Rainwater Harvesting

©Karlis D. Viceps
http://www.solarplans.com
(edited from <u>Solar and Holistic Residential Design</u> ©2001 Rev.©2007 by K. Viceps)

Rainwater harvesting is integral to sustainable site and home planning. Our buildings typically have a hard roofing surface that displaces the water from the land area it originally fell on and concentrates it at drainage points. The land area surrounding the home still receives the same amount of rainfall it always has. If this concentrated roof water runs off onto this land it can drastically change the prior natural pattern. By capturing and storing this rainwater we now have produced a source of water that can be distributed during dry periods through drip irrigation.

This captured water can also be used for all household needs. A harvesting and storage system for water can replace the need to consume water from wells, either private or municipal. Using only the water available from the land area now covered by a structure does constrain our use of this limited resource. Other design solutions must be considered to reduce the demand on this amount of rainwater. Low water use fixtures, composting toilets, and native landscaping are natural extensions of this design change. When one component or aspect of a design is reconsidered for sustainability it initiates other changes to improve the performance of the overall system. All of these steps serve to encourage sustainable living at home.

Water used in our homes disappears down the drain after its one use: taking a shower, doing the dishes, brushing our teeth, flushing the toilet. This approach is very wasteful and unsustainable. Consider water as a precious and limited resource similar to energy resources. One distinct difference is that **water** is not replaceable. When and if fossil fuels are depleted, there are other forms of energy to replace it. There is no substitute for water. After just several days, a human suffers dehydration and will soon die without water. Therefore preservation of quality and quantity of water is of the highest priority.

What each person does at home can be a substantial step in the right direction.

Many approaches to reduced water use have become commonplace. All flush toilets in the U.S. are required to use less than 1.6 gallons per flush. Low flow aerators at sinks and shower heads are available at every hardware store. These changes have made great strides in reducing water use compared with 20 years ago, but only in comparison to the very wasteful systems that were developed when water seemed limitless.

Additional tactics to reduce water use follow:

1. Showers with "Navy" shutoffs: The greatest amount of time in the shower is spent with soap or shampoo in hand. During these minutes the water does not need to run, so the "Navy" shutoff is a quick stop valve on the shower head to stop the flow of water once you have gotten wet to do the cleaning with soap and then to start the flow of water for rinsing. The savings of 2 gallons per minute while the water is off reflects an average savings of 6 to 10 gallons for every shower taken.
2. While waiting for hot water do not let the clean cold water just disappear down the drain. Keeping a clean bucket in the bathtub to fill whenever waiting for the hot water is simple. This water can be used for filling water bowls for animals and watering house plants.

3. When handwashing dishes, the use of two tubs partially filled with water, one for washing, one for rinsing will use far less water than running water during the whole process. Probable savings are in the range of 10 to 20 gallons. Also fill the rinse tub first with the cooler water while waiting for the hot water to reach the faucet.
4. Appliances: Advances in recent years have reduced the water consumed by clothes washers and dishwashers. Research horizontal axis clothes washers for both water and energy efficiency.
5. Toilets: A variety of options are available to deal with our human waste. This issue is large enough to be discussed separately below.

In North America we are used to wisking our human waste away as quickly as possible down the drain to the hidden underworld. This is done using lots of water to keep the porcelain bowl shiny and clean leaving fresh water in the bowl waiting to be fouled. It is difficult for many to imagine an alternative because this is extremely hygienic for the user. The pollution and depletion of a clean and important resource is hidden from the user of this system. Flush toilets are typically the largest water consumer in a home.

Dry toilets are a viable option. The most effective are aerobic composting toilets. These work on the same principle that a compost pile in the yard does for food scraps and other vegetable matter. Only a small amount of water may be necessary to assist the composting process.

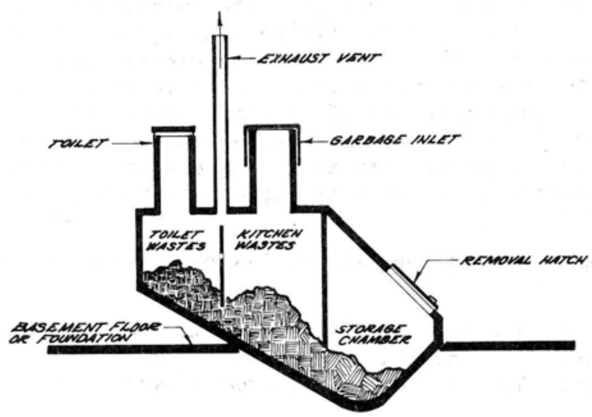

Fig.7.2 Compost toilet cross section view

DROPLETS OF GOLD FROM THE SKY

Every step taken to reduce water use extends the healthy life of an aquifer. Therefore solutions which further reduce the water removed from below ground will be valued.

Rainwater harvesting is a design element that can be one of these solutions. Many areas of the world already use roof areas for water harvesting, but this approach has almost always been ignored here in North America.

Rainwater harvesting benefits:

1. easy to collect, store, and pump water
2. easy to filter
3. soft water

Draining water off of roofs can be centralized via downspouts to storage containers. Water can then be used as needed from the containers (cisterns) either by gravity or with pumped disbursement.

It is easy to determine the amount of water you will capture from a roof area.

0.62 gallons per square foot of roof per 1 inch of rain

How do you determine there will be 0.62 gallons per sq.ft. per 1" of rainfall?

Density of water = 62.3 lbs. / cu.ft.

Weight of water = 8.35 lbs. / gallon

$$\frac{62.3\ \text{lbs.}}{\text{cu.ft.}} \times \frac{1\ \text{gallon}}{8.35\ \text{lbs}} = \frac{7.47\ \text{gallons}}{\text{cu.ft.}}$$

$$\frac{1\ \text{foot}}{12\ \text{inch}} \times \frac{7.47\ \text{gallons}}{\text{cu.ft.}} = \frac{0.62\ \text{gallons}}{\text{square ft. x inch}}$$

Example determination:

First: Determine how many inches of rain your site receives on average for a year.
A semi-arid climate region has 10" of rainfall a year.

Second: How many square feet of roof area do you plan on having to capture rainwater from?
This is the projected flat area, not the actual roof dimensions on a slope. The flat roof area often mirrors the floor plan "footprint" so that enclosed square footage will work to roughly estimate the roof area.
1000 square feet for this example.

Third: The problem is to determine the total amount captured in a year and how many gallons per day would be available.

$$\frac{0.62\ \text{gallons}}{\text{sq.ft. x inch}} \times \frac{10\ \text{inches}}{\text{year}} \times 1000\ \text{sq.ft.} = \frac{6200\ \text{gallons}}{\text{year}}$$

$$\frac{6200\ \text{gallons}}{\text{year}} \times \frac{1\ \text{year}}{365\ \text{days}} = \frac{17\ \text{gallons}}{\text{day}}$$

17 gallons per day does indicate that frugal use of water is very necessary, but this makes sense when living in an area that has little water. Many locations in North America have three times this amount of rainfall, resulting in 50 gallons per day available from 1000 square feet of catch area.

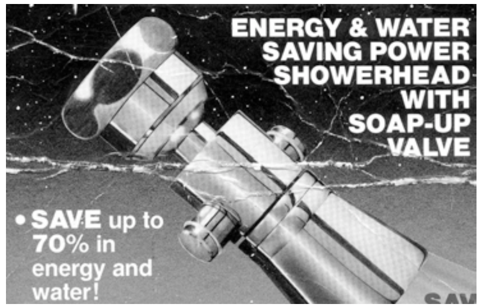

Fig. 7.3 "Navy" shutoff shower head

Is this feasible for all my household needs?

Daily shower using the low flow "Navy" shutoff type:

One minute to get thoroughly wet, shut off, soap, then one minute to rinse = 2 minutes
Low flow shower head rated at 2 gallons per minute = 4 gpd/person

Dishes washed twice a day, using two basins with one gallon water in each (one for soap, one for rinse).
Adequate estimate for one to four people. = 4 gpd

Cooking: one to two gallons	= 2 gpd
Drinking: one to two gallons	= 2 gpd
Composting toilet -no water used	= 0 gpd
TOTAL:	= 13 gpd
2nd person showering add 4 gallons per day	= 17gpd

Two people, with 1000 square feet of catchment in a semi-arid climate could probably manage their water use to sustain themselves. Some inconvenience may be felt with this small amount of water. An example is having to take your laundry to wash elsewhere.

In wetter climates a family of four may add two laundry loads a week at a distributed average of 10 gallons per day. This could be halved to 5 gallons/day average with a highly efficient washer.

A 1.6 gallon flush toilet x two flushes per day per person x 4 people adds 13 gpd.

This amount of use rapidly adds up to approximately 50 gpd, indicating a 1000 sq.ft. of collection may just meet the demand in a climate with average of 30” of rain a year.

Winter sun oriented roof designs can effectively melt snow in winter. Roof slopes oriented to the north will evaporate more of the water content in the snow.

Knowing the roof area and knowing the rainfall in your region you can determine the total gallons in a year. Larger storage reduces the number of times water is released to an overflow during a rainstorm. Also, if the weather pattern creates a dry spell it is good to have stored enough water to get by. Take the total gallons in a year and by dividing by four you can determine the amount of storage needed for 3 months worth of water.

rainfall	roof sq.ft.	gal./inch of rain/sq.ft.	=	gallons/year	/4	=	3 month storage
10"	1000	0.62		6200	/4		1550 Gallons
15"	1000	0.62		9300	/4		2325 Gallons
20"	1000	0.62		12400	/4		3100 Gallons
25"	1000	0.62		15500	/4		3875 Gallons
30"	1000	0.62		18600	/4		4650 Gallons

Double the roof area, double the water.

With the tendency for larger homes, many families have the capacity to capture more water.

A cistern is the common term for a water storage tank. Several materials for cisterns may be considered: food-grade polyethylene plastic, poured in place concrete, pre-cast concrete, steel, and fiberglass.

As of this writing, fiberglass tanks have a potable water coating for the interior. Concrete has little strength in tension resulting in greater potential of cracking. Steel may eventually rust, causing water quality problems and eventual leaks. Galvanized steel will not rust and there is very little evidence of the galvanization leaching into the water. Currently the polyethylene tanks are one of the best options. They are limited in size, so several tanks may have to be plumbed together to achieve the total storage capacity desired. Burying tanks in the ground needs to be done with care so as to not compress or collapse them.

The benefit of burying cisterns is the insulating effect of the earth. If water can be stored below 55ºF (12.8ºC) and without light bacterial growth is extremely slow. Also with burial, the water will not freeze so it is available all winter.

MOVING THE WATER TO POINTS OF USE

How do I get the water from storage into the house and to my faucets?

Most people in North America enjoy a pressurized water system. A home connected to the municipal water system receives water at whatever pressure the municipality has designed for. For homeowners with their own source of water this pressurization requires a pump and a pressure tank. Capturing water by gravity from the roof and storing it in a large container usually determines that the water stored will be below the household plumbing. A pump is needed to move the water from the cistern and to pressurize it for conventional household uses. This plumbing arrangement is common for rural homes with water wells. The cistern storage acts as the well.

The small elevation difference between a cistern and the household plumbing is an advantage over drilled water wells because the pump size and, therefore, the electrical demand is less. DC pumps powered directly from photovoltaics or from storage batteries are easier and more cost effective to incorporate in a cistern based system.

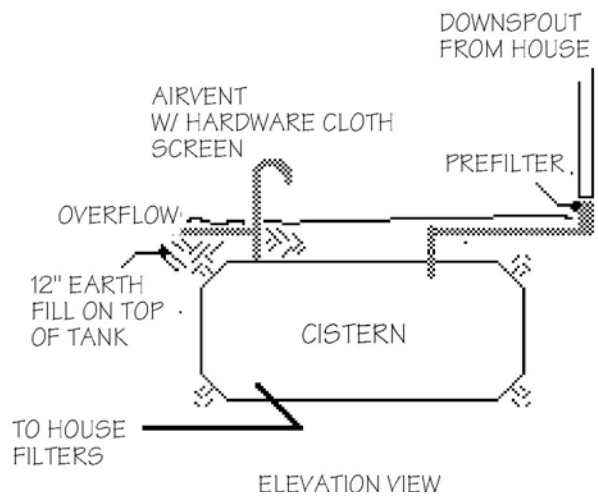

Fig. 7.4 Plumbing schematic of rainwater storage system

WATER FILTERING

Rainwater has the invisible quality of being naturally "soft". The benefit of soft water is reduced build-up of minerals in piping and on fixtures. Also far less soap is needed for bathing and washing. Homes using hard (high mineral content) well water often have water softeners which use salts . Effective wastewater treatment is easier with rainwater.

Rainwater is also devoid of all the mysterious chemicals that end up in municipal water supplies, in particular chlorine based additives for purification.

Roof catchment water does need to be filtered of the dust and pollutants that end up on the collection surface and, depending on the system design, possibly filtered for bacteria. A filter prior to the storage cistern is invaluable for simplifying the system. It is especially important to prevent organic debris and animals from falling into the storage.

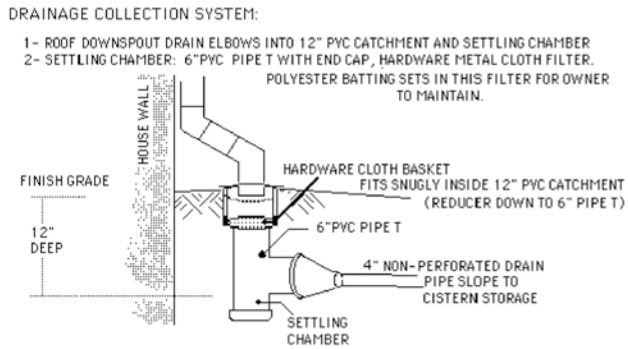

Fig. 7.5 A prefilter before cistern

Keeping the cistern water temperature below 55ºF will tremendously reduce any bacterial growth. Finer filters are in order between the cistern and household points of use. At least a 5 micron "rust and sediment" filter should be incorporated. A 0.5 micron filter will remove taste and odor if necessary. If there is question of some unknown pathogen that may pass through the filters, a UV light chamber can be added to kill the bacteria. Reverse osmosis (RO) is an excellent filtering system but it backwashes the membrane to clean it, wasting water. It also is a slow process so another small storage usually follows the RO filter to meet demand at the faucet.

Fig. 7.6 10 micron and 0.5 micron filters

Since the storage cistern should be sized for at least three months of water demand it is important to allow for fresh air ventilation so that the water does not become stagnant.

resources:
Rainwater Collection for the Mechanically Challenged. Banks, Suzy and Heinichen, Richard.
Real Goods Solar Living Sourcebook, 8th Edition. Schaeffer, John. Chelsea Green Publishing Co.
Texas Guide to Rainwater Harvesting [available on the web]
http://www.twdb.state.tx.us/publications/reports/RainwaterHarvestingManual_3rdedition.pdf

Karlis D. Viceps
Solar Plans LLC
P.O. Box 2264
Taos, NM 87571
USA
575-770-0225
WEBSITE: www.solarplans.com

Providing consulting, systems research and design for architectural and engineering firms integrating sustainable living and USGBC-LEED principles. Background includes over 25 years of eco-sensitive residential design and construction.