follows a downward grade from its recharge zone, groundwater can become pressurized as it flows. This can create artesian wells that flow freely without the need of a pump. The top of the upper unconfined aquifer is called the Water table, where water pressure is equal to atmospheric pressure.

Lower water tables in the shallow aquifer have led to a decline in the base flow to local rivers in dry weather which is a direct source of clean water to the cities at its bank. One of the biggest challenging aspects of urbanization is to mitigate the impact of impervious surfaces that cause groundwater reduction in infiltration rates and increase in surface runoff volumes to surface waters. Low-impact of this modified urban hydrology can be made by:

Preserving natural areas with highly permeable soils

Minimizing soil compaction during development.

Restoring permeability of disturbed soils.

Using permeable hard capes.

Routing runoff from impervious surfaces to infiltration practices.

The two types of source water are surface water (rivers, streams, and lakes) and ground water, which comes primarily from underground aquifers. The geography of a particular US region is normally the primary determinant for which water sources supply households with drinking water.

Source water is constantly under threat from environmental contamination, making it an important drinking water and land use planning concern. While ground water can become polluted by "naturally occurring" contaminants and sometimes by human-made contaminants, surface water is particularly at risk. "Naturally occurring" contamination includes contaminants from animal fecal matter, algal growth, or geologic formations. Surface water also is vulnerable to human-made contamination, both from point sources (such as pipes or man-made ditches that discharge pollutants into water bodies) and non-point sources (such as run-off from streets and farmland). While the Clean Water Act has reduced point source contamination, non-point sources are still a considerable threat to the health of waterways.

Although source water protection does not solve all drinking water contamination problems, it can play a crucial role in eliminating contamination before it starts.

In Nigeria, the estimated available annual surface water resources is about 2.24×10^{11} m^3 (Hanidu 1990), while the estimated groundwater resources is about 5.0×10^{19} m^3/year (Akujieze et al. 2003). The average annual withdrawal however is about 3.63×10^{9} m^3, with domestic, industrial and agricultural uses constituting 31%, 15% and 54% respectively (African Development Bank 2002). Rainfall, though variable across the country, constitutes a significant source of water, with average annual rainfall ranging from 250 mm in the extreme north to 5000 mm in the south.

There are no major rivers in Katsina State and drainage pattern is not prominent because the area is water-shed. A few rivers drain north of Niger, i.e. the Gada, Tagwe and Sabke. All the rivers in the state are seasonal, except for the Sabke river.

2.5 Current Water Supply Situation

According to the WHO/UNICEF Joint Monitoring Programme Report for the year 2006, only about 65% (46.1 million) of the urban and 30% (22.1million) of the rural populations had access to improved drinking water. Moreover, the total water supply coverage was only 47%, which implies that only about 68 million Nigerians had access to improved water supply source, leaving 77million without access.

The projected population of Nigeria by the year 2020 is 194.04million; calculated using a growth rate of 2.2% from the 2006 population figure of 140million. Based on this population figure and the basic human water requirements of 30l/c/d, 60l/c/d and 120l/c/d for Rural, Small Town and Urban settlements respectively. (Nigerian Vision 2020).

About 71% of those living in rural communities do not have access to safe water supply. Many entities involved in rural water supply include the following: the Federal Ministry of Water Resources, State Water Agencies, River Basin Development Authorities, Local Governments, and External Support Agencies such as UNICEF, UNDP, World Bank, JICA, CIDA and ZONTA International etc. These institutions employ their own implementation strategies and involve individual communities and LGAs to varying degrees. In most cases, however, services have been introduced with little or no community involvement.

Although the MDG drinking water target refers to sustainable access to safe drinking water, the MDG indicator –"use of an improved drinking water source" – does not include a measurement of either drinking water safety or sustainable access. This means that accurate estimates of the proportion of the global population with sustainable access to safe drinking water are likely to be significantly lower than estimates of those reportedly using improved drinking water sources. Between 1990 and 2008, the proportion of the world's population with access to improved drinking water sources increased from 77% to 87%. This constitutes an increase of almost 1.8 billion people worldwide and puts the world well on track for meeting the MDG drinking water target of 89%. Despite this progress, it is estimated that in 2008, there were still 884 million people that did not use improved drinking water sources. At the current rate of progress, 672 million people will not use improved drinking water sources in 2015. It is likely that many hundreds of millions more will still lack sustainable access to safe drinking water.

In the two decades that WHO and UNICEF have been tracking progress in water and sanitation, advances have been made in the availability and quality of data and the methods used to measure them. A shift from provider- to user-based data: Initially the JMP relied almost exclusively on government data, which were largely drawn from water-utility companies and line ministries and were based on the number of facilities constructed. The figures did not reflect facilities that had fallen into disrepair or were constructed by others outside of government-supported program. A key improvement in the mid-1990s was a shift to user-based data, collected through household surveys and population censuses, which more accurately reflect actual use of water and sanitation facilities by individual households.

More standardized data: Lack of comparability of data on drinking water sources and sanitation facilities among countries and over time has posed a huge challenge to global monitoring. In response, WHO and UNICEF assisted the major household surveys to incorporate harmonized questions into their questionnaires, and in 2006 they published 'Core Questions on Drinking

Water and Sanitation for Household Surveys' to encourage their more widespread use. This increased standardization has greatly enhanced the comparability of data.

Increased availability of data: The late 1990s saw an unprecedented increase in the availability of household survey data, largely due to the implementation of the UNICEF-supported Multiple Indicator Cluster Survey (MICS) and the Demographic and Health Survey (DHS), initiated by the United States Agency for International Development (USAID).

Expanded JMP database: In 2000, some 220 sources of data could be found in the JMP database; this current update reflects more than 1,400 sources.

Greater disaggregation of data: The introduction of drinking water and sanitation ladders has allowed categories such as 'piped drinking water on premises and open defecation to be highlighted. Still, data limitations abound. One major information gap is the safety of drinking water supplies. Since cost-effective, periodic and standardized water quality testing was not possible on a global scale when the MDG target was formulated, and since nationally representative information on water safety was not available for the period following the baseline year (1990), WHO and UNICEF were obliged to use a proxy for sustainable access to safe drinking water, as specified in the MDG target. The agreed proxy was use of an improved water source, where improved was determined by the type of technology a household reported as their primary source. An improved source is one that, through technological intervention, increases the likelihood that it provides safe water. To date it has remained impractical to obtain water quality data at the national level for all countries. The main international household surveys – MICS and DHS – are piloting the inclusion of a water-quality module that will include testing for the presence of *E. coli*. This is made feasible in part by the availability of new, rapid, low-cost water quality testing kits. If successful, it could lead to further evolution in monitoring and pave the way for a future drinking water target that includes a measure of water quality

Similarly, a proxy for sustainable access to basic sanitation is the use of improved sanitation facilities. Measuring the actual sustainability of both water and sanitation facilities remains an area that could benefit from further attention.

Monitoring the global targets for drinking water and sanitation: Challenges and achievements Drinking water coverage increased from 76 per cent in 1990 to 89 per cent in 2010

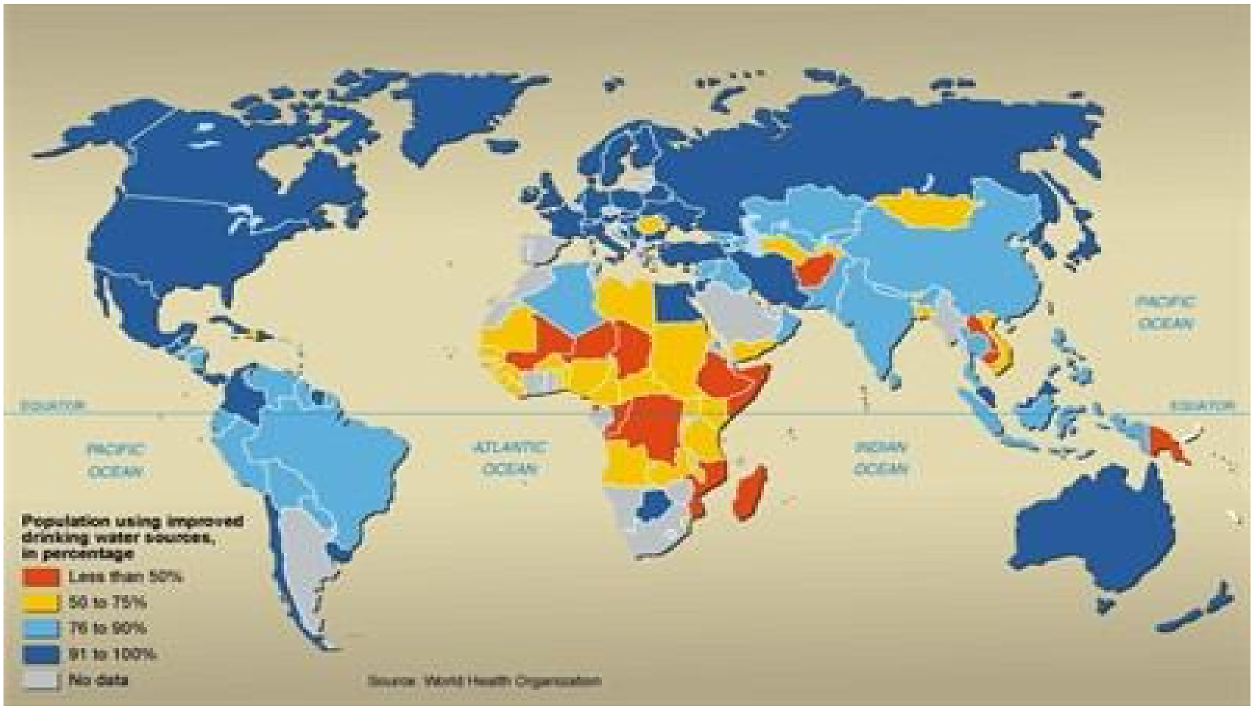
Katsina state has a population of about 6,000,000 million (census 2006) and Water supply is sourced through the damming of rivers and digging of wells and boreholes that reach subsurface or underground water sources. Existing dams include Ajiwa Dam (supplying Katsina town and environs), Malumfashi dam (supplying Malumfashi town and environs), Jibia Dam (supplying Jibia town and environs), and Mairuwa Dam (supplying Funtua town and environs). In some other villages, there are some form of sources, like wells and boreholes, but with the dry season, these sources deplete. Another problem affecting potable water is desertification and lack of underground water in many community areas.

The state, being agrarian, has 70 percent of people living in rural communities, while 30 percent live in urban areas. The result of the survey conducted by IFAD-CBARDP showed in (table 2-2) that the most prevalent source of drinking water to the respondent happens to be the well. This was attested to by about 65% an closely followed by through Rivers/streams about 31% as presented in Table

Only about 4% of the sample respondents have access to either tap/borehole or public stand tap in the study areas. During the rainy seasons, rural communities seldom have water challenges, as the wells, rivers and local storage facilities are full. But as soon as the dry season sets in, usually from November to May, rural dwellers have to face the uphill task of getting water for their daily use. So to maintain the basic water requirements in these months we can use the system of harvesting by collecting the rainwater from roof top, land surface or other catchments for later use.

The last two decades have seen major shifts in the proportion of the global population using various types of drinking water sources. The biggest change has been the increase in piped water supplieson premises, which were usedby 54 per cent of people worldwide in 2010 – up from 45 per cent in 1990. In rural areas, the use of piped wateron premises grew even faster – from 18 per cent in 1990 to 29 per cent in 2010. Over the same period, reliance on surface water was halved, from 10 per cent to 5 per cent in rural areas and from 6 per cent to 3 per cent for the total population. In urban areas, the proportion of people using piped water on premises remained almost the same in percentage terms, but the massive increases in urban populations during this time meant that the absolute number of urban dwellers using water piped to their homes grew by a billion, from 1.8 billion to 2.8 billion. The number of people relying on tanker trucks and small vendors for drinking water has almost doubled over the same 20-year period, from 44 million to 85 million (this category does not count as ‘improved’, due to concerns over water quality). The number of people using bottled water to meet their drinking water needs also increased, rising more than sixfold – from 37 million in 1990 to 228 million in 2010. A large majority of bottled-water users live in urban areas, and most are also users of piped water on premises. Bottled water is considered ‘improved’ only when the household also uses water from an improved source for cooking and personal hygiene. The number of people using boreholes (which are usually hand pump-operated) grew from 1 billion in 1990 to 1.3 billion in 2010. Eighty per cent of borehole users, almost a billion people, are in rural areas. While boreholes offer significant advantages over dug wells in terms of water quality, many boreholes with hand pumps still impose a considerable burden on users in terms of the time and effort needed to collect the water. Assessing progress towards the MDG target alone creates an incomplete picture, since countries that started out with low baseline coverage have had to work much harder to halve the proportion of the population without water and sanitation. Added to this is the challenge of rapid population growth, which can easily mean that any gains in people served are overtaken by population growth. Moreover, it is the poorest countries that are often characterized by a combination of low baseline coverage and high population growth. This means that countries may be making significant progress in the absolute number of people served, but still be persistently ‘off track’.

Nigeria is among the countries that have 50-75 percent coverage in water supply



Source: World Health Organization

Figure 2-5: Water Supply Situation

2.6 Demand

The total volume of water used by all households divided by the total population give the per capita water use. The result of the analysis from the distributed questionnaires[r1] showed that the residential water use in low density areas ranged between 70.25 l/c/d to 115.22 l/c/d with an average value of 92.74 l/c/d. The residential water use for medium density areas ranged from 55.02 l/c/d to 66.94 l/c/d, with an average of 61.22 l/c/d. Also the residential water use in high density areas was between 46.07 l/c/d and 96.37 l/c/d with an average value of 71. 22 l/c/d. The differences that exist in the water use rates among the study areas are as result of variation in socio economic level, standard of living, age of community, population, availability of waterand level of sanitation awareness. The population of households affects total water use. The population distribution is as shown in Table 1 for the various residential areas. 142 households out of 272 sampled in medium density areas have the number of residents between 5 and 8. For the low density areas, most of the households have between 5 and 8 (i.e. about 52% of the total households sampled in this category). None of the households in the low density residential areas have its number of occupants greater than 16.

Table 2 gives the detail analysis of the type of houses that exists in the study areas under each category. Forthe densely populated area, 47% of the people live in multi-tenant buildings popularly called ‘face to face’, 23% in storey buildings, 20% in flats or apartments and 10% in bungalows. Bungalows type house were most common for medium populated areas, followed by flats, multi-tenant houses, and storey buildings in that order. Most of residents do not depend on direct public supply (tap water alone), they also source for water from combination of wells and boreholes. Table 3 shows that in the low and medium density areas , more households depend on a combination of taps and wells, while in the high density areas, residents depend on a combination of taps and wells, while in the high density areas, residents depend more on wells and boreholes. Size of property in the various categories of the residential areas was plotted against the total demand.

The quantity of water used by individuals each day varies greatly around the world from less than 5 liters to greater than 1000 liters

Water quality is not was not investigated in this study; however rainwater is generally free of pollutants as it falls on a collection surface. Micro organism represents the greatest risk to most systems due to contamination from leaf litter or animal droppings carried from the collection surface In to the tank. A proper maintenance program can reduce the risk of contamination from these sources (Cunliffe 1998). An analysis of water could be investigated in future work.

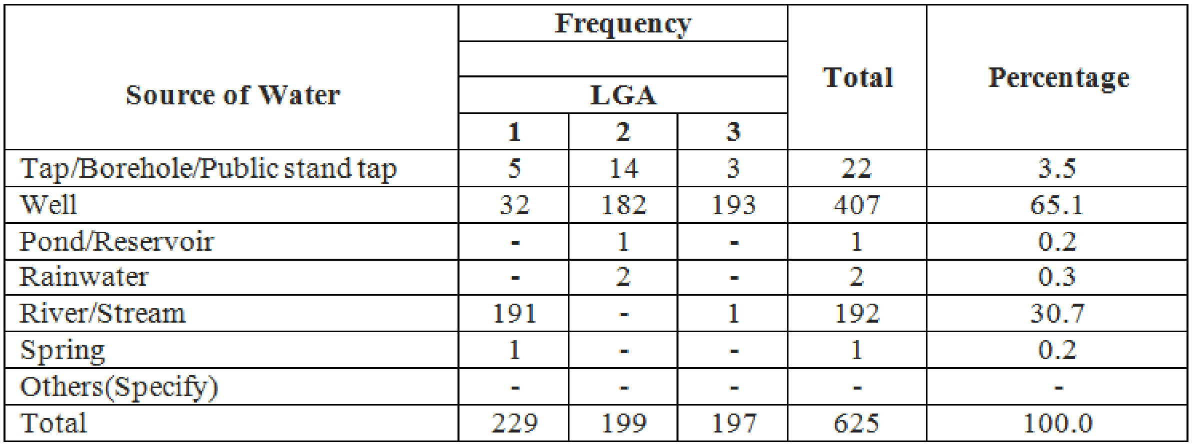
1960s-early 1970s, this increased demand was met by pumping groundwater from the aquifers of the Giber basin, which soon resulted in negative impacts on the environmental flows and aquatic ecosystems in the area. First of all, the depletion of the groundwater was not matched by the natural recharge, making the pumping of water unsustainable. Secondly, as a consequence, the springs feeding the Giber basin, an ecosystem targeted for provision of recreational services, were running dry, particularly in the summer, when recreational use was high. Moreover, the low-flow discharge of the river consisted mainly of treated waste water discharges from the municipal treatment plants in the basin, with concomitant enrichment concerns. These impacts initiated considerable political concern, as the environmental movement was growing and the demand for recreational areas for use by the urban population became an important electoral issue. Despite demand management enforcement, which was able to decrease the water use from 350 litres/day/person in 1970 to less than 200 litres/day/person in 2005, the authority realized that rainwater harvesting could be supportive in terms of maintaining the ecosystem and the related services it provides. In fact, the Giber basin contains several flood retention reservoirs, constructed in accordance with municipal regulations for storm water control, one of which was found to be feasible for storing rainwater for later controlled release, as a supplement to the natural flow. To conclude, the mechanism for supporting the environmental flows in the Giber basin was found

in rainwater harvesting through urban storm water management. With limited investment and a change in operational rules, the low flow of Giber basin could

be supported by harvested rainwater. This simple and practical solution illustrates the potential of rainwater harvesting within a river basin as an area of cross-sectoral convergence (involving nature, urban stormwater management systems, and recreational use demands), within a basin, for human and ecosystem well-being. Specifically, the positive impacts of rainwater harvesting on the ecosystem were increased river flow in the landscape, supporting and regulating the related services of improved water quality, groundwater recharge and an increased water flow downstream and in springs Water consumption is directly proportional to the financial status of the society. Higher income group consumes more water as compare to low income residents. The use of dish-washers, washing machines and bathing showers etc encourage higher water consumption. The value of water consumption per capita increases from 135 to 270 depending on the financial status of the people. Since the people living in the metropolitan area, have higher income, so is then water consumption rate.

Urbanisation, especially in the developing countries has directly increased pressure on urban water recourses. Municipal authorities are neither equipped nor efficient to quench the ever increasing thrust of the rapid urbanisation. Most of the time, due to an insufficient or nonavailability of potable water by municipal supply, the inhabitant, have to bore their own private tube wells to pump out water to meet their requirements. Some municipal authorities are putting further strain on ground water by exploiting it to meet the industrial, commercial and other municipal requirements. Assessing your indoor and outdoor water needs will help determine the best use for the rainwater. If you are already connected to a municipal water system, then a rainwater harvesting unit designed to fulfill outdoor requirements such as lawn and garden irrigation may be most cost-effective. If you have already invested in a well-water system, rainwater could augment or enhance the quality of mineralized well water for purposes such as washing, or provide back-up water when underground water sources are low. Some people are installing a full-service rainwater system designed to supply both their indoor and outdoor water needs. If you are considering this option, it is imperative that you employ best conservation practices to ensure a year round water supply. Three variables determine your ability to fulfill your household water demand: your local precipitation, available catchment area, and your financial budget. If you are accustomed to simply turning on a tap to get your water and then paying a bill at the end of the month, the switch to a rainwater system will require some adjustment. While the associated tasks are not difficult, they are important to keep your water safe and your family in good health. These responsibilities include regular inspections of all the previously discussed components, including pruning branches that overhang roof, keeping leaf screens clean, checking tank and pump, replacing filters, and testing the water. A maintenance schedule and checklist based upon your particular system are recommended to ensure proper performance.

Table 2-2: Current Water Supply



Source of Water	Frequency			Total	Percentage
	LGA				
	1	2	3		
Tap/Borehole/Public stand tap	5	14	3	22	3.5
Well	32	182	193	407	65.1
Pond/Reservoir	-	1	-	1	0.2
Rainwater	-	2	-	2	0.3
River/Stream	191	-	1	192	30.7
Spring	1	-	-	1	0.2
Others(Specify)	-	-	-	-	-
Total	229	199	197	625	100.0

Key to LGAs: 1-Kurfi (Tsauri), 2-Musawa-Jikamshi (Garu), 3-Danja

2.7 Household Composition

The terms household and family are not always used consistently in the literature. A household is usually defined as a group of persons (or one person) who make common provision for food, shelter, and other essentials for living, but practices vary significantly among countries. As a consequence, measures of household size and composition obtained from censuses or other sources in different countries are sometimes not directly comparable. The term family is used even less consistently. In the social science literature and in common usage "family" refers generally to a group of kin—persons related by blood, marriage, or adoption (Burch 1979). In contrast, demographers and economists usually follow the recommendations of the United Nations (1980) and define a family as the members of a household who are related through marriage, blood, or adoption. That is, they focus on the residential family. A drawback of the latter approach is that related individuals living in other households and the social and economic interactions with such individuals are often ignored (Lloyd 1998).

Households in Nigeria consist of an average of 4.4 people. Forty-five percent of household members are children under age 15. Twenty percent of households have foster children or orphans.

2.8 Housing Conditions

Overall, 56% of households use an improved source of drinking water. There are large differences, however, by residence—75% of urban households use an improved source of drinking water compared with 45% of rural households Access to drinking water from an improved source is significantly higher in urban than in rural areas. In rural areas, in virtually the entire developing world, drinking water coverage from an improved source remains unacceptably low. Urban drinking water coverage remained the same from 1990 to 2004 at 95%, whereas in rural areas coverage increased to 73% in 2004 from 64% in 1990. In 27 developing countries, less than 50% of the rural population have access to improved drinking water Urban coverage of drinking water from an improved source in 2004.

Table 2-3: Rainfall Data

Katsina State 20-Year Rainfall Data(mm) (1989-2008)
Station : Katsina

Year	Jan	Feb	March	April	May	June	July	August	September	October	November	December
1989	0	0	0	0	4.5	43.5	131.9	235	94.4	68.2	0	0
1990	0	0	0	0	37.1	54.7	234.7	203.5	39.7	0	0	0
1991	0	0	14.2	19.5	125	974	130.5	167	44	7	0	0
1992	0	0	0	0	42.5	30.7	161.1	245.5	90.3	0	0	0
1993	0	0	0	0	0	27.1	140.5	218	77	0	0	0
1994	0	0	0	3.1	0	0	236.5	376.2	258.5	32.6	0	0
1995	0	0	0	13	54	92	318	300	0	0	0	0
1996	0	0	0	0	108	91	181	170	142	0	0	0
1997	0	0	26.2	37	95	107.1	179	187	123	11	0	0
1998	0	0	0	0	21	111	168	190	210	0	0	0
1999	0	0	0	0	180.2	52	264	216.1	381.4	0	0	0
2000	0	0	0	0	10	102	340	135	49	58	0	0
2001	0	0	0	10	100	187	254	193	47	0	0	0
2002	0	0	0	0	0	131	176	192	210	188	0	0
2003	0	0	0	7	70	117	155	364.4	102	59	0	0
2004	0	0	0	11.01	82	186	249	616	56	0	0	0
2005	0	0	0	10	25	100.5	224.4	329.6	180	65	0	0
2006	0	0	0	10.5	29.1	165.2	144.5	448	116	57	0	0
2007	0	0	0	9	146	206	172	486	0	0	0	0
2008	0	0	0	0	15	15	63	40	0	0	0	0
20	0	0	2.02	6.5055	57.22	139.64	196.155	265.615	111.015	27.29	0	0

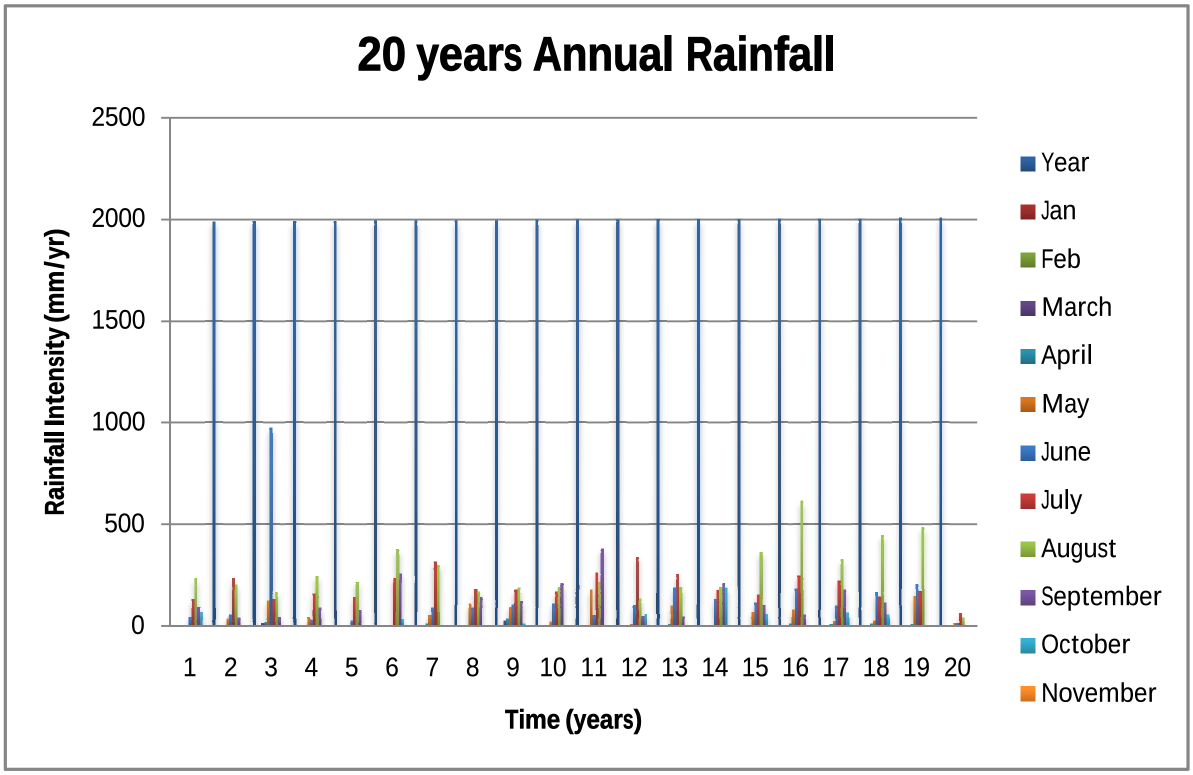


Figure 2-6: Annual Rainfall Chart

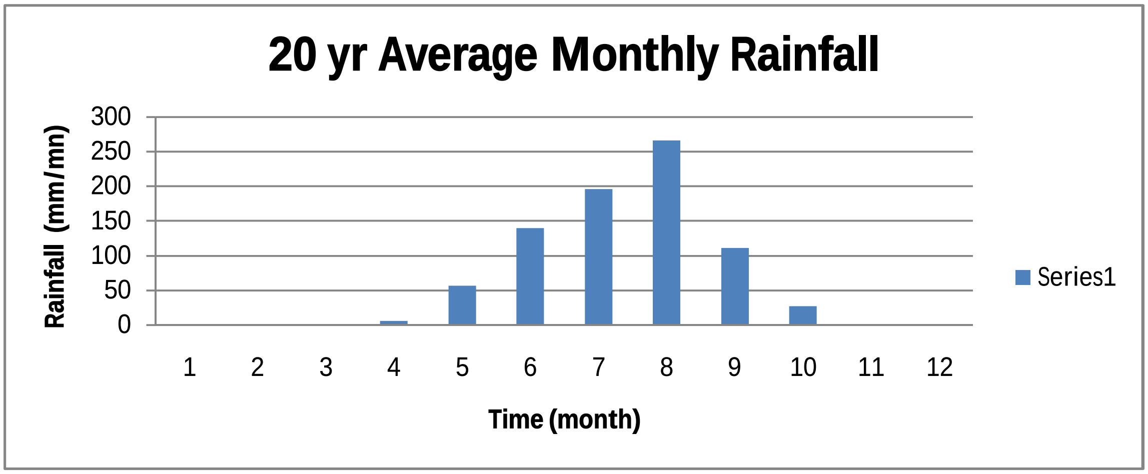


Figure 2-7: Average Rainfall Chart

Chapter III

3 METHODOLOGY

The effectiveness of household rainwater harvesting for Katsina was modeled using an Excel spreadsheet. A simple daily water balance model is developed to calculate the rainwater tank size (Equation 1). The volume of rainwater in the tank depends on the volume of water flowing into the tank and the demand for rainwater as an alternative water source to conventional supply. It is important to ensure that there is enough water in the tank to supply the demand with minimum risk of tank being empty (maximum reliability). The monthly storage level of the water tank would depend on the frequency and the amount of precipitated rainfall and the end use. A monthly time period was considered for the study as it is important to ensure that there is sufficient water for the domestic use intended. Evaporation of water from the tank was not considered assuming that the tank would be closed.

The model uses monthly rainfall data and parameters to calculate the reliability and demand satisfaction of a given rainwater harvesting system, and output includes a graph of the system's storage tank level over the simulation time period. The model assumes that a family's collection systems runs as single unit combining all tank volumes and collection areas and that water withdrawals are made equally from all tanks. The parameters of tank volume, roof area and family size are all independent variables specific to each family. The initial tank volume was set to zero. In late January when the rainfall record begins tanks would not empty however; to standardize the model inputs this was selected. Water demand rates were selected based on WHO water service for drinking only definitions. Galvanized, corrugated roofing was the material for collection areas with runoff coefficient of 0.75 because of the low level of annual rainfall.

Storage tank over was determined by adding the runoff to the storage at the end of the previous day and comparing this to the tank volume; if grater, the storage is set equal to the tank volume, and overflow is computed as the excess amount.

The water balance equation used for the study is given in Equation 2.

$$S_t = S_{t+1} + Q_t - D_t \qquad 0 \leq S_{t+1} \leq C \qquad (1)$$

Where,

S_t = Storage volume at the beginning of tth month

S_{t+1} = Storage volume in the tank at the end of tth month

Q_t = Runoff volume from the roof into the tank on the tth month

D_t = Total demand for water on the tth month

C = Active tank capacity

As first step, the tank capacity C was assumed. The daily runoff from the roof (Q_t) depends on the daily precipitation. The daily water demand (D_t) will depend on number of factors such as the number of occupants in the house, cooking, drinking washing, weather and other domestic uses but in my analysis I consider drinking only due to the monthly amount of rainfall is relatively small. Equation (1) was applied at the end of each time step (month) to obtain the water storage level. On a particular month if the water storage level (S_{t+1}) was greater than the tank capacity (C) the excess water will spill over and the tank storage level and at the end of the day will be equal to C. The amount of water spilled is calculated using Equation (2). The probability of tank having sufficient water to meet the demand was given as reliability (Equation 3). If the required reliability was not achieved with the assumed tank capacity, a new tank size (C) was assumed and the above procedure repeated until the required reliability level was achieved.

Spill on the t^{th} month = $S_{t+1} - C$ (2)

Reliability, Re = $\frac{N-U}{N} * 100$ (3)

Where,

Re = Probability of the tank being not empty as a percentage (reliability)

N = Total number of months

U = Number of months in a year the tank does not meet the demand

Chapter IV

4 RESULTS AND DISCUSSIONS

The viability of Rainwater Harvesting System is rainfall characteristics based. It is a function of the quantity and quality of water available from other source. Therefore, it is of paramount importance to know the rainfall characteristics especially in heterogeneous spatial and temporal regional rainfall pattern.

The success of rainwater harvesting system will depend on many factors. Water demand in the area, cost feasibility and precipitation are some of the most important issues to consider when analyzing the viability of implementing such systems.

Precipitation data is needed to determine the volume of water that can be captured, with rain depth and roof area, and then use that information to compare the monthly demand in average household

Precipitation record from period of 20 years (1989-2008) obtained from the Katsina State Directorate of Water Resources Hydro-meteorological department was used for the analysis.

The average monthly rainfall data for twenty years (1989-2008) of the study area ware obtained from Katsina State Directorate of Water Resources Hydro-Meteorological Service Department for the analysis. Below Figure shows the rainfall pattern of the study area. As the rainfall is unevenly distributed throughout the year, rainwater harvesting can only serve as a supplementary source of household water.

Considering the rainfall pattern of the study area, there is relatively small amount of rainfall that can be harvested. Therefore, the analysis will be on only for drinking purpose.

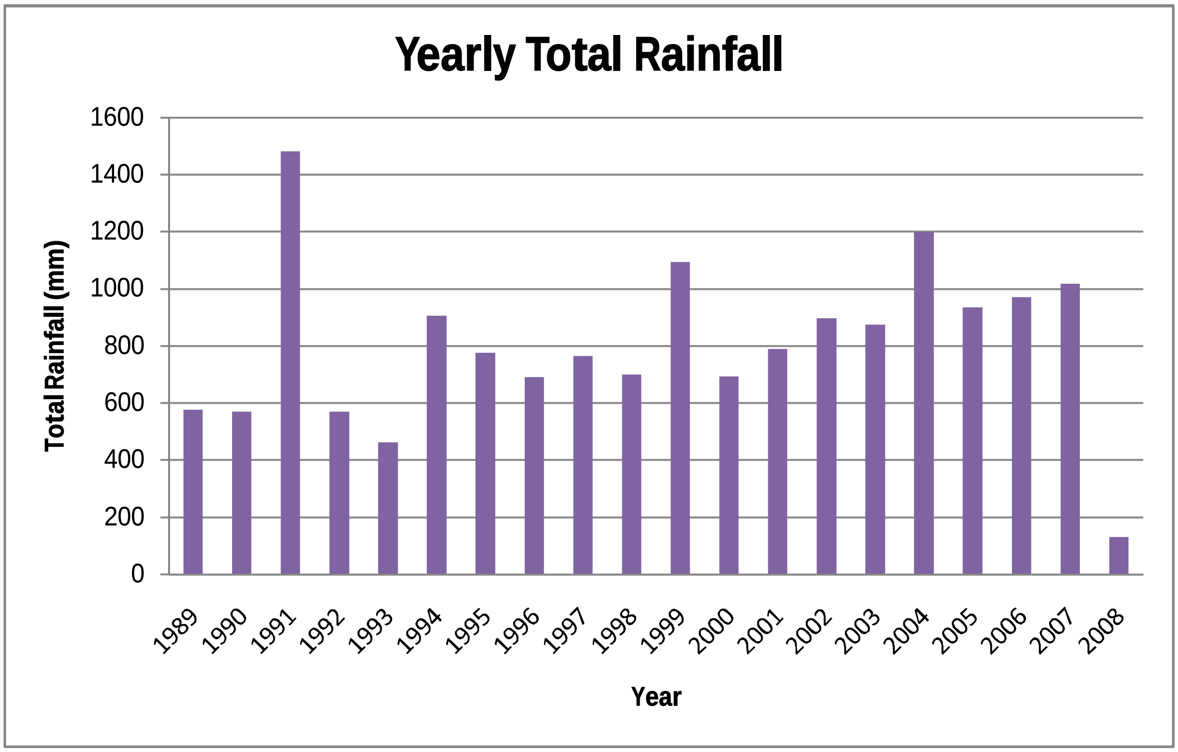


Figure 4-1: Study area Rainfall Pattern (1989-2008)

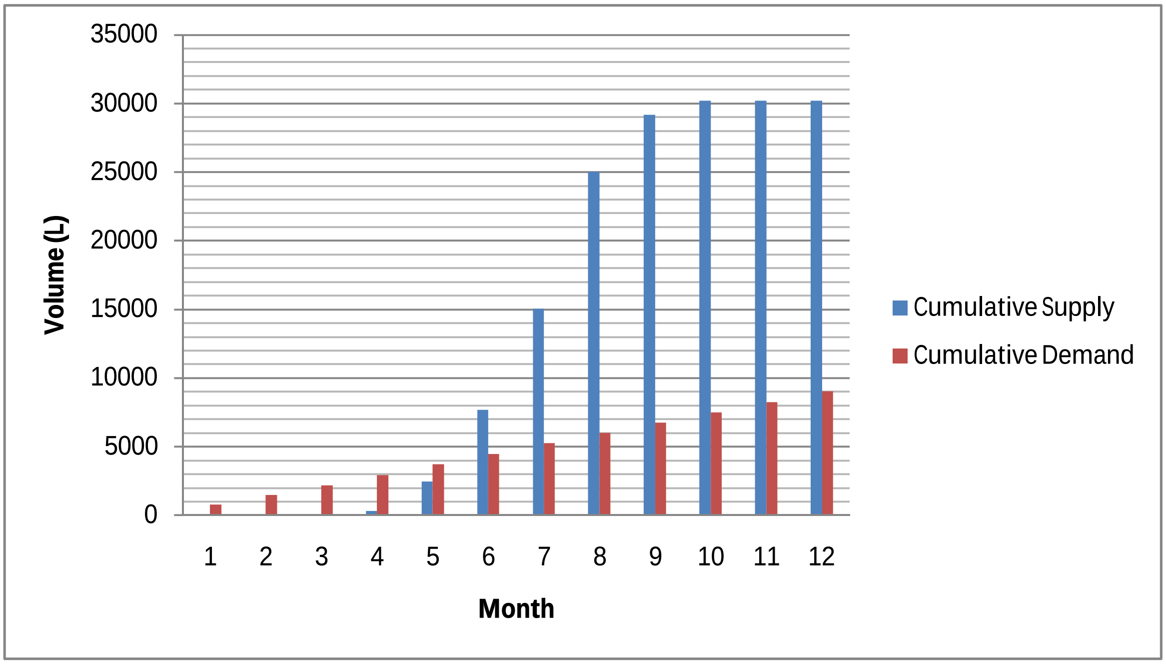


Figure 4-2: Supply-Demand Chart

4.1 Design Curve

Simple design curves were developed using the mass curve analysis. The mass curve analysis was carried out using the adjusted monthly rainfall at various rainfall amounts to estimate storage capacity from a maximum supply perspective. Water demand is proportional to the storage capacity and hence the catchment area, the storage volume (liter) was determined for varying demand (liter per capita per day) for 5 number household and available roof area (m2) of 10, 15, 20, 30, 40 and 50 respectively. Storage may be tank or cistern, because the available polyethylene tanks in the market are 500, 1000, 1500, 2000, 3000, 4000 and 5000 liters which are the most common and easiest to clean and connect to the piping system. Therefore if the storage is above 5000 liters we have to go cistern. The tank reduces as the roof area increases for a fixed demand. The mass curve analysis may also be used to evaluate the adequacy for the design of the existing RWHS and their reliability. This could be accomplished by comparing the cumulative monthly catchment runoff and the cumulative monthly consumption throughout the year. If the difference is positive for all months, the RWCS is adequate, otherwise a negative difference in any month indicates that the system is not sufficient. Precisely, an adequate design should give a cumulative difference between the water yield and demand close to zero at the end of the hydrological year, otherwise a large positive difference means that the system is over-designed whilst a large negative means that the system is inadequate, and hence the catchment area needs to be increased and/or water consumption reduced to make the system viable.

To ease the determination of RWHS design parameters, design curves presented in Figure 1 were developed for various water demand, reliability of rainfall amount and distribution. Such design curves simplify the process of design and/or evaluation of the RWCS. They also provide the designer with an option in terms of the reliability of water supply and thus facilitate the planning and operation of RWHS

Design curves were produced to show the relationship between required tank storage volume collection for a given demand based on given rainfall pattern. This was done by adjusting the collection area while holding the tank volume fixed.

The tank volume available and collection area being used were normalized for the number of individuals living there. These values were then plotted against the design curves to determine the initial conditions of the area.

The estimation of minimum volume of storage is a very important aspect of RWH design. It entails sizing of the tank required to store enough water to satisfy the appropriate demand as required by the user(s). The minimum volume of storage is a function of many variables embedded in the supply (rainfall, catchment area, co-efficient of runoff) and demand pattern. The values of these variables are not always available so approximations are usually used with attempts to ensure maximum reliability. However, results from a highly accurate hydrological estimation of minimum storage volume might not be the final answer in determining the required tank capacity. Affordability by the users and ease of construction of the tank may eventually be the deciding factors (Pacey and Cullis, 1986). The various methods, including the mass curve analysis and dimensionless constant, for estimating minimum tank storage volume have been discussed in World Bank (1985). The mass curve analysis and dimensionless constant is a detailed analysis with a graphical output as the end-result. The advantage with this method is that the resulting graph has a high degree of flexibility in its application within a specific local rainfall pattern

Major cost involvement in Rainwater Harvesting System is the storage reservoir. It depends on the no. of family members and consumption pattern. The storage tank volume (liter) was determined for an estimated water consumption of 2, 4, 6, 8, 10 and 12 (liter per capita per day) as 3160, 7220, 10830, 14435, 18042 and 21649 liters respectively. The amount of water you can harvest varies depending on the size of your roof. You will be surprised how much water you will be able to collect from even the smallest roof.

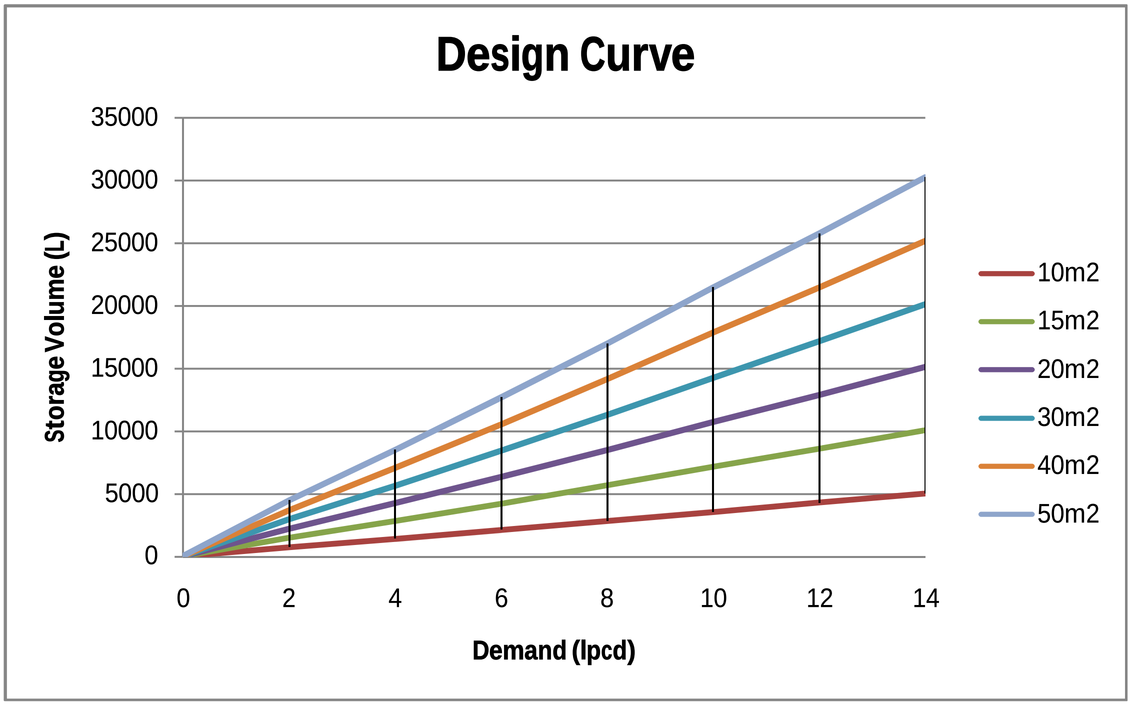


Figure 4-3: Design Curve

4.2 Reliability Curve

The relationship between reliability and tank size shows that, there in change in reliability for tank size of 5L, 10L and 20L only. This yield with an increase in tank size above 50L the reliability is not changing due to the amount of water is very small. As the amount of water is not increasing with the change of storage size, it is observed that the maximum reliability of the system is only 66.67%. Therefore, the water from supply main has to be used to fulfill the demand. The reliability can be increased by increasing the roof area and storage. Depending on the needs of your household, that can be significant amount of water to augment your water supply. In sizing a rainwater harvesting system, there must be a balance between system performance and system cost, particularly in developing nations (Thomas 2005). Approaches to sizing a rainwater system should be based on both community water demand and available water supply.

We should consider that rainwater harvesting systems aren’t necessarily 100% efficient. Most sources estimate efficiency between 70% and 90%. All rainwater harvesting systems lose some of the rainwater. It may spill out of the gutters or the wind may blow it away. Evaporation will undoubtedly affect some of it. To maximize your collection of rainwater, you can use out buildings such as barns or sheds. If you're creative, you can even use rainwater from a patio or other paved areas around your house.

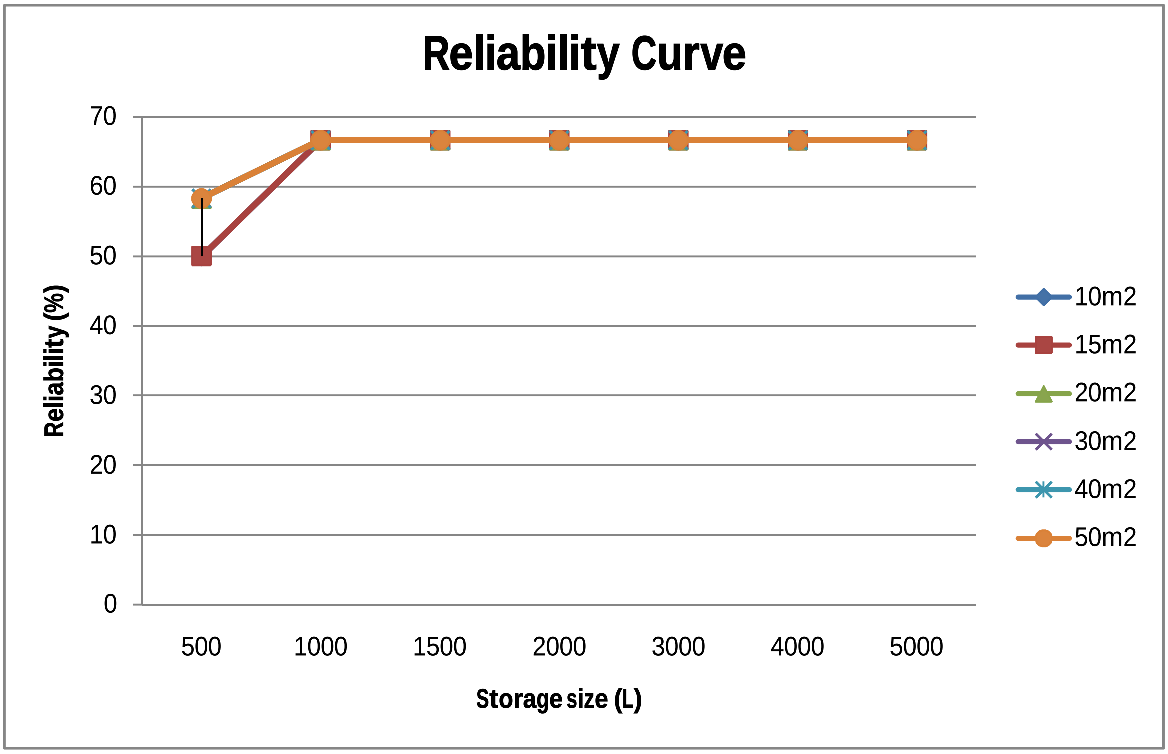


Figure 4-4: Reliability Curve

4.3 Volume of Spilled Water

When the rain barrel reaches its capacity, the overflow pipe discharges the excess water so that water won't start spilling out from around the lid. Cut a hole near the top of the barrel and connect an overflow pipe there The total amount of water available to the consumer is a product of the total available rainfall and the collection surface area. Due to uneven distribution nature of the rainfall, there will be an excess amount of water that is beyond the storage capacity. Because the storage reservoirs are usually the most expensive component in any rainwater harvesting system, using the most appropriate size depends on the range and price of locally available commercial options and on the availability of building materials. Due to cost of construction of cistern, volume of spilled water was determined based on various available polyethylene tanks and roof area.

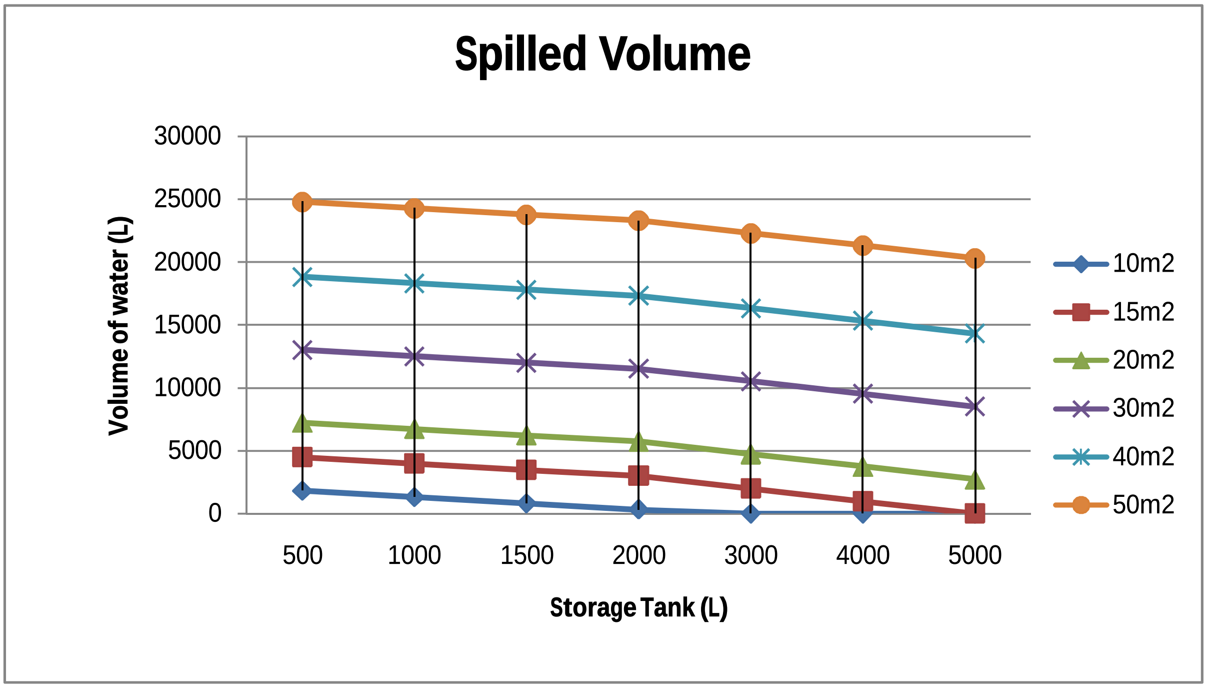


Figure 4-5: Volume of Spilled Water

Chapter V

5 CONCLUSION & RECOMMENDATION

Water scarcity issues are one of the biggest problems in Katsina State. Many factors are contributing to aggravate this situation such as growing population, insufficient infrastructure, poor governance from the authorities and lack of initiatives from public and private sectors. There are some parts of the state receiving water only for some days or no water at all; users are forced to get their supply from water vendors. Rainwater harvesting is a solution worth exploring, though not proposed as a single answer to solve water scarcity, it can be used as complement to alleviate the need in many areas

Rainwater harvesting can provide additional water management options for rural and urban water supply. In developing country like Nigeria, rainwater harvesting for domestic supply can positively address multiple issues regarding safe and reliable water supply, whilst reducing negative impacts on ecosystems, such as over abstraction of surface and ground waters. In addition, implementation can often prove less costly than many traditional, engineered public water supply infrastructure projects.

Rainwater harvesting consists of collecting precipitation from rooftops and storing it in the tanks. It could give users some independence from public water supply being a chance to use the water they collect for their best interests. This type of project, however, aims to alleviate scarcity conditions for users live in rural areas who are not connected public water supply from water board.

Improved local management of water, especially of rainwater, will close the loop and upgrade ecosystems on the community scale. Rainwater harvesting provides multiple benefits in rural areas, including health, income, food, and water security benefits.

A series of storage volumes achieved are calculated for multiple sizes of tank from the model. The curve assists the user to choose the appropriate tank size. Larger tanks yield more retention but they are more costly.

From the study, the maximum reliability that can be obtained is 67%. Therefore, for higher reliability there is need of larger storage to accommodate the harvested rainwater.

Larger storage volume would be required and because the storage component holds the bulk of the system’s cost, implementing these systems can pose as a financial setback to many of the qualifying households. Governments would need to provide subsidies and other incentives for the public to accommodate the increased cost. In addition, cistern will take up more space in comparing with the polyethylene tank which can be placed on roof top.

However, rainwater harvesting systems are very dependent on the amount of precipitation falling during the wet season in Katsina. Climate and varying precipitation patterns make this system uncertain and that is why it is recommended as a complement to other solutions

This type of solution analyzed here for a household level, could be implemented at a larger scale for small communities, some of which are managed through RUWASSA being responsible for providing water for citizens of Katsina State, could sponsor and promote this technology to ensure better coverage. Taking no action and buying water would be more expensive. It makes sense from an economic perspective and could be an option worth considering by RUWASSA to implement at larger scale. Taking no actions means users are relying on authorities to take action and depending on poor infrastructure and severe shortage

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