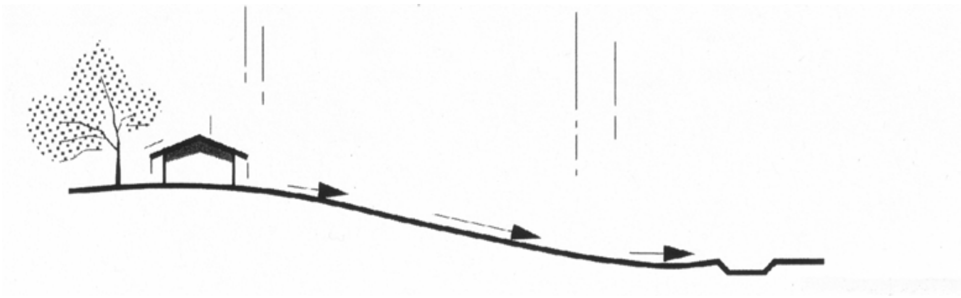
Rainwater Harvesting

Franziska Meinzinger

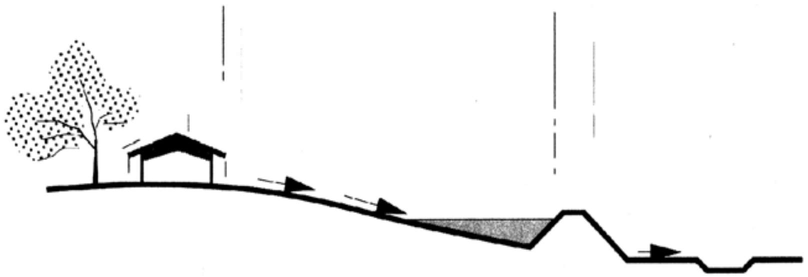
Rainwater Management Options

Conveyance

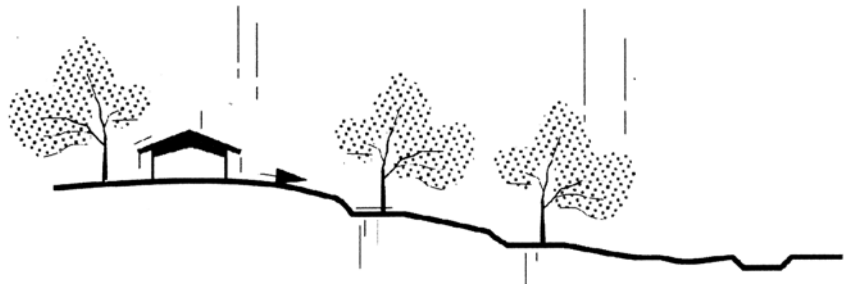


Infiltration

Detention



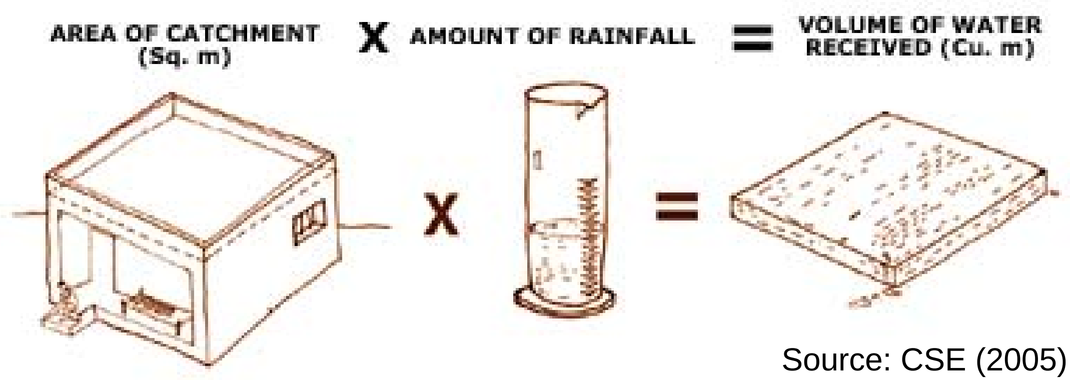
Rainwater Harvesting



Source: Ferguson, 1998

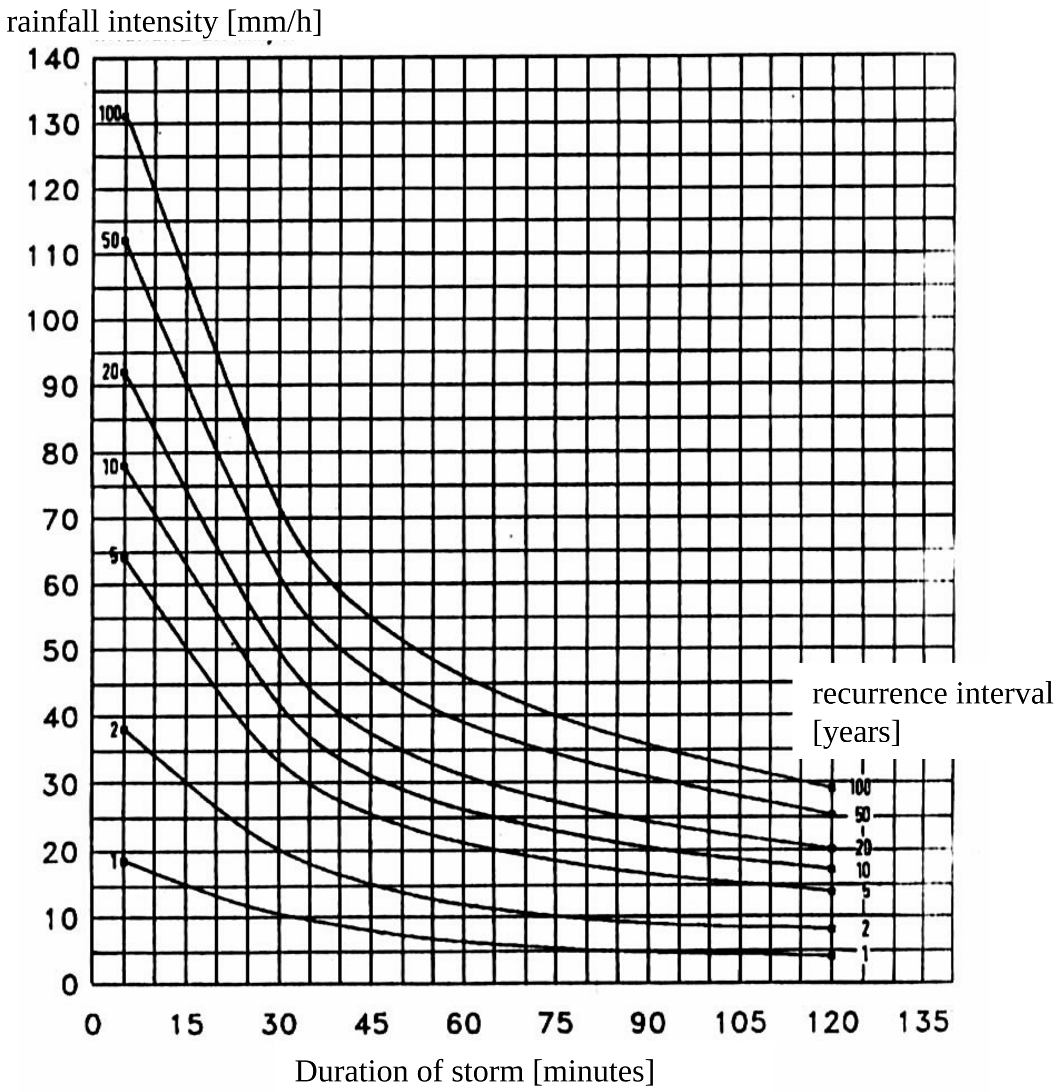
Overview

- Runoff calculation
- Rainwater Infiltration
- Rainwater Harvesting



Source: CSE (2005)

Data Needs - The Design Storm



Example of an intensity-duration-frequency curve

Rainfall event characterised by rainfall intensity & duration
-> total volume of rainwater

Recurrence interval for design storm is chosen balancing risks and costs

Data Needs - The Design Flow

The total runoff volume is calculated based on:

- design storm
- size of the catchment area
- runoff coefficient: e.g.

Type of surface or land use	Runoff coefficient C
Forest	0.1 - 0.3
Turf or meadow	0.1 - 0.4
Cultivated field	0.2 - 0.4
Bare earth	0.2 - 0.9
Pavement, concrete or asphalt	0.8 - 0.9
Flat residential, about 30% impervious	0.4
Flat residential, about 60% impervious	0.55
Sloping residential, about 50% impervious	0.65
Sloping, built-up, about 70% impervious	0.8
Flat commercial, about 90% impervious	0.8

Runoff coefficients (Source: Ferguson & Debo, 1990)

For flat slopes or permeable soils use the lower values, for steep slopes or impermeable soils use the higher values.

Data Needs - The Design Flow

Runoff can be calculated using following formula:

$Q_T = C * I_T * A$

with:

Q_T: runoff rate for a T-year storm, in liters/second
C: runoff coefficient, nondimensional
I_T: rainfall intensity for a T-year storm at a storm duration t, in liters/(second*hectare)
A: area of the catchment area, in hectares

The cumulative volume of rainwater over the storm duration can be calculated by multiplying the average runoff rate Q by the design storm duration t:

$$V_T = 3600 * Q_T * t$$

with:

V_T: total runoff volume at time t for a T-year storm, in liters
t: storm duration in hours

Rainwater Infiltration

Some advantages of local infiltration:

- recharge of groundwater
- preservation and/or enhancement of natural vegetation
- reduction of pollution transported to the receiving waters
- reduction of downstream flow peaks
- reduction of basement flooding in combined sewer systems
- reduction in the settlement of the surface in areas of groundwater depletion
- smaller storm sewers at a lesser cost

Rainwater Infiltration

Possible drawbacks of local infiltration:

- soils seal with time
- pollutants may be transferred to soil and groundwater
- some infiltration facilities may not receive proper maintenance
- groundwater level may rise and cause basement flooding or damage to building foundations

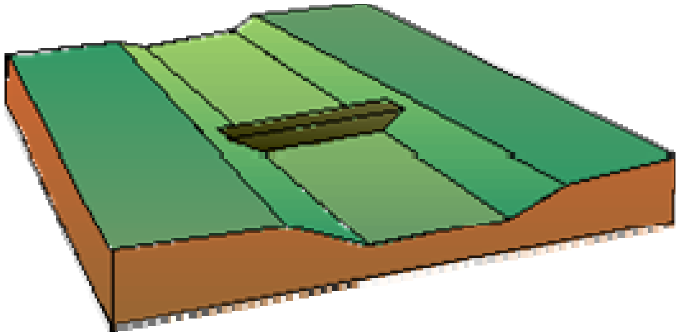
Source: Urbonas & Stahre (1993)

Preconditions for Rainwater Infiltration

- **Vegetative cover**: Rainwater can be absorbed by plant roots and can be returned to the atmosphere through plant respiration. The soil-vegetation complex functions to a certain degree as a filter that reduces clogging of the surface pores of the soil.
- **Soil type and conditions**: Effective porosity and permeability are soil parameters that influence the infiltration process (see slide “infiltration capacity”). Bedrock should not be within less than 1.2 meters of the infiltration surface.
- **Groundwater conditions**: Distance to groundwater and variation in groundwater levels are some of the information needed for planning infiltration facilities. It is recommended that the distance to groundwater is at least 1 meter.

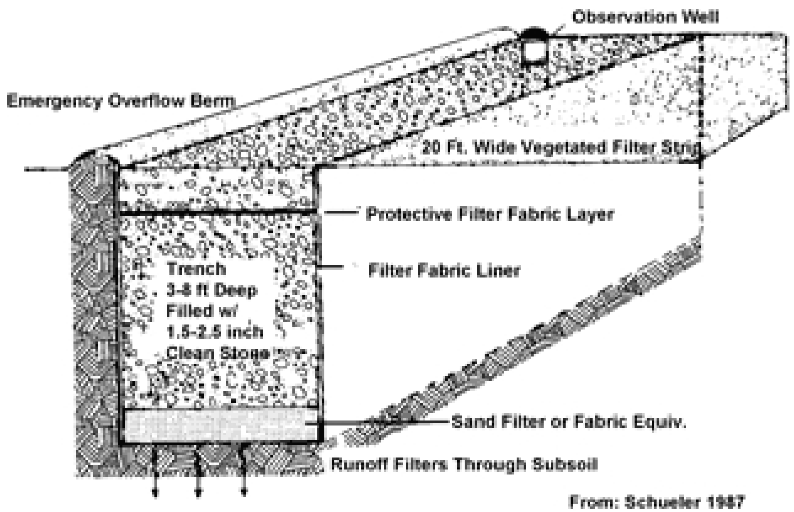
Types of Infiltration Systems - Vegetated Swales

Source: Beecham (2001)



Source: CASQA (2004)

Types of Infiltration Systems - Infiltration Trench



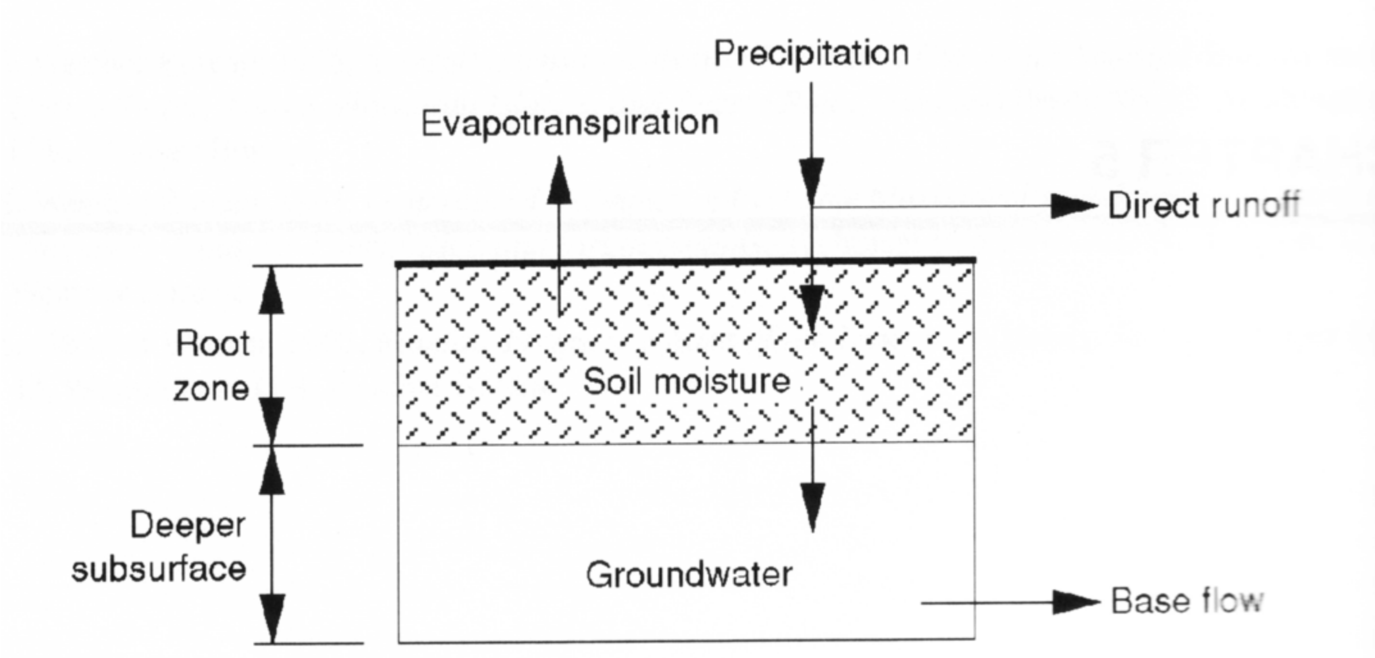
Source: Tanski (2000)

Source: CASQA (2004)

Source: Universität Trier (2004)

Design of Infiltration Systems

Water Balance: Storage = Inflow - Outflow



Source: Ferguson, 1998

Infiltration Capacity

Soil Type	Hydraulic conductivity k [m/s]
Gravel	10^{-3} - 10^{-1}
Sand	10^{-5} - 10^{-2}
Silt	10^{-9} - 10^{-5}
Clay (saturated)	$<10^{-9}$

Source: Urbonas & Stahre, (1993)

Darcy's Law: $U = k * I$

with:

U: flow velocity in meters per second

k: hydraulic conductivity in meters per second

I: hydraulic gradient in meters per meter (≅ 1m/m)

Required Storage Volume

e.g. for swales, infiltration ditches etc.:

$$V_{req} = \left(\sum Q_{in} - \sum Q_{out}\right) \cdot t$$

$$V_{req} = \left[\left(A_{red} + A_S\right) \cdot 10^{-7} \cdot I_T - A_S \cdot 0.5 \cdot k\right] \cdot t \cdot 60 \cdot f_Z$$

V_{req}: required storage volume [m^3]

A_S: percolation surface area, can be assumed to vary between 0.05 * A_{red} and 0.2 * A_{red} [m^2]

A_{red}: reduced catchment area (A_{red} = A * C) [m^2]

k: hydraulic conductivity in saturated zone [m/s]

I_T: rainfall intensity for a T-year storm at a storm duration t [l/(s*ha)]

t: duration of the rainfall event [min]

f_Z: safety factor (e.g. 1.2)

Rainwater Harvesting

Comprises many techniques that are used to supply rainwater collected from surfaces (roofs, ground surface, rock surface) for domestic or agricultural use.

Three main components:

- catchment area
- storage reservoir
- delivery system

Rainwater Harvesting

Benefits:

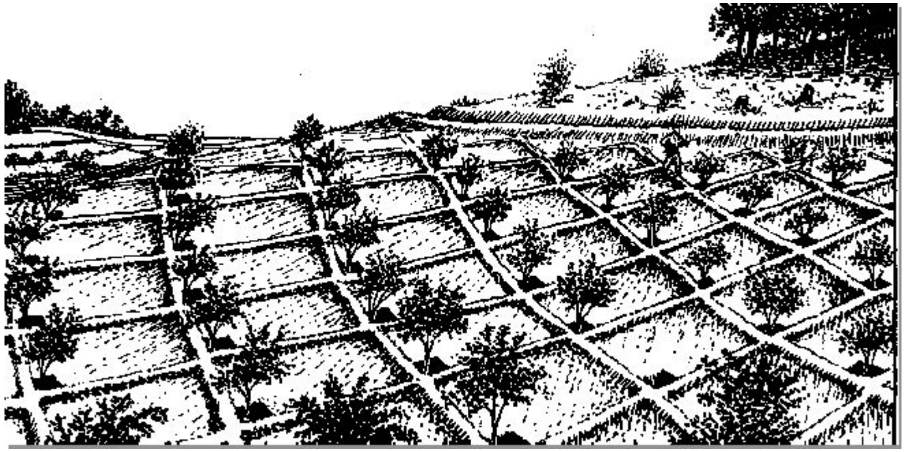
- Provision of inexpensive water, where there is inadequate groundwater supply or surface resources
- Recharge of groundwater
- Control of soil erosion and prevention of flooding

Limitations:

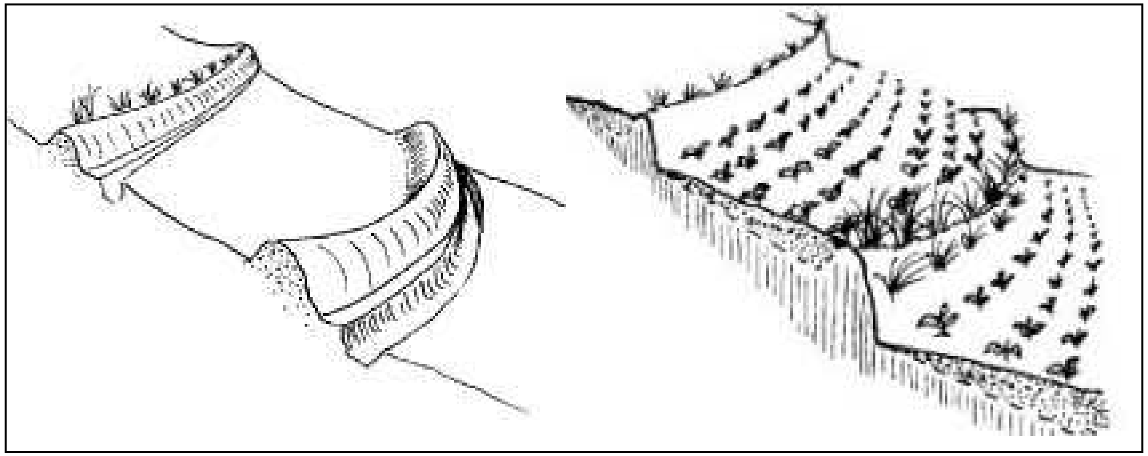
- Large storage tanks may be required
- Seasonal and interannual variations
- Possible pollution of rainwater

Examples of micro-catchment water harvesting

Source: FAO, 1999

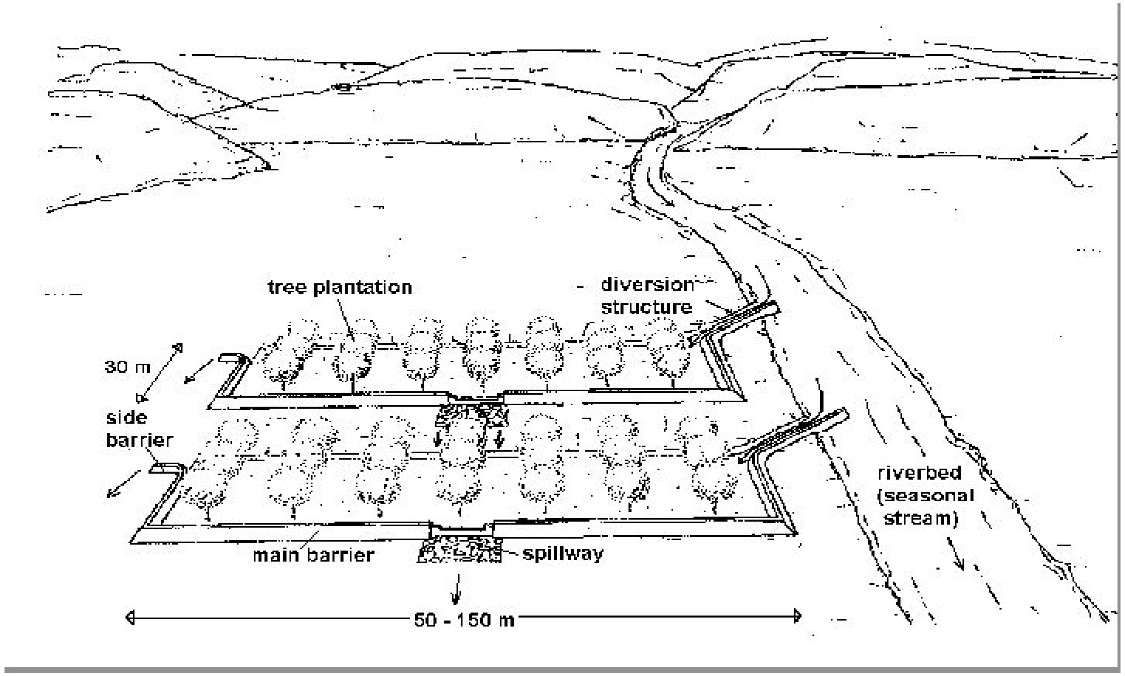


Source: FAO, 1999



Source: IIRR, 1998

Examples of macro-catchment water harvesting

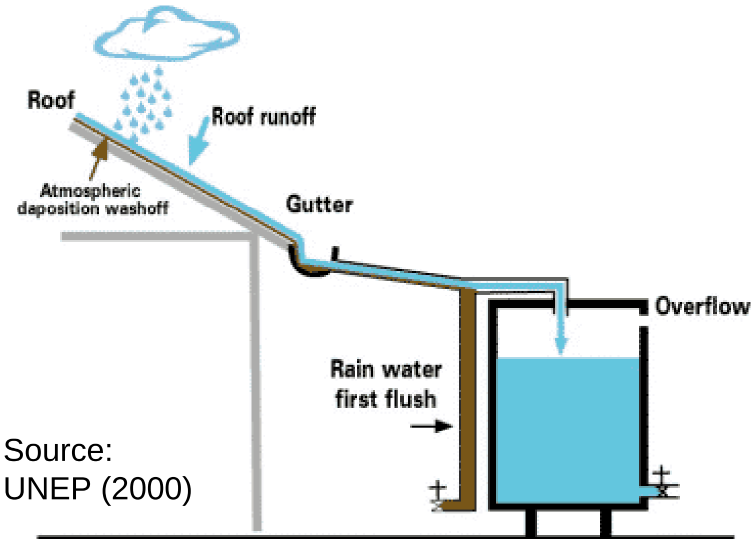


Source: FAO, 1999

Photo: Klemm

Photo: Meinzinger

Rainwater Storage Tanks



Source:
UNEP (2000)

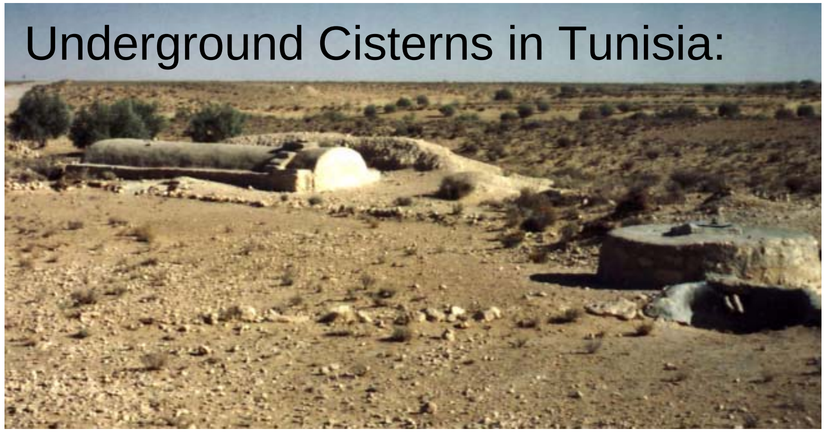
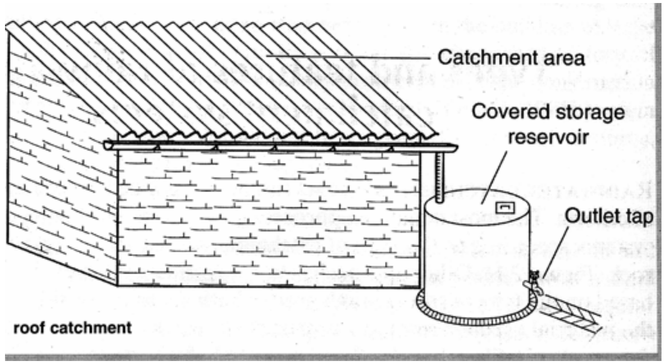


Photo: Meinzinger


Source:Opus One (2000)

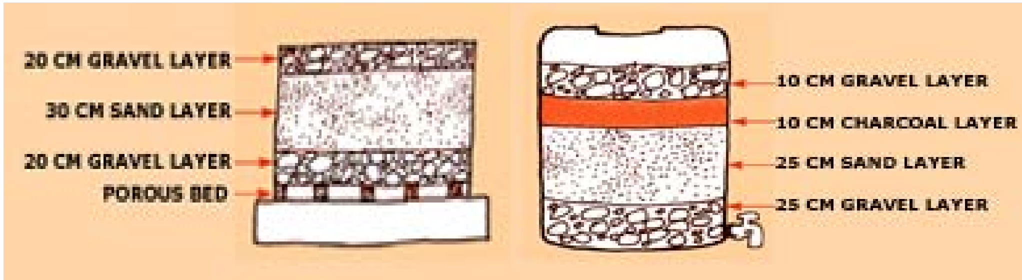

Source:NERD (2005)



Source: Gould & Nissen-Petersen, 1999

Storage Tanks

- Storage tanks should be watertight with a solid, secure cover, a screened inlet, an overflow pipe and a covered manhole
- Filters to remove suspended pollutants (examples):



sandfilter

charcoal filter

WISY Vortex Filter

WISY Floating Suction Filter

Source: CSE (2005)

Calculation of Storage Capacity

<u>Demand side approach:</u>
storage requirement $R = C * n * d$

with:	C:	Consumption per capita per day
	n:	number of people
	d:	longest average dry period

<u>Supply side approach:</u>
annual available water $W = A * C * R$

with:	A:	catchment/roof area
	C:	runoff coefficient
	R:	average annual rainfall

Demand $D = R$ as calculated above in the demand side approach

The storage requirement can be derived as maximum difference between the cumulative harvested water and the cumulative demand.

References

- Beecham, Simon (2001). *Stormwater Drainage*. http://services.eng.uts.edu.au/~simonb/Switch%20site/
- CASQA California Stormwater Association (2004) *Stormwater Best Management Handbook*. http://www.cabmphandbooks.com/
- CSE (2005) *Rainwater Harvesting*. Center for Science and Environment. www.rainwaterharvesting.org
- Ferguson, Bruce K. (1998). *Introduction to Stormwater: Concept, Purpose, Design*. John Wiley & Sons, USA.
- IIRR (1998) *Sustainable Agriculture Extension Manual*. http://www.iirr.org/
- Tanski, Jay (2000) *Stormwater Runoff Best Management Practices for Marinas*. http://www.seagrant.sunysb.edu/pages/BMPsForMarinas.htm
- UNEP (2000) *International Source Book On Environmentally Sound Technologies for Wastewater and Stormwater Management*. http://www.unep.or.jp/ietc/Publications/TechPublications/TechPub-15/main_index.asp
- Universität Trier (2004). *Muldenrigolensystem*. http://geo133.uni-trier.de/~regenwasser/dimensionierung/
- Urbonas, Ben & Stahre, Peter (1993). *Stormwater: best management practices and detention for water quality, drainage and CSO management*. PTR Prentice-Hall, Inc. USA.