

# Water Harvesting: An Overview

By Robert Rutherford

## **Introduction**

A method of water collection that has, historically, been “applied in arid and semi-arid regions where rainfall is either not sufficient to sustain a good crop and pasture growth or where, due to the erratic nature of precipitation, the risk of crop failure is very high,” (Prinz, 1996, pg. 1) water harvesting is now being employed all over the world. As new developments have been made, more and more regions are employing water harvesting to help offset pressures on existing water resources. This resurgence in popularity comes on the crest of a new wave of environmentalism and drive towards sustainable development where the focus is on renewable sources of water collection. Water harvesting (WH) is aimed at reducing the pressure that development and the consequences thereof has placed on what is now being reconsidered as a limited resource, our water.

WH has been defined as the collection of runoff for its productive use (Critchley and Siegert, 1991), yet this initial definition is too general and has been more accurately defined as the process of collecting and concentrating water from runoff into a run-on area where the collected water is either directly applied to the cropping area and stored in the soil profile for immediate use by the crop (Prinz and Singh, 2000). As such, WH has been employed for thousands of years to irrigate and restore productivity to the land, provide drinking water (to both humans and animals), minimize risk in drought prone areas, increase groundwater recharge, and reduces storm water discharges (Rainwater Harvesting, 2006). Today, WH is used for crop irrigation, groundwater recharge and water storage for future use in drought prone areas.

Water plays the most crucial role in our everyday lives, water is needed for basic human needs, such as drinking, cooking, sanitation and hygiene, productive activities, for example agriculture, commercial activities and services, and various other uses, like religious ceremonies, environmental enhancement and aesthetic values (Mokgope and Butterworth, 2001). It is for these reasons among others that water harvesting has been practiced for centuries. “Many peoples in the world have continued to rely on water harvesting practices. Others have returned to it in order to relieve pressure on

overburdened underground water tables or municipal water systems” (Palmbach, 2004).

The purpose of this working paper is four fold; first to provide a historical context for WH, looking at ancient technologies and the societies that employed these ingenious techniques to ensure their survival in often harsh environments. The second, outlines the external factors that need to be considered when implementing WH systems and the third aims to define and outline the three principle WH techniques and provides examples of each. Finally this paper examines WH as it is understood today and profiles various non-governmental organizations that have employed WH techniques with a critical analysis on their development strategies and their work.

### **History of Water Harvesting:**

For almost as long as humans have engaged in agriculture, they have engaged in water harvesting. The act of harvesting rainwater, floodwaters and groundwater has been in practice for thousands of years, from the most rudimentary techniques to large, complex methods such as the roman aqueducts. For many cultures, water harvesting (WH) was an effective way to meet their water needs in a time when no other alternatives were available to them. This was mainly due to the fact that alternative sources of drinking water and water for agricultural purposes were not readily available.

Historically, many settlements have been situated in arid and semi-arid climates, such as the Middle East, Northern Africa, and Western Asia. These cultures were largely dependent on subsistence farming and there were few other opportunities to generate income. WH became widespread in many of these regions and although various methods were devised almost universally, each emerging culture established their own unique way of collecting or diverting runoff for productive purposes (Prinz, 1996).

### **The Middle East**

The Middle East was one of the first regions in the world to practice harvesting water for consumption in both domestic and agricultural realms. WH structures found in this

part of the world date back over 9,000 years, to Southern Mesopotamia where simple WH structures were used as early as 4,500BC (Prinz, 1996).

In the Negev Desert region, now modern day Israel, runoff irrigation farming has been in practice since the 10<sup>th</sup> century BC. This form of WH was used throughout Roman rule and well into the Byzantine era (*Ibid.*). “In North Yemen, a system dating back to at least 1,000 B.C. diverted enough floodwater to irrigate 20,000 hectares (50,000 acres) producing agricultural products that may have fed as many as 300,000 people” (*Ibid.*, pg. 11). This method of floodwater management is still in use today, making this region one of the few places where runoff agriculture has been continuously practiced since the earliest settlement (*Ibid.*, Pg. 11). Similarly, floodwater systems have also been used in the regions of modern day Pakistan and Saudi Arabia, both varying the design and process to meet the needs of their climate and terrain.

## **Africa**

Africa, Northern Africa in particular, has a long history of WH, where the technique was often devised to match the terrain of each region. Historically known as the granary of the Roman Empire, in Libya, runoff irrigation was often used as a way to grow barley, wheat, olive oil, grapes, figs and dates in this arid region of the continent. As well, this form of water harvesting also allowed for sheep, pigs and cattle farming (Prinz, 1996). “The farming system lasted for over 400 years and sustained a large stationary population, often wealthy, which created enough crops to generate a surplus” (*Ibid.*, pg. 12).

Many of the other WH methods employed in this region are still used today and include; rainwater storage ponds called “lacs collinaires<sup>1</sup>” in Algeria, the Meskan<sup>2</sup> and Mgouds<sup>3</sup> harvesting systems in Tunisia, the Caag<sup>4</sup> and Gawan<sup>5</sup> systems in Somalia and finally the Zay<sup>6</sup> system in Burkina Faso.

---

<sup>1</sup> Ponds traditionally used for agricultural purposes as well as for watering livestock and other domestic animals (Prinz, 1996).

<sup>2</sup> The “Meskat” microcatchment system consists of an impluvium called a “meskat”, of about 500 m<sup>2</sup> in size, and a cropping area of about 250 m<sup>2</sup>. Both are surrounded by a 20cm high bund, equipped with spillways to let runoff flow into the cropping area plots” (*Ibid.*).

<sup>3</sup> Mgouds are a system of channels used to divert flood water from a stream bed to agricultural fields (*Ibid.*).

To the east, in Tanzania, water harvesting has been a mainstay with rural farmers using rainwater harvesting to irrigate their crops for centuries. “People who rely completely on rainwater for their survival have over the centuries developed indigenous techniques to harvest rainwater” (Mbilinyi *et al.*, 2005, pg. 1). These indigenous methods include the Majaluba, excavated banded basins used for rice production in the lake zone, Vinyungu, raised broad basins in the Iringa region, and the Ndira, which are water storage structures in the Kilimanjaro region (Mbilinyi *et al.*, 2005). As well as these physical structures, the concept of “*mashamba ya mbuga*” has been used to describe the use of rainwater harvesting to grow water intensive crops by making use of rainwater from the surrounding highlands (*Ibid.*). “These traditional rainwater-harvesting systems have been perfectly sustainable for many years as they are compatible with local lifestyles, local institutional patterns and local social systems” (*Ibid.*, pg. 2).

### **Western Asia**

In Asia, many communities have emerged and thrived in harsh arid regions, where their social life has evolved around water scarcity and indigenous water harvesting techniques. India is one such nation where the ordering of certain social groups has been arranged around water scarcity.

In India the national annual average rainfall comes to 120cm, yet the regional variations of this average can be as high as 1000cm per year in the north east and as low as 15cm per year in the desert regions (Krishiworld, 2006). In the cool arid region of the Spiti valley situated in the northern province of Himachal Pradesh, an intricate systems of channels called Kuls have been devised to harvest melt water from glaciers. This water is then delivered to the local village(s) in the valley where the harvested water is used for irrigation purposes, turning this desert-like valley into one where agriculture is the mainstay (Rainwater Harvesting, 2002).

---

<sup>4</sup> Uses diversion channels to redirect small water courses, gullies or roadside drains into the cropping area through the use of earth bunds (*Ibid.* pg. 14).

<sup>5</sup> “The Gawan system is used where the land is almost flat and where is less runoff. Small bunds are made which divide plots into "grids" of basins” (*Ibid.* pg. 15).

<sup>6</sup> “Is a form of pitting which consists of digging holes that have a depth of 5 - 15 cm and a diameter of 10 - 30 cm...Manure and grasses are mixed with some of the soil and...are applied in combination with bunds to conserve runoff” (*Ibid.*, pg 15).

The Kul begins at the glacier head, in the nearby mountains, where the water is “tapped.” The water then travels into a circular tank where the water is stored until it is needed, allowing for the water flow to be regulated (*Ibid.*). “Water from the Kul is collected through the night and released into the exit channel in the morning. By evening the tank is practically empty and the exit is closed. This cycle is repeated daily” (*Ibid.*). This water harvesting system is specific to the Spiti region and an interesting method of water sharing has arisen to equitably distribute the limited hydrological resources.

In order to prevent the fragmentation of land holdings, Spiti inheritance laws specify that the eldest son will not only inherit all the landholdings, but the farm implements, the family house and the family's water rights as well (*Ibid.*). The water rights are controlled by the “Bada Ghars” (big houses) in the community and other families are required to purchase water from the Bada Ghars or provide free labour in exchange. To this day the Bada Ghars have first claim to the stored water for which they use to irrigate their fields, the remaining water is then dispersed down through hierarchal order to each family farm. A system of crop rotation has emerged as a result with the Bada Ghars growing and harvesting their crops at the beginning of the season with other houses doing so later in the year. In this way, the limited labour supply is also shared equitably to ensure a successful harvest among all houses (*Ibid.*). Today this system is threatened by the Union government which is attempting to implement change in hopes of “modernizing” the Spiti valley. “The Union government has slowly made its presence felt in the Spiti valley as a modernising agent, whose actions are profoundly changing traditional production practises and social patterns” (*Ibid.*)

Other historical forms of water harvesting techniques from India include Kunds of the Thar Desert and the bamboo irrigation method. Kunds are a local name given to a covered, underground tank that was designed to store drinking water. Found mainly in the western regions of Rajasthan, the first known Kund was built in 1607AD by Raja Sursingh in the village of Vadi-ka-melan (*Ibid.*). The Kund has a saucer-shaped catchment area with a gentle slope towards a tank in the centre. The opening of the tank is blocked by mesh to prevent debris from contaminating the water. Kunds are

generally circular in shape and have a depth between 3 – 4.5m and are constructed using local materials such as lime plaster or cement (*Ibid.*).

In the province of Meghalaya, systems of bamboo pipes have been in use for over 200 years as a way for local farmers in the Khasi and Jaintia hills to irrigate their crops. This method of water harvesting has been perfected so that “about 18-20L of water entering the bamboo pipe system per minute, gets transported over several hundred meters and is reduced to 20-80 drops per minute” (*Ibid.*).

### **The Americas**

Ancient WH techniques aren't restricted solely to the old world. In the Americas, structures left behind by the Mayan civilization indicate a long history of WH. The Mayans used structures known as Chultuns, an early type of cistern which had the capacity to hold 20 to 45 thousand litres, to harvest clean drinking water.

Furthermore, the Aguadas, an artificially dug rainwater reservoir designed to hold 10 to 150 million litres of water, and Aquaditas, small artificial reservoirs that could store 100 to 50,000 litres of water, were commonplace (Gnadlinger, 2000).

Despite these historical accounts, water harvesting has, within the last few centuries, experienced a decline in implementation and practice. This has been a result of several factors including; the decline of central powers (e.g. of the Byzantine empire in the Middle East) due to political shifts, warfare incl. civil war, economic changes, e.g. in competitiveness on local or export markets, social changes, incl. availability of cheap labour, aspirations or attitudes of the people involved in water harvesting, climatic change (increasing aridity, change in precipitation regime), increasing salinity, decreasing soil fertility (nutrient status) and soil erosion (wind and water erosion) (Prinz, 1996).

Only in recent decades has this renewable water source made a resurgence in popularity. This is mainly due to a number of factors such as improved technology, increased demand for agricultural products, a shift in paradigm regarding environmental protection and increased value placed on indigenous knowledge regarding water harvesting (Mbilinyi *et al.*, 2005).

### **Requirements for Water Harvesting:**

“It is evident that there is enough freshwater available every year to fulfil the needs of the present population of this planet. However, in certain regions and countries the annual renewable supply of water is less than 500m cubed” (Qadir *et al.*, 2007, pg. 3). This need for WH, as mentioned above, arises from many factors such as low rainfall and uneven distribution, high losses due to evaporation and runoff, and an increased demand on water due to population growth. (Abu-Awwad and Shatanawi, 1997). With a large portion of the human race living in arid to semi-arid regions of the globe, it is necessary to look to WH to increase water access in these areas.

As WH becomes an important strategy to deal with water scarcity or water stress, it is important to consider the factors that go into selecting the appropriate WH methods to maximize hydrological returns. “It is tempting to assume that a system which works in one area will also work in another, superficially similar, zone. However there may be technical dissimilarities such as availability of stone or intensity of rainfall, and distinct socio-economic differences” (Critchley and Siegert, 1997).

In Prinz and Singh’s article, “Technological Potential for Improvements of Water Harvesting,” there are a number of critical factors that need to be taken into consideration when selecting the appropriate WH method. These will be outlined below:

### **Rainfall**

WH depends on limited and uncertain rainfall, and thus understanding the dynamics of precipitation within the environment can influence the method of WH that would fit best in each context (Qadir *et al.*, 2007).

Various factors which should be taken into account include:

1. The number of days in which the rain exceeds the threshold rainfall of the catchment, on a weekly or monthly basis.
2. Probability and occurrence (in years) for the mean monthly rainfall.
3. Probability and reoccurrence for the minimum and maximum monthly rainfall.
4. Frequency distribution of storms of different specific intensities.

(Prinz and Singh, 2000).

### **Land Use or Vegetation Cover**

Working to reduce erosion and redirect runoff into appropriate catchments can lead to high labour inputs resulting from the necessity to keep the catchment area free from vegetation, to ensure that it is as efficient as possible. The vegetation of the selected area will heavily influence runoff, infiltration and retention levels and must be taken into account prior to implementation, to reduce high labour costs in the future (Qadir *et al.*, 2007).

Maintenance of the catchment system must also be understood when selecting the size of catchment. The system may be damaged during heavy rainstorms or require regular maintenance which could prove problematic in the future (*Ibid.*).

### **Topography and Terrain Profile**

Topography is an important aspect of WH as the slope of the terrain and gradient will greatly impact the size and type of catchment area of the WH system (Prinz and Singh, 2000).

### **Soil Type and Soil Depth**

Soil type and depth helps judge the percolation and infiltration rates, potential for runoff, and storage potential of water within the soil itself (*Ibid.*).

### **Hydrology and Water Resources**

Hydrology monitors the available water sources that are involved in storage, production and runoff of the WH system, which will aid in the informed selection of the appropriate WH technique for the proposed site (*Ibid.*).

### **Socio-Economic and Infrastructure Conditions**

There are several social, cultural and economic factors that are important to consider when selecting the appropriate WH techniques.

People's Priorities – Need to be taken into account when opting to introduce WH methods to a specific area. WH aims to increase the availability of water resources for productive use, and it is therefore important that the WH infrastructure meet the needs of the individuals who are using it (Critchley and Siegert, 1997).



Participation – When implementing projects surrounding WH, for example development schemes implemented by governments or NGO's, it is imperative that the community, farmer or individual be involved in the process from beginning to end. This helps create a sense of ownership of the project within the community. Knowledge plays an important role here for individuals involved in the WH scheme as they need to fully understand how it operates. One potential negative effect of implementing complex WH technologies is that those who are left to use it are unfamiliar with the technology and thus unable to properly maintain it (Oweis and Hachum, 2005).

Adoption of Systems – Indicates the importance of selecting the appropriate WH method for each site. “Widespread adoption of water harvesting techniques by the local population is the only way that significant areas of land can be treated at a reasonable cost on a sustainable basis.” (Critchley and Siegert, 1991).

Area Differences – It is not always possible to implement the same WH system in different areas. This is due to subtle but important differences that exist between sites that can cause a WH system to be a success in one region and a failure in another (*Ibid.*).

Land Tenure – Not having full ownership of the land on which one lives can cause an individual to be reluctant to invest in a WH scheme that would only benefit the user in the short term (*Ibid.*).

Land Use Management - How land, both communal and private, is managed and used can determine the effectiveness of the WH strategy being proposed or implemented. Effective land management is important as conflicts and disputes over water rights, land ownership and use can arise (Oweis and Hachum, 2005).

### **Environmental and Ecological Impacts**

Ecosystems are often fragile and can be adversely affected if the water table is tampered with. Thus it is important to pay attention to these factors, understanding where the water flows and how it affects the surrounding ecology, before implementing any kind of water harvesting system. Some negative impacts that water

harvesting can potentially have on the existing environment are the reduction of valuable cropland that would be occupied by the catchment area. The catchment often requires a large area and thus occupies valuable crop land (Qadir *et al.*, 2007). However, today the technology exists to allow for WH to occur on a larger scale, allowing for various commercial uses such as plant nurseries, garden centres, vehicle washing plants, agricultural uses and for use in washrooms and urinal flushing in public buildings (Rainharvesting Systems, 2006).

### **Forms of Water Harvesting**

There are three main categories of WH that have been devised and perfected over the years. Each category has its own subset of methods and techniques that are employed to get the maximum amount of profit from each water source, be it floodwater, rainfall or groundwater. The three main forms of WH include Rainwater Harvesting (RWH), Floodwater Harvesting (FWH) and Groundwater Harvesting (GWH).

### **Rainwater Harvesting**

“Rainwater Harvesting uses a wide range of techniques for concentrating, collecting and storing rainwater and surface runoff for different uses by linking a runoff-producing area with a separate runoff-receiving area” (Mbilinyi *et al.*, 2005, pg. 2). In this sense, RWH collects rainwater runoff and stores it for future use, be it for agricultural, domestic or drinking purposes. As such, RWH encompasses all WH techniques that collect and harvest runoff from roofs or ground surfaces (Critchley and Sievert, 1991). The three main forms of water collection that make up RWH are water collection, rooftop harvesting and micro-catchments.

Water Collection – Also known as water conservation, this method of RWH is essentially the prevention of net runoff from a given area by retaining rainwater and prolonging the time for infiltration (Mbilinyi *et al.*, 2005). This practice employs a number of different techniques to “catch the water where it falls” (*Ibid.*, pg. 2). The methods for this form of RWH are diverse and are often a product of local ingenuity and varying cultural practices. Examples of water collection include deep tillage, dry seeding, mixed cropping, ridges, borders, terraces, trash lines, ponds, fog harvesting and finally rooftop harvesting (Prinz, 1996). For the most part, these practices are mainly used for irrigation.

Rooftop Harvesting – Is generally practiced as a way to obtain relatively clean drinking water as well as water for domestic purposes. This method involves a relatively small catchment area, the size of the individual's roof of their house, with gutters and pipes to guide the water into a tank on the ground. Often a tap is attached to the tank for individuals to access this water (Mbilinyi *et al.*, 2005). There is concern over whether or not the water is clean enough for drinking, as pollutants in the atmosphere have been known to be present in rainfall. "Today water harvesters must be wary of pesticide contamination, high mineral levels, bacteria and other impurities in their runoff water" (Palmbach, 2004). Most rooftop harvesting systems have screens and purification systems built into the infrastructure to remove leaves and twigs from the water as well as to purify the water prior to use (*Ibid.*).

In Zambia, there is a growing focus on looking to other sources of safe, clean drinking water in many of the rapidly expanding urban centres. In Lusaka, for example, the city is experiencing large deficits in water access, reaching levels of almost double the actual supply. (Handia *et al.*, 2003). A study, conducted in Lusaka, by Handia *et al.*, looked at the potential of rooftop water harvesting systems as alternative sources of safe drinking water. In the capital city of Lusaka, the annual rainfall exceeded 306 million cubic meters in 1999, drastically surpassing the 73 million cubic meters of piped water that was used by the city's residents. This excess water has, until recently been considered waste water, The purpose of this study was to investigate appropriate WH systems that would be successful in reclaiming this lost water and fit within a Zambian context. A series of pilot projects were set up at various locations within two urban communities, Chazanga and Linda. The project consisted of rooftop water harvesting systems fitted with a guttering system to harvest the water into tanks where it was stored until needed for use. The conclusions drawn from this study surmised that water harvesting systems have great potential within Zambia and that the proposed rooftop water harvesting system can potentially be used as a source of drinking water, yet recommended further research into the matter as the pilot test was small and could not be applied to the country as a whole (*Ibid.*).

Micro-Catchment – Involves a distinct division of a runoff-generating catchment area, and a cultivated basin where runoff is concentrated and stored in the root zone and productively used by plants (Mbilinyi *et al.*, 2005 pg. 2). There are multiple

advantages to this WH system than the others in that the design is simple and cheap, there is a higher runoff efficiency than larger scale WH systems, they often prevent or reduce erosion and, finally, can be implemented on almost any slope and many level planes (Prinz, 1996).

Micro-catchments vary in size, method and technique from region to region. A micro-catchment system in Ethiopia, for example, may be completely different in style and operation than a micro-catchment system found in Western Asia. Although there are variations, there is a basis of methods used within the micro-catchment category, they include; pitting, contour ridges, negarin, semi-circular hoops, meskat-type, vallerani-type, contour bench terraces, and eye brow terraces or hill slope micro-catchments (*Ibid.*).

### **Floodwater Harvesting**

Often referred to as water spreading or spate irrigation, FWH is involved in the collection and storage of creek flow for irrigation use (Prinz and Singh, 2000, pg 3). The main characteristics of FWH are a turbulent channel of water flow harvested either by diversion or spreading within a channel bed/valley floor where the runoff is stored in soil profile (Critchley and Siegert, 1991). Two categories in FWH include Macro-Catchments and Large Catchments.

Macro-Catchments – Macro-catchments, sometimes called medium-sized catchments, are characterized by large flood zones that are situated outside of the cropping area. Often farmers must use structures such as dams or bunds to divert, transfer, collect and store the runoff. Such systems are often difficult to differentiate from conventional irrigation systems and are considered FWH as long as the harvested water is available year round. (Mbilinyi *et al.*, 2005). Examples of macro-catchments include the following; stone dams, large semi-circular hoops, trapezoidal bunds, hillside conduit systems, and cultivated reservoirs, all of which have a scale of between 1,000m squared to 200 ha (Prinz, 1996).

Large Catchments Water Harvesting – Comprises systems with catchments many square kilometres in size, from which runoff water flows through a large stream bed (also known as a Wadi) necessitating more complex structures of dams and

distribution networks. There are two major forms of large catchments water harvesting outlined in the literature, floodwater harvesting within a streambed and floodwater diversion (*Ibid.*, pg. 8).

Floodwater Harvesting within a Streambed involves blocking the water flow to flood the valley of an entire flood plane and force the water to infiltrate the ground and use the wetted area for crop production or pasture improvement (*Ibid.*, pg. 8). Floodwater Diversion is a method in which water in a river, stream (wadi) or creek bed is diverted from its natural course and used to flood nearby cropping areas as an irrigation method (*Ibid.*, pg. 8).

Examples of each can be illustrated by looking at the Nabataen and Jessour systems of water harvesting respectively. The Nabataen system diverts the water from a large wadi (stream flow) in a valley by the use of a dam. This diverts the water into a cropping area situated further away from the fertile banks of the stream. The Jessour system “is a terraced wadi system with earth dikes (“tabia”) which are often reinforced by dry stone walls (“sirra”). The sediments accumulating behind the dikes are used for cropping in the lateral/central spillway.” (*Ibid.*, pg. 13).

### **Groundwater Harvesting**

GRH encompasses all methods, traditional and contemporary, of harvesting water from the ground for productive use. It has also been used as a storage method for the other forms of water harvesting outlined above, with many of these techniques requiring a certain type of terrain so that the water diverted from its original source can seep into the ground for crop use. Traditional methods of groundwater harvesting include the use of dams, wells, cisterns and aquifers.

Dams – Groundwater harvesting dams pertain to the blockage of groundwater sources for the use in agricultural practices. The subsurface dam and the sand storage dam are used to “obstruct the flow of ephemeral streams in a river bed. The water is stored in the sediment below ground surface and can be used for aquifer recharge” (Prinz and Singh, 2000, pg. 3).

There are several advantages to this as evaporation losses are reduced, there is no reduction in storage volume due to siltation, the stored water is less susceptible to pollution, and health hazards due to mosquito breeding are avoided (*Ibid.*, pg. 3).

Wells – Probably the most common of GWH techniques, they tap into the water table from a hole excavated on the surface. Wells have been employed as a source of water for thousands of years, with one of the oldest wells found dating back to 8100 – 7500 BC. Like other forms of water harvesting, wells have been adapted to meet the needs of individuals living in specific regions. Technology has also increased the returns from wells, making water easier to obtain.

Dug wells commonly used in Ethiopia, range from 3 to 15m deep and are major sources of water for both agricultural and domestic water uses (Alem, 2003). Elias, are generally deeper than dug wells and are often used to supply drinking water to livestock. The water of these wells is manually transported to the trough where the livestock drink from. Elias are generally found in Southern Ethiopia.

Cisterns – “Are man-made caves or underground constructions to store water. Often the walls of these cisterns are plastered to prevent water loss, deep percolation and/or evaporation” (Prinz and Singh, 2000, pg. 4). The underground cistern (China Type), found in Ethiopia, is employed to supply water for domestic for irrigation purposes to drought prone areas. There are two variants to this cistern, one being shaped like a bottle, the other in a circular formation. Both are constructed in a similar fashion with the ground excavated to form the shape of the cistern. The surface is covered with polyethylene or concrete plastering to avoid seepage loss. Both cisterns are expensive and difficult to build, often too complex for individual farmers to construct themselves. The capacity of each is 60,000L (Alem, 2003, pg. 5).

Aquifers – Form underground layers of water seeped into permeable rock or other materials such as sand, gravel silt or clay. They generally occupy large areas under the earth’s surface and will often supply other water sources such as streams, rivers, and springs. Often, aquifers are on the receiving end of water harvesting, in that they are often used as a way to store harvested rainwater. Recently, awareness of depleting aquifers has spurred an increase in WH techniques that aim at directly recharging

these rapidly depleting resources. “Many forms of rainwater harvesting collect water and store it underground for future use. Not only does this recharge depleting groundwater sources, it also raises the declining water table and can help augment water supply.” (Edugreen, 2006).

Qanats are an example of how an aquifer can be accessed to provide fresh water. “Widely used in Iran, Pakistan, North Africa and even in Spain, the Qanat consists of a horizontal tunnel that taps underground water in an alluvial fan, bringing it to the surface due to gravitational effect. Qanat tunnels have an inclination of 1-2% and a length of up to 30 km. Many are still maintained and deliver steadily water to fields for agriculture production and villages for drinking water supply” (Prinz and Singh, 2000, pg. 3).

These examples of water harvesting methods are a combination of ancient methods fine-tuned over thousands of years and new technologies developed within the last half century. Today WH is experiencing a renewed vigour as nations all over the world are establishing organizations dedicated to WH and developing new technologies, in conjunction with traditional and indigenous knowledge, to improve the extraction of water resources for productive use.

### **The Status of Water Harvesting Today and Water Harvesting Organizations:**

After a large decline in the practice of WH and water collection, the 1950's began a renewed interest in both the research and practical fields. This resurgence of WH began with the successful reconstruction of ancient WH forms in the Negev region of the Middle East. Today most research in the field is taking place in Israel, Australia, the United States and India (Prinz, 1996).

The Jordan basin, a large ancient aquifer shared between Jordan, Israel, and Palestine, supplies fresh groundwater to these riparian nations. “Groundwater is the most important source of freshwater supply in the area and consists of the main aquifer systems that are located and recharged from rainfall in the West Bank” (pg. 4, Middle East). At present the average rainfall in the West Bank is 2,597mcm per year, which is not nearly enough to recharge these ancient aquifers with water that has been

extracted to drive the agricultural sector in the Middle East (Applied Research Institute Jerusalem, 1996).

Today many different organizations, including various government organizations, are experimenting with methods using WH as an alternative to groundwater extraction and as a way to augment crop production and development in the region. For example, studies in Israel are looking at research into the following four areas of WH; testing specific WH techniques, studying soil surface characteristics, studying and modelling runoff behaviour and finally analyzing the economy of WH techniques. (Prinz, 1996).

In Jordan as well, WH technology is making leaps and bounds with the implementation of large scale WH projects initiated by the government, specifically Jordan's Ministry of Agriculture, and various university organizations (e.g. ACSAD). The "Jordan Highland Development Project" was put into action in 1972 which involved using rock dams, contour stone bunds, trapezoidal bunds and earth contour bunds to increase soil moisture around trees planted on steep lands.

In Tanzania WH, particularly rainwater harvesting, is quickly becoming widely accepted within this east African nation. Seen as a way to improve water availability and land productivity, RWH has become a key element in the Agriculture Sector Development Strategy, as implemented by the Tanzanian government (Mbilinyi *et al.*, 2005). There has been particular interest in understanding the indigenous knowledge of traditional WH methods, so that new legislation and implementation schemes can effectively incorporate time-tested strategies with new development.

In India, a country that has had a rich history of WH, has again taken the lead in this renewed global interest in WH. Spurred on by a national water harvesting campaign initiated by the Centre for Science and Technology (CSE) and IIT Delhi, the city of Indore adopted an official strategy of RWH in order to combat the water demands on groundwater and other water resources brought on by increased urbanization and over population (Surana and Mankad, 2003).



In 2000, the Indore Municipal Corporation (IMC) established a Rainwater Harvesting and Recharging Department to create awareness among citizens and assist them in adopting WH techniques (*Ibid.*). Techniques employed by the city department included; recharge of dry dug wells, recharge of used and unused bore well by perforated casing pipe, recharge of tube well by circular trench method, water recharge by pile/column, ground water recharge through well-shaft tube, and well recharge by injection recharge method (*Ibid.*). In the few years after this official development strategy, over 3000 residential buildings have adopted various WH techniques, as well as in various other government buildings, schools and public areas.

In addition to this augmentation of WH among individual cities, nations and governments around the world, many NGO's and Not-For-Profit Organizations have adopted various WH methods into their developmental strategies. Many of these organizations have arisen to "tackle poverty by working with local communities to establish sustainable supplies of clean water for improved health and increased agricultural production" (PumpAid, 2007). These WH methods are employed by the organizations to increase agricultural potential and improve the quality of life for those living in water scarce areas.

The following three organizations, PumpAid, the Greater Horn of Africa Rainwater Partnership (GHARP), and the Southern and Eastern Africa Rainwater Network (SEARNet) are outlined in this paper due to their contribution to the development of African communities through water harvesting.

### **PumpAid**

PumpAid's mission is to relieve poverty by providing communities with reliable access to clean, safe water for drinking and irrigation in rural Zimbabwe and neighbouring countries. It is focused on providing appropriate, sustainable water systems using the elephant pump to schools and communities.

The elephant pump is a reinvention of 2000 year old technology adapted from the Chinese. The system uses a rope, fitted with rubber washers at equal intervals, which runs through a pipe that is connected to the water supply. When the wheel is turned,

the rope with the washers runs through the pipe drawing the water up and out of the pump (PumpAid, 2007). This system has several benefits which include; fully protected water source providing clean drinking water, rate of extraction is approximately 1 litre per second, low cost of construction, ease and extremely low cost of maintenance, ease of operation for children and the elderly, and is suitable for extraction from depth of up to 30 meters (*Ibid.*).

PumpAid prides itself on being culturally sensitive and works to create a sense of ownership within the community for their projects (*Ibid.*). Contact is made at all levels in the community, from the grass-roots to community leaders and government agencies. This is done to ensure that the entire community understands the purpose behind PumpAid and are willing to accept the organizations help prior to any action taken within the community. PumpAid has strict requirements regarding the construction, implementation and maintenance of their projects. Locals must provide materials, and the manpower needed in construction and upon completion of the pump, are responsible for its maintenance and upkeep.

This organization aims to work as a facilitator, providing communities with the skills they need to create, implement and maintain these water projects themselves.

## **GHARP**

The Greater Horn of Africa Rainwater Partnership (GHARP) is a regional network of National Rainwater Associations (NRWA) which uses RWH techniques to improve the lives of people living in poverty in the Greater Horn of Africa (GHA). This organization is a conglomerate of smaller regional organizations that have come together to work towards the promotion of RWH techniques in Eastern Africa. GHARP was formally established in March 2001 and has since been working tirelessly to improve water access in Eastern Africa.

Member organizations include:

- Ethiopia Rainwater Harvesting Association (ERHA)
- Kenya Rainwater Association (KRA)
- Rainwater Association of Somalia (RAAS)
- Rainwater Harvesting Association of Tanzania (RHAT)

- Uganda Rainwater Association (URWA)

(GHARP, 2005)

“Strengthening Regional Rainwater Networking Mechanisms: Promoting Adaptive Strategies for Food Security” was a GHARP project that was funded by the United States Agency for International Development (USAID) through the institutional Strengthening and Grant Management (ISGM) administered by PACT/MWENGO with a budget of US\$250,000. This project was aimed at strengthening a regional rainwater network to coordinate the identification and evaluation for RWH technologies with the purpose of promoting best practices in rainwater management to enhance food security and water availability in the GHA (*Ibid.*).

The purpose of this study was to identify and analyze the technical, socio-cultural, gender, economic and agronomic factors that affect promotion, adoption and adaptation of promising technologies. A second, follow-up study was conducted called “Promotion of Rainwater Management Technologies in the Horn of Africa: Multi-Sectoral Approach towards Sustainable Livelihood of Pastoral Communities.” This project was designed to demonstrate and test viable integrated RHM systems and dissemination approached among rural communities in semi-arid districts (*Ibid.*).

Finally, a third project was conducted, called “Integrated Rainwater Harvesting and Management Systems and Complementary Technologies for Improving Water Supply, Food Security and Sustainable Livelihoods in Semi-Arid Districts of Kenya.” It was designed to enhance poverty reduction and sustainable livelihoods through the promotion of integrated RHM systems and complementary technologies in the marginal districts of Kenya (*Ibid.*).

WH methods that have been implemented in this region include; Ferro cement tanks in Makueni, Kenya, the construction of reinforced Masonry tanks in Oromia regional state, Ethiopia, An Earth Dam in Laikipia, Kenya, Rock Catchments in Kitui, Kenya, Underground tanks in Tanzania, as well as various terraces, planting pits and micro-irrigation schemes throughout the region (*Ibid.*).

## **SEARNet**

The Southern and Eastern Africa Rainwater Network (SEARNet) was conceptualized in 1998 at a regional WH workshop organized by the Regional Land Management Unit (RELMA) in Machakos, Kenya, where it was believed that a regional network should exist to inform, educate and implement developmental strategies related to water conservation (SEARNet, 2006). In 2001, at a meeting held in Livingstone, Zambia, a statement of intent was established and the organization was on its way to becoming registered as an international NGO. Today, SEARNet consists of 10 partner nations, Botswana, Ethiopia, Kenya, Malawi, Rwanda, Somalia, Tanzania, Uganda, Zambia and Zimbabwe, as well as three affiliates, Eritrea, Mozambique and South Africa (*Ibid.*).

The purpose behind SEARNet is to “network among its member associations within the region for the promotion of rainwater harvesting and utilization” (SEARNet Mission statement). With this network firmly established, It is the vision of SEARNet to “improve livelihoods of the people living in these regions through the contribution of sustainable management, utilization of rainwater and encouraging community based water harvesting” (*Ibid.*). SEARNet works on a similar scale as GHARP, to develop sustainable water harvesting techniques and infrastructure. Both organizations share a number of the same partners in their development strategies, with many countries that form the horn of Africa also sharing in SEARNet’s goals.

SEARNet has developed several methods through which it tries to increase RWH awareness and augment development in this field. These methods, through which they aim to achieve their vision, include creating publications, website development, working through awareness campaigns, establishing model/demonstration sites and conducting policy research (*Ibid.*). Some examples of the network’s demonstration sites include, Magoya in the Lake Victoria basin of Kenya. Here RELMA and the University of Nairobi have focused on the use of river, wells and runoff water for agricultural production (*Ibid.*). Another focus of the organization is conservation farming in rural Zambia. This project is situated on a farm located 20kms from Lusaka. SEARNet publishes a quarterly newsletter called “SEARNet Briefs” with the intent to create awareness of WH within the network’s organizations and partner countries.

There are many more examples of organizations and governments who are using WH as a means to combat poverty, reduce drought and increase agricultural production. As awareness of WH grows through organizations like the ones profiled here, many lives can be improved through WH.

## **Conclusions**

“Water is life's mater and matrix, mother and medium. There is no life without water.” (Albert Szent-Gyorgyi, 1937). Never has this been more true than today. Natural resources are quickly becoming scarce commodities. Once thought to be a never-ending renewable resource, clean, fresh water supplies are rapidly depleting, causing drought and drought-like conditions around the world. “Today, one billion people lack access to safe and affordable sources of clean water, and over 2.4 billion people lack adequate sources for sanitation” (Postnote, 2002). Now, more than ever, WH is needed to ensure that water needs in these water-scarce areas are met.

Water harvesting has played an important role in the development of many regions throughout history. Methods devised thousands of years ago are finding new life in today's technology as WH and hydrological conservation have become increasingly important. Today many organizations, such as PumpAid, GHARP, and SEARNet, are working together with governments, research groups and other agencies to bring WH into the forefront of development around the world. Working together, these organizations are trying to improve access to clean sources of water for many in water-stressed areas. WH allows for users to harness sources of water that would not be possible to obtain through conventional means. WH systems also allow for crop irrigation in (semi) arid regions and can be used to recharge groundwater in order to alleviate pressure exerted on these limited resources. WH also has the potential to catch the water where it lands and use it as a clean source of drinking water and for other domestic purposes making it an ideal method for water conservation.

## Bibliography

Alem, Getachew. "Water Harvesting: A Water Security Strategy For Mitigating The Impact Of Drought In Ethiopia." *Water Security in the 21<sup>st</sup> Century*. (~2003): 1-5.

A. M. Abu-Awwad and M. R. Shatanawi. "Water harvesting and infiltration in arid areas affected by surface crust: examples from Jordan." *Jouranal of Arid Environmets*. 37 (1997): 443–452.

Applied Research Institute Jerusalem. "Water Conflicts in the Middle East from a Palestinian Perspective." *Water, Culture, Politics: Interactions and Options*. 19 – 21 September 1996: 1-17.

Handia, Lubinga, James Madalitso Tembo, and Caroline Mwiindwa. "Potential of Rainwater Harvesting in Urban Zambia." *Physics and Chemistry of the Earth*. 28 (2003) 893–896.

Mbilinyi, B.P., S.D. Tumbo, H.F. Mahoo, E.M. Senkondo and N. Hatibu. "Indigenous Knowledge As Decision Support Tool In Rainwater Harvesting." *Physics and Chemistry of the Earth*. 30 (2005) 792–798.

Mokgope, K. and J.A. Butterworth. "WHIRL Project Working Paper 4: Rural water Supply and Productive Uses: A Rapid Survey in the Sand River Catchment." *Water, Households and Rural Livlihoods (WHIRL)*. November (2001): 1-21.

Mugwe, Jayne, Mick O'Neil, Samuel Gachanja, Jonathan Muriuki, Jack Mwangi. "Participatory Evaluation of Water Harvesting Techniques for Establishing Improved Mango Varieties in Small Holder Farms of Mbeere District, Kenya." *Sustaining the Global Farm*. (2001): 1152-1157.

Oweis, Theib. and Ahmed Hachum. "Water Harvesting and Supplemental Irrigation for Improved Water Productivity of Dry Farming Systems in West Asia And North Africa." *Agricultural Water Management*. 80 (2006): 57–73.

Pandey, Deep Narayan, Anil K. Gupta and David M. Anderson. "Review Article: Rainwater Harvesting As An Adaptation To Climate Change." *Current Science*, Vol. 85, No. 1, 10 July (2003): 46-59.

"Postnote: Access to Water in Developing Countries." Parliamentary Office of Science and Technology. Vol 178, (2002): 1-4. <http://www.parliament.uk/post/pn178.pdf>.

Prinz, D. "Water Harvesting: Past and Future." In: Pereira, L. S. (ed.), *Sustainability of Irrigated Agriculture*. Proceedings, NATO Advanced Research Workshop, Vimeiro, 21- 26.03. (1996), Balkema, Rotterdam, 135-144.

Prinz, D.& Singh A. K. Technological Potential for Improvements of Water Harvesting Study for the World Commission on Dams, Cape Town, South Africa. *Report: Dams and Development*. (2000).

Qadir, M., B.R. Sharma, A. Bruggeman, R. Choukr-Allah, F. Karajeh. "Non-Conventional Water Resources and Opportunities for Water Augmentation to Achieve Food Security in Water Scarce Countries." *Agricultural Water Management*. 87 (2007): 2–22.

Sekar, I. and T.O. Randhir. "Spatial Assessment of Conjunctive Water

Harvesting Potential in Watershed Systems.” *Journal of Hydrology*. (2006): Article in Press.  
Surana, N.K. and Urvi Mankad. “Rain Water Harvesting INDORE Municipal Corporation/INDIA.” *City Managers’ Association Madhya Pradesh*. (~2003): 1-4.

Tabor, Joseph A. “Improving Crop yields in the Sahel by Means of Water Harvesting.” *Journal of Arid Environments*. 30 (1995): 83-106.

Yuan, Tian, Li Fengmin and Liu Puhai. “Economic Analysis of Rainwater Harvesting and Irrigation Methods, with an Example from China.” *Agricultural Water Management*. 60 (2003): 217–226.

### **Websites**

BBC News. “Africa’s Famine: Country by Country.” 11 November 2002.  
<http://news.bbc.co.uk/1/hi/world/africa/2027079.stm>.

Critchley, Will and Klaus Siegert. “A Manual for the Design and Construction of Water Harvesting Schemes for Plant Production.” 17/1991. *FAO Corporate Document Repository*.  
<http://www.fao.org/docrep/U3160E/u3160e00.htm#Contents>.

Gnadlinger, Johann. March 16 - 22, 2000. “Rainwater Harvesting in Rural Areas.” *2nd World Water Forum*. <http://www.irpaa.org.br/colheita/index.htm>.

Greater Horn of Africa Rainwater Partnership (GHARP). 1999-2005. Greater Horn of Africa Rainwater Partnership (GHARP). <http://www.gharainwater.org/>.

HarvestH2O.com – The Online Water Harvesting Community. 2004. HarvestH2O.com.  
<http://www.harvesth2o.com/>.

Krishiworld. “Water Resources.” Krishiworld: The Pulse of Indian Agriculture. 2006.  
[http://www.krishiworld.com/html/water\\_resources1.html](http://www.krishiworld.com/html/water_resources1.html)

Palmback, John. Traditional Water Harvesting. Spring 2004. *University of Wisconsin – Eau Claire, USA*. <http://academic.evergreen.edu/g/grossmaz/PALMBAJP/>.

PumpAid. January 22<sup>nd</sup> 2007. PumpAid. <http://www.pumpaaid.org/>.

Rainwater Harvesting. 2001 – 2002. TWAD (Tamilnadu Water Supply and Drainage) Board.  
[http://www.aboutrainwaterharvesting.com/rwh\\_history\\_storage\\_twhc.htm](http://www.aboutrainwaterharvesting.com/rwh_history_storage_twhc.htm).

Rainwater Harvesting. 2006. Centre for Science and Environment.  
<http://www.rainwaterharvesting.org/methods/methods.htm>.

Rainwater Harvesting. September 05<sup>th</sup> 2006. Directorate of Town Panchayats.  
<http://www.tn.gov.in/dtp/rainwater.htm>.

South and Eastern Africa Rainwater Network (SEARNet). 2006. South and Eastern Africa Rainwater Network (SEARNet). <http://www.searnet.org/home.asp>.

Water Conservation. 2006. *EduGreen*.  
<http://edugreen.teri.res.in/EXPLORE/water/conser.htm>.