# WATER HARVESTING IN SUDAN

## Introduction

In semi arid zones such as North Darfur where the rainfall is concentrated over short periods of time, balancing water demand with supply is difficult. The regularity of rainfall and quantity of rainfall in North Darfur has been decreasing; for example the mean rainfall in Kutum has dropped from 345mm to 243mm between 1967 and 1982. The increase in desertification of agricultural land through changing climatic conditions and exploitation of the natural resources is forcing farmers and agro-pastoralists to adapt to their changing surroundings. This has lead to the spread of water harvesting techniques particularly those aimed at catching water in times of flood.

The degradation of farmland has hit the poor first, the rich have monopolized the fertile growing areas known as Wadis in Northern Darfur which are areas of land with subsurface water and therefore more capable of producing crops. Farmers in Darfur have worked to overcome the problem of irrigation, whilst avoiding the high costs of many modern irrigation techniques, through the rehabilitation and expansion of traditional water harvesting techniques in the area.

## Water harvesting techniques

Rain water harvesting techniques have been developed for various types of water collection from domestic rain water harvesting schemes through the micro to the macro flood control levels. The harvesting schemes shown below discuss two methods of water harvesting, the first looks at floodwater harvesting through the building of dams, these as discussed vary in design. The second method is the collection and slowing of water through contour systems.

It is important when choosing a water harvesting technique to consider not only the physical aspects of the project but the socio and economic requirements of the community it is to serve. These may include the initial costs, the quality of the water, operation and maintenance requirements of the technique. Lower risk and cheaper alternatives such as springs or shallow wells should be given consideration before large-scale projects are taken on.

## Technical criteria for water harvesting

The basic principle of water harvesting is shown in a very simple diagram.

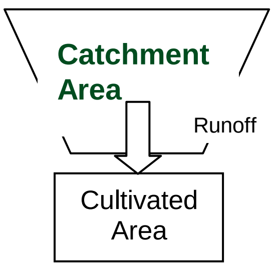


Figure 1: Basic principle of water harvesting

**The catchment area**
The catchment area is kept smooth and vegetation free as vegetation slows the water allowing further filtration. However constant vegetation cover is used in soil conservation to prevent soil erosion from impact of the rain.

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### Slope
Water harvesting is not recommended on slops of over 5%, as there is likely to be an uneven distribution run off and the requirement of large earthworks, which is often uneconomical.

### Soils
The soil should have the ability to be fertile, i.e. they should be deep, not saline or sodic. Sandy soils are limiting to water harvesting as their infiltration rate is high and thus water run off does not occur.

### Costs
Earth/stonework movement directly affects cost and labour intensity of the scheme.

In the next section four major water harvesting techniques for large and flood scale water harvesting are outlined.

## Floodwater Harvesting

### Check Dams
The check dam is usually located where there is a stream in a narrow valley; the velocity of the water during a rainy season will often lead to soil erosion. The dam acts to slow the water, allowing percolation and the recharging of aquifers. Over time the dam will gather fertile silt carried down the valley, which enhances the soils fertility.

Check dams vary in complexity; the simplest are the build up of stones in lines across the rivers path. When the rainfall is less regular or more destructive, it is often necessary to introduce schemes to allow the control of the amount of water behind dam such as sluice gates, spill ways and channels. This also allows a more controlled spread of the water.

### Permeable Rock Check Dams
These check dams primarily act as a spreader of water across the valley slowing water rather than containing it. The dam is built across a gully or riverbed.

### Sizes
The dam may range in length considerably, from 50m to 1000m at extremes. The larger and longer the dams the more costly the operation so it is beneficial to estimate the required size previous to construction. The expected catchment can be used to determine the height of the dam within the gully; the dam height may also vary depending on whether there are a number of dams in series. In this case, starting from the highest dam the lower dam should come to the height of the base of the previous dam.  It is often beneficial to locate a dam where there are high sides so as not to risk huge areas of flooding behind the dam and the creation of large shallow pools. Where back flooding does take place it is often necessary to build embankments to protect the village etc.

It is important to have sized the system as a whole and compared it to the expected the rainfall characteristics of the area. This ensures that the project is not undersized and unable to cope with the predicted amount of water, which may damage the structure. Also due to the nature of the projects they are often low technology and on low budgets, it therefore important not to have oversized the project for the predicted rainfall characteristics as making a dam and embankment system stronger requires a larger capital which often not feasible for the community.

### Layout
Dams are often used in series with each other down a valley providing stability throughout. Where dams are on a prominent slope the dam edges are swept back to follow the contours, on flatter slopes the dam may become straighter acting a spreader on to the flood plain. Dam designs may also include spillways, sluice gates, channels and embankments to allow control of the water at times of flood. The use of channels allows the water to be directed to certain

areas of land. Consideration of how floodwater may affect any local housing must be taken; embankments are often used where back flooding from a dam may affect housing.

**Stages to construction**

Stage 1: Site identification, characteristic analysis, design choice; depending on the characteristics of the rainfall the design will vary, if rainfall is very low and irregular then the dam may be required to store more water than act just as a spreader. The larger amount of water held back may require more control mechanisms such as spillways, sluice gates and canals. A control mechanism such as a spill way or a sluice gate allows excess water during excessive rainfall to be released, preventing damage to the dam, through the release of water at certain times the silt build up on the up stream side of the dam is released preventing any blockages. The characteristics of the gully will also affect design as a rule of thumb where a gully is greater than 1m in depth then a spillway may be added as a control measure.
Stage 2: Permanent construction: The spillway needs to be designed using stones, which cannot be moved during a flood, gabions (stones sealed in cages) are most appropriate for this. A sluice gate will also require a permanent construction, which needs to be built first within the gully. The control mechanism is often wooden planks/ logs, which are removable.
Stage 3: Alignment of the bund with contours; this is why the shape of the dams are swept back until the bund becomes parallel with the watercourse. The contours can be measured using a water tube or line level.
Stage 4: A trench is then dug along the line of the bund so as to lower the bund below the surface, this adds stability and also prevents percolated water undermining the structure. This trench can also be lined with gravel this is appropriate where the soil is particularly susceptible to erosion.
Stage 5: Bund construction: The core of the dam is built using smaller stones packed together, the more packed these stones are then the less permeable the dam. The core is then sandwiched with larger facing stones, which provide protection from erosion and stability. The dam is not symmetrical in cross section, the slope of the upstream side is far less than that of the downstream, the lower slope adds stability but increases cost. Construction in layers, as in wall building, provides a more stable structure as the rocks are interlinked laterally.
Stage 6: Dam series: if a series of dams are to be constructed it is advisable to start with the dam at the upper most end of the valley. This will allow the distance between the dams to be set. It is rule of thumb that the height of the lower dam should be at the base level of the upper dam.

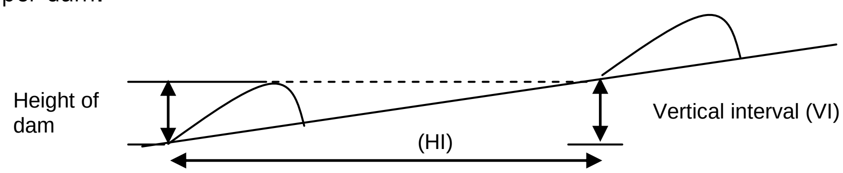


Figure 2: Shows the ideal distance between dams.

Horizontal interval = (VI x 100)/%slope)

## Hafirs

The 'hafir' is the local name in Sudan for water reservoir. The hafir is a hollow dug in the ground designed to store water runoff after a rainy season, the hafir is usually used in semi arid regions where rainfall is annual but over short periods and storage is required for the rest of the year. The hafir can be natural or man made, water storage is not a new concept, however the technology of today can improve the efficiency of the traditional water storing methods. The water is used by all the community, farmers, nomads, livestock and for domestic drinking water.

### Requirements

- Situated in clay soils so filtration is reduced allowing maximum storage and less labour requirements to provide an impermeable base.
- Near an annual water source, allowing the hafir to be refilled, as well as filling from surface runoff and it's own catchment.
- Basic filtration system, to prevent the deposition of silt in the hafir.

### Layout

The hafir is often a considerable distance from the area that it is supplying. This is because of the requirement for a clay soil type and a near by annual water source, a hafir is normally found in areas where no underground occurs, this formation is known as a "basement complex", because of this many towns in Sudan are reliant on the water that hafirs can store. Water from the source is diverted to the hafir through a dug canal.

The hafir can vary in size and shape an average volume would be 30000m³, the hafir is often conical in shape with an average depth of approximately 3.5m.

Picture 1: The Azagarfa hafir in Darfur, Sudan ©Practical Action

### Construction

The hafir can be natural or man made, depending on the technology available in the area the hafir may be dug by hand or machinery. The hafir is connected to the water source by a canal, during periods of rain when the water in the river or source is available the content of the water which will enter the hafir will contain a large amount of solids, as the water settles it will then want to sink and sediment. If this is allowed to occur within the hafir it will quickly be subsumed in silt. To prevent this occurring within the hafir a silt trap is built before the inlet pipe. This is a deep trough in to which the water pours and settles, the clear water is then tapped off the top leaving the silt at the base. The trough can then be separated from the rest of the water when the silt has built up substantially. During times of high flood the quantity of water does not allow a settling period long enough for the clay particles to sediment, the water trying to enter the hafir is therefore very turbid. To prevent this occurring the inlet pipe is closed when the flow is a maximum. This stops the water entering the hafir. Once the flow rate has dropped and the turbidity improves the water can then be allowed back in to the hafir, hopefully with fewer suspended solids.

The water within the hafir is often used to supply a whole community with water, from agriculture, livestock to domestic washing and drinking. Contamination is therefore a major consideration. To prevent livestock and washing contaminating drinking water an outlet can be made to another storage tank/ well, where water can be extracted using a bucket and chain mechanism to water cattle etc. The main body of water is often fenced off to prevent any further contamination from people or animals.

### Operation
Water can be saved in the hafir for about 3-5 months after the end of the rainy season. A number of factors affect the storage period the most important of which is the soil type and its infiltration rate. If it has a high infiltration rate then water cannot be stored for a long period. The second is the consumption rate of the community; livestock require large amounts of water, the passing through of nomadic agro-pastoralists can reduce water supplies substantially.

To reduce filtration rates more expensive materials can be used such as polythene lining. This may be particularly beneficial if there is not enough water supply till the following rainy season, but will obviously depend on the finance available.

## Contour schemes
Contour schemes are used to slow the movement of water runoff; this enables the water to be used for a longer period of time. It also reduces the soil erosion, which takes place when water runs quickly over bare earth.

### Negarim micro catchments
These catchments are used for the growing of trees and bushes. The land is split into diamonds using small earth bunds; the diamond is contoured in such away that in the lowest corner there is an infiltration pit dug. Runoff from the small catchment area is then collected and stored in the pit. By segmenting a larger area of land into smaller catchment areas the collection of water can be used more efficiently and prevents the large movement of soil through erosion.

### Size
- The catchment areas can range from $10m^2$- $100m^2$
- Depending of tree or bush to be grown.

To calculate the size and ratio of the catchment area needed, several figures must be worked out or estimated for the surrounding topography.

1) Runoff Ratio (R), this is the ratio of the amount of rainfall expected to reach the Cultivated area to the total amount of rain fallen / $m^2$
2) Efficiency factor, the part of the water harvested which the crop can use. It can only be estimated through experience. It is normally taken as between 0.5 –0.75.
3) Crop Water requirements/$m^2$ Many tables can be found foe the water requirements of various crops.
4) Design rainfall, the quantity of rainfall expected through the crops season. This figure can be difficult to get right as the variability in rainfall be as much as 100mm – 200mm.

The size of catchment area required to cultivation area is found by equating the amount of water available from the Catchment area to the amount of water needed by the cultivated area.

Catchment area: The rainfall, which could be expected to runoff the catchment area to the cultivation area, must be calculated. It is important to remember that figures must be taken for the growing season of the crop or plant, which is to be planted.

Runoff ratio x Area x Expected rainfall x Efficiency = Possible runoff to cultivated area

Cultivation area: the water needed for this area depending on the plant.

[Crop water requirements – Design rainfall] x Cultivated area = Water needed for cultivation

The ratio of catchment area to cultivated is there for given as:

$$\frac{\text{Catchment area}}{\text{Cultivation area}} = \frac{\text{(Crop water requirements- Design rainfall)}}{\text{R X Design Rainfall x Efficiency factor}}$$

**Configuration**
The field layout is shown in figure 3. The infiltration pit is the area of cultivation where the trees or bushes are planted.

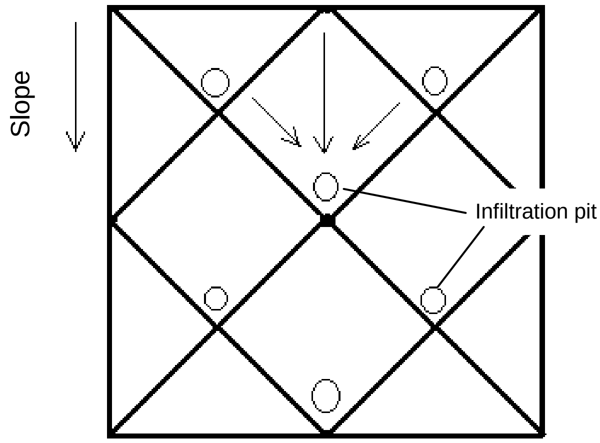


Figure 3: Nigarim microcatchment

The earth banks used are called bunds these range in size depending on the slope and size of the micro catchment area. An approximate size would be in the range of 0.25m in height and 0.75m in width. Designed with a trapezoidal cross section for stability and reduction in materials needed.

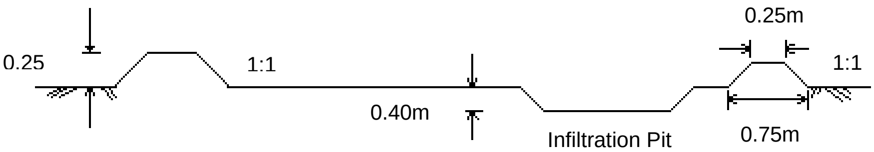


Figure 4: Cross section of catchment area.

Table 1: Critchley, Water Harvesting: A Manual for the design and construction…1991

| Size of catchment m² | Slope 2% | 3% | 4% | 5% |
|---|---|---|---|---|
| 3x3 | | | | |
| 4x4 | | | | 30 |
| 5x5 | | | 30 | 35 |
| 6x6 | | | 35 | 45 |
| 8x8 | | 35 | 45 | 55 |
| 10x12 | 30 | 45 | 55 | |
| 12x12 | 35 | 50 | | |
| 15x15 | 45 | | | |

Alternatives to the Nigarim design

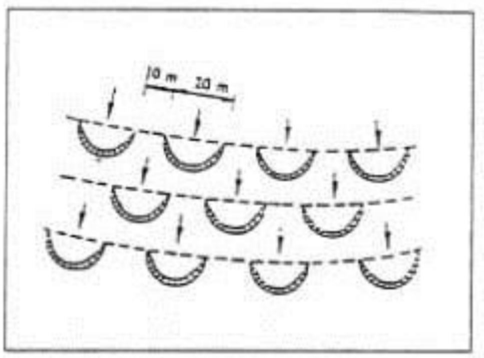

Figure 5: RWH with semi-circular bunds:

**Construction**

Stage 1 Identifying the contours of the land.

- Using a line level it is important to identify how the contours move across the land, some clearing and levelling may be required to avoid small land irregularities. The level line is made of two pole connected by string. On the string in the centre is hung level. The two poles are placed a part with the string taught when it is level then this is the contour.

Stage 2 Marking the Bund tips

- Moving a long the contour it is possible to mark out the size of the bunds.

Stage 3

- To ensure the catchment areas are the same size use two lengths of string pinned at one end along the first contour the correct distance apart and then taken down slope to meet. They can then be pinned and used as lines for the bunds.
- Figure 7 shows how the bunds are then laid out using the contour as a reference.

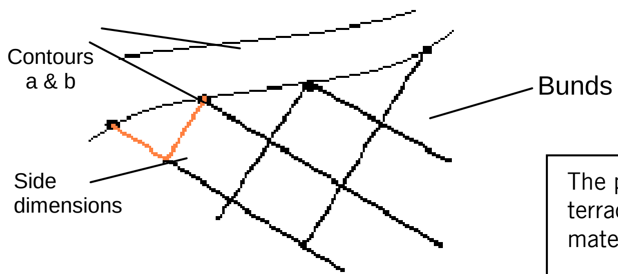


Figure 6: Laying out the bunds using contours

The picture (left) shows terracing in Northern Darfur, terracing can use several methods depending on the material around.

This method uses earthen banks and ditches following the contours of the land, which catch and slow water runoff down the slope allowing percolation. In other areas a ditch may be dug and then filled with stones until a stone bank is formed this then provides a subsurface control of water infiltration.

Terracing is particularly applicable in areas where the slope is short but steep.
The distance between terraces (or the banks) can be as small as 10m up to 30m depending on the steepness of the slope. The height of the terrace banks will depend on the amount of water expected on the terrace, if the terrace bank is not high enough there will be over spill this will mean the lower terrace must catch more water, this will often cause the bank to break down creating a channel through for water to move.

## Terracing & contour trenches

Sudan ©Practical Action.

The terrace and contour ridge have been adapted worldwide depending on the surrounding environment different characteristics are added or altered. The stone embankments are used where rainfall is relatively high (200- 750mm) and water does not need to be stored in ponds as the rocks do not form an impermeable boundary, the water is only slowed to allow infiltration. If storage is needed earth may be added to form an impermeable barrier.

Where rainfall is known to be destructive it is often safer to provide overflow systems integrated into the earth terraces. This combines earth bunds with stone spillways in the terrace. These spillways protect the earth bunds from excess water damaging them. The off setting of the spillways stops large channels being dug out of the slope and thus still slow the water and prevent soil erosion as the water must zig-zag down the slope.

## References and further reading


- *Runoff Rainwater Harvesting* Practical Action Technical Brief
- *The Sri Lankan 'Pumpkin' Tank ~ Case Study* Practical Action Technical Brief
- *The Underground Brick Dome Water Tank ~ Case Study* Practical Action Technical Brief
- *Cement Mortar Jar ~ Case Study* Practical Action Technical Brief
- *Rainwater Catchment Systems for Domestic Supply,* by John Gould and Erik Nissen-Petersen, Practical Action Publishing 1999.
- *Ferrocement Water tanks and their Construction,* S. B. Watt. Practical Action Publishing 1978
- *Rainwater Harvesting: The Collection of Rainfall and Runoff in Rural Areas,* Arnold Pacey and Adrian Cullis Practical Action Publishing 1986
- *Water Harvesting – A Guide for Planners and Project Managers*, Lee, Michael D. and Visscher, Jan Teun, IRC International Water and Sanitation Centre, 1992
- *Water Harvesting in five African Countries*, Lee, Michael D. and Visscher, Jan Teun, IRC / UNICEF, 1990. As snapshot of the status of RWH in five African countries.
- Waterlines Journal Vol. 18, No 3, January 2000 and Vol. 14, No.2, October 1995 Both issues are dedicated to rainwater harvesting, available through Practical Action Publishing
- Photo-manuals by Eric Nissen-Petersen. A range of manuals on how to build a number of tank types including: cylindrical water tanks with dome, an underground tank, smaller

water tanks and jars, installation gutters and splash-guards, available from the author at: P.O. Box 38, Kibwezi, Kenya.
- Rainwater Catchment Systems – Reflections and Prospects, John Gould, Waterlines Vol.18 No. 3, January 2000.
- Domestic Water Supply Using Rainwater Harvesting, by T.H.Thomas, Director of the Development Technology Unit (DTU), University of Warwick. The article is available on DTU's Website
- Waterlines back issues containing rainwater harvesting articles: Vols 17(3), 16(4), 15(3), 14(2), 11(4), 8(3), 7(4), 5(4), 5(3), 4(4), 4(3), 3(3), 3(2), 3(1), 2(4), 2(1), 1(1).

## Video
- *Mvua ni Maji – Rain is Water, Rainwater Harvesting* by Women's Groups in Kenya, FAKT, 1996. 27 min VHS/PAL. A Kenyan film team documented this success story on the occasion of the visit of a delegation of Ugandan women who came to learn the skills of rainwater harvesting from their Kenyan sisters. Available through FAKT
- *A Gift from the Sky – An Overview of Roofwater Harvesting in Sri Lanka*. Available from the Lanka Rainwater Harvesting Forum
- *Construction of Water Tanks for Rainwater Harvesting* – a video manual prepared by Eric Nissen-Petersen (see above).
- *Rock Catchments*. Several designs of rock catchment system looked at in detail by Erik Niseen-Petersen.

## Useful contacts

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http://www2.warwick.ac.uk/fac/sci/eng/research/civil/crg/dtu/
- a number of case studies from around the world, with good descriptions.
Contact Dr Terry Thomas. Also the co-ordinators of the Rainwater Harvesting Research Group (RHRG) http://www2.warwick.ac.uk/fac/sci/eng/research/civil/crg/dtu/rwh/links/

**International Rainwater Catchment Systems Association (IRCSA)**
Dept. of Natural Resources, Chinese Cultural University, Hwa Kang, Yang Min Shan, Taipei, Taiwan.
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Website: http://www.ircsa.org/
IRCSA Fact sheets http://www.ircsa.org/factsheets.htm

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**United Kingdom Rainwater Harvesting Association**
Website: http://www.ukrha.co.uk

**The Pelican Tank Rainwater Collection System** - a packaged RWH collection system developed in Australia for use in developing countries
http://www.trade.altconcepts.net/

**SimTanka**
http://simtanka.sourceforge.net/
software for sizing reliable rainwater harvesting systems with covered storage tanks – SimTanka, is freely available.

**JRCSA (Japan Rainwater Catchment Association)**
http://takeyam.life.shimane-u.ac.jp/jircsa/homepage.html

**SA WATER (South Australian Water Corporation)**
http://www.sawater.com.au/sawater/

**Centre for Science and the Environment (CSE)**
http://oneworld.org/cse/html/cmp/cmp43.htm -
Rainwater harvesting page - a very active Indian Group

**Sunstove**
http://www.sungravity.com/
The Sunstove Organization's web site provides free instructions, photos, drawings and specifications to build a roof catchment system, sand filter, cement water tank, and spring capping systems

**Global Applied Research Network (GARNET)**
http://info.lut.ac.uk/departments/cv/wedc/garnet/tncrain.html
Site of the Global Applied Research Network (GARNET) Rainwater Harvesting Page –

http://www.unep.org/publications/ - link to a recent UNEP publication titled 'Sourcebook of Alternative Technologies for Freshwater Augumentation in Small Island Developing States' that includes some useful information on RWH

http://www.unep.or.jp/ietc/Publications/TechPublications/TechPub-8e/index.html
Sourcebook of Alternative Technologies for Freshwater Augumentation in Some Countries in Asia - another in this series of **UNEP publications**

**World Meteorological Organisation (WMO)**
http://www.wmo.ch/

Rainwater Harvesting in the Loess Plateau of Gansu, China - a paper presented at the 9th **IRCSA** Conference in Brazil http://www.greenbuilder.com/sourcebook/Rainwater.html#CSI - Sustainable Building Sourcebook Website

## Information Centres

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E-mail: geoferro@ait.ac.th
Website: http://www.ait.ac.th/

**Center for Library and Information Resources (CLAIR)**

**International Ferrocement Information Center (IFIC)**

**WELL**
http://www.lboro.ac.uk/well/resources/technical-briefs/36-ferrocement-water-tanks.pdf
A technical brief on how to make a ferrocement water tank

Roofwater harvesting discussion forum
http://www.jiscmail.ac.uk/lists/rwh.html

**Internet**
http://www.rainwaterharvesting.org/Rural/Contemporary_more.htm:
Flood water harvesting designs.

http://www.unep.or.jp/ietc/Publications/TechPublications/TechPub-8f/B/Runoff2.asp:
Sourcebook of Alternative Technologies for Freshwater Augmentation
in West Asia, information on Hafirs

http://www.fao.org/ag/agl/aglw/wharv/wh02/sld014.htm:
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