WATER HARVESTING DESIGN PRINCIPLES & CALCULATIONS

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The Eight Principles of Successful Rainwater Harvesting

(From Brad Lancaster's Book - Rainwater Harvesting Volume I)

1. Begin with long and thoughtful observation. Use all your senses to see where the water flows and how. What is working, what is not? Build on what works. Try to understand the site as whole, not as separate pieces.

2. Start at the top (highpoint) of your watershed and work your way down. Water travels downhill, so collect water at your high points for more immediate infiltration and easy gravity-fed distribution. Start at the top where there is less volume and velocity of water. **Watershed:** a *catchment area* – the total area of a landscape draining or contributing water to a particular site or drainage.

3. Start small and simple. Work at the human scale, so you can build and repair everything. Many small strategies are far more effective than one big one when you are trying to infiltrate water into the soil. *(K.I.S.S. – Keep It Simple Stupid!)*.

4. Spread and infiltrate the flow of water. Make water stroll, not run, through the landscape. Spread out the flow of water so it can slow down and infiltrate into the soil. Slow it, spread it, sink it! Practice the art of waterspread… the gentle harvesting, spreading, and infiltrating of water throughout a watershed rather than the rapid shedding or draining of water out of it. Turn *runoff* into *soak-in*!

5. Always plan an overflow route, and manage that overflow as a resource. Always have an overflow route for your water harvesting system in times of extra heavy rains. Where possible, use that overflow as a resource – to feed a rain garden or another source.

6. Maximize living and organic groundcover. Create a living sponge of mulch and plants to improve the soil's ability to infiltrate and hold water. Brad says "I've found the roots of these plants, coupled with surface mulch and the associated soil life grow to create a living sponge that can more than double stormwater infiltration rates in previously bare basins, reducing evaporation, runoff, erosion, and mosquito breeding." Native vegetation – indigenous plants found within 25 miles of your site and within an elevation of 500 feet above or below your site – are generally best adapted to local rainfall patterns and growing conditions and therefore often make the best groundcovers.

7. Maximize beneficial relationships and efficiency by "stacking functions" Get your water-harvesting strategies to do more than hold water. Berms can double as high and dry raised paths. Vegetation can be placed to cool buildings and provide food. Rainwater tanks can provide shade, privacy, or support structures. By stacking functions, you get far more efficiency and productivity for the same amount of effort.

8. Continually reassess your system: the "feedback loop" Continual reassessment is the key to long-term maintenance of a water-harvesting system. Observe how your work affects the site – beginning again with the first principle – long and thoughtful observations. Make any needed changes, using the principles to guide you.

When Considering Water:

- Quality
- Quantity
- Availability
- Accessibility

Active vs. Passive Water Harvesting

- Active water harvesting means equipment is used to collect, filter, store, and deliver water. (ex// rainwater tank)
- Passive water harvesting means no mechanical methods of collection – passively collecting water to absorb it into the land. (ex// earthworks mulch basin)

RAINWATER CISTERNS -ACTIVE HARVESTING

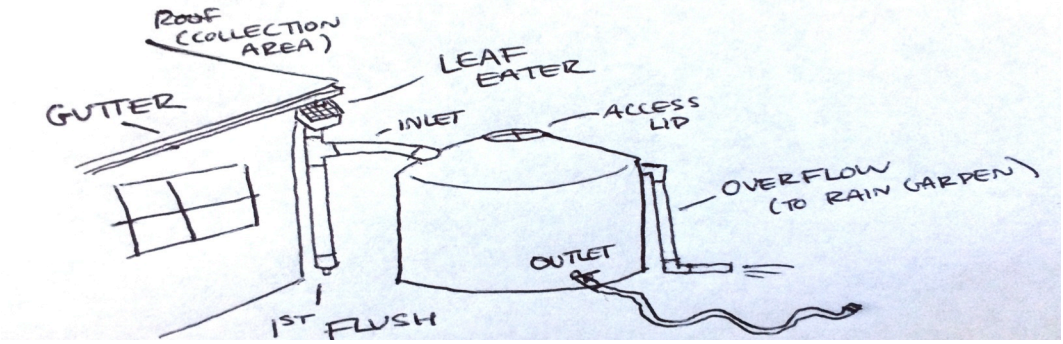
Purpose of Rainwater Tanks: part of comprehensive water harvesting system & a sustainable landscape; conserve water; reduce reliance on extractive delivery systems; storm water management, etc.

What is your Site Objective? Irrigation? Food production? Non-potable indoor use? Potable use? Fire protection? To be cool & eco-chic?

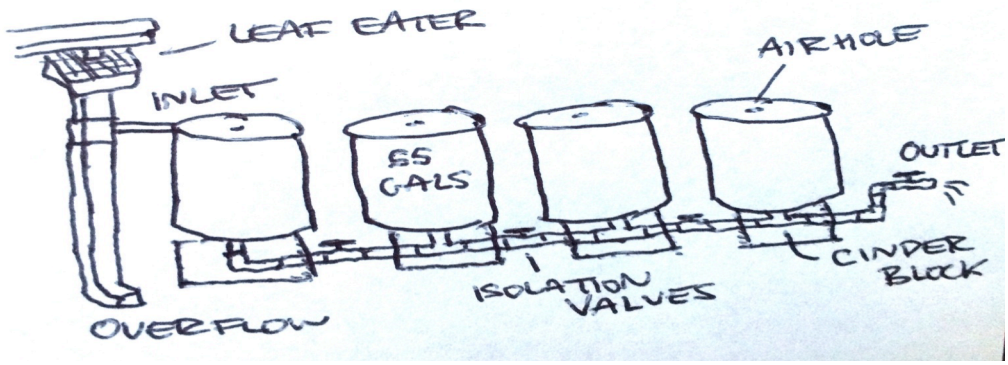
Benefits: Reduce groundwater reliance; energy savings; promotes healthy soils & plants; clean & soft water – no chlorine; emergency water

Consider Local Climate: general climate; rainfall patterns; temperature extremes (freezing?); rainfall intensity; precipitation event frequency

Rainwater Collection Diagram – Rainwater Cistern



Rainwater Collection Diagram – 55 Gallon Barrels



Rainwater Tank System Components:

- Roof-Catchment Area
- Collection Components – Gutters & Downspouts
- Pre-Filtration – first-flush (captures first flush of dirty rainwater off roof, must be emptied between rainfall events); leaf eater (mesh box to prevent leaf debris)
- Inflow – Wet conveyance (connects to base of tank) vs. Dry conveyance (connects to top of tank)
- Tank – materials & types, sizes
- Delivery – gravity (passive drain) vs. pump supply *(always use full-port hose outlets instead of half-port hose outlets to increase water delivery)*
- Overflow – to beneficial use (rain garden?)
- Post-Filtration – depends on use (need filter for potable use – asphalt roofs are not appropriate for potable use)

How-to Calculate Rainfall Volume from Roof

(based on roof (square feet - sf) and a rainfall depth (inches)

Surface Area Roof (sf) **x** Rainfall (inches) **x** 0.623gallons/sf-in **=** Gallons Rainfall / In. Rain

- ***Ex#1*** *- For a roof that is 12ft x 20ft and with an annual SF Bay rainfall of ~24 in./year:*

(12ft x 20ft) = 240sf **x** 24 inches/year **x** 0.623gallons/sf-in **=** 3588 gals rain / year

- ***Ex#2*** *- For a roof that is 80ft x 22 ft with a 1" rainfall event:*

(80ft x 22ft) =1760sf **x** 1 inch rainfall **x** 0.623gallons/sf-in **=** 1096 gals rain / 1" rainfall event

Rainwater Site Assessment – Questions to Place Tanks:

- Do I need a tank? Stack Functions (shade? thermal mass? privacy?) Overflow to Rain Garden? Proximity to Plants? Relation to Gutters? Human Use & Access? Rainwater Tank Foundation? ***Will the Cistern Water be Easier to Use then City Water???***

Types of Rainwater Tanks

- Plastic Tanks: lightweight, portable, can be expensive (bigger tank = better value), puncture-able & not easily repaired, not fire resistant, very common rainwater tank
- Ferrous Cement: rebar & cement tank, material costs low, labor high, durable / repairable / fireproof
- Metal Tanks / Metal Culvert Tanks: metal tanks are either fabricated or can be made from large metal culverts, can be expensive, can be portable, fire resistant
- Recycled Tanks: food-grade 55 gal blue barrels or 275 gal IBC totes, must be food-grade, have to be cleaned, IBC totes need sun protection to prevent algae build-up, can be connected in series, cheap
- Poured Concrete Tanks – can be underground (same companies that make pools)

Sizing Rainwater Tank:

Sizing your rainwater tank depends on several factors including intended use; rainfall volume calculations; space allotted; local climate / rainfall patterns; type of irrigated vegetation; budget; etc. ***(Typically tanks over 5000 gallons will require a permit)*** Every gallon of water is ~8lbs!

EARTHWORKS - PASSIVE WATER HARVESTING

<u>Earthworks</u> involves shaping the landscape to passively harvest rainwater into the soil and the organic cover (mulch and plants). The goal is to slow it, spread it, sink it – "turn the *run-off* into *soak-in*." Earthworks better connect the water cycle with the carbon cycle (plants, soil, mulch = carbon = organic matter = life!). This can be the simplest form of rainwater harvesting (shovel time!) but it can also be the most ecologically beneficial and regenerative. Earthworks systems can be scaled for your residential home, for your land project, or to help regenerate an entire watershed.

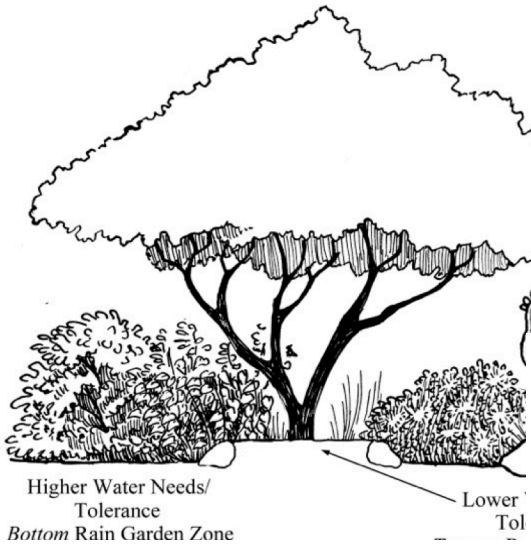
<u>Collection, Conveyance, Infiltration:</u>

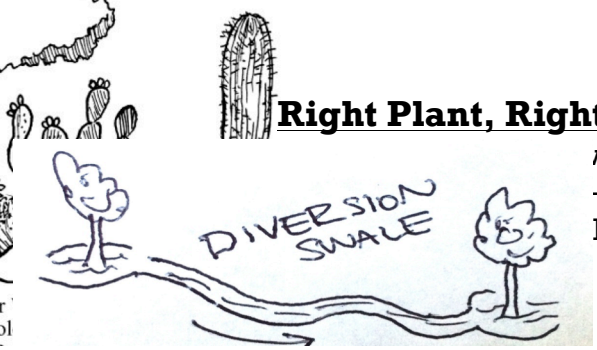
- **<u>Basin</u>** – used for retention & infiltration

- **<u>Berm</u>** – used to slow down / capture water

- **<u>Swale</u>** – conveyance of water - *hydrologist's definition*

(Permies – swale on contour, bro!)
*(Brad says: – **berms 'n basin** for contour, **diversion swale** for conveyance)*





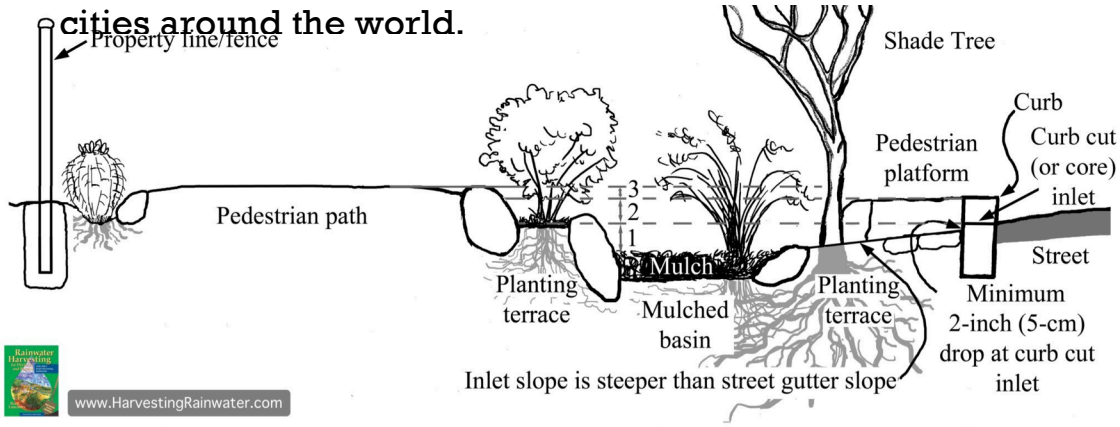
<u>Right Plant, Right Place</u>:

*w*est water needs
- lower water needs
higher water needs

Sizing Earthworks:

1) **Stormwater Retention (Peak Event):**
   a. Basin volume depends on potential maximum storm event sizes. Can size to meet estimated stormwater runoff from particular storm event – 20 year, 50 year, 100 year. To calculate runoff from catchment area use same formula as rainwater off roof but multiply by a 0.5 runoff coefficient (a rough average of only ½ of the rainwater will runoff into basin)
2) **Percolation Rate:**
   a. The percolation rate is the rate at which water will infiltrate a particular soil. This information is critical for sizing our earthworks basins (and our greywater mulch basins as well).
   b. Perk test – make a 5 gallon bucket size hole, fill with water and use measuring stake to measure how far water drops (inches) in a given number of minutes. Continue to fill with water until there is a consistent rate of water percolation – that is your rate (min/in).
3) **Plant Demands:**
   a. The basin should be sized to capture sufficient runoff from catchment area to irrigate specific plants.
4) **Always Include Overflow!**
   a. Always include an overflow at the right elevation below the berm height to allow heavy rainfall to flow into another basin or into another catchment area / stream / storm drain.
   b. Use a water level (long plastic tube with water and measuring stake) to calculate relative differences and determine critical elevations for sizing basins

Curb Cuts / Green Infrastructure: By cutting a slot into the curb of a sidewalk meridian, we can harvest storm water into our soil and organic matter (plants & mulch) rather then having this polluted water flow down channelized cement pipes to the bay & ocean. This connects the water cycle with the carbon cycle which creates LIFE! Brad Lancaster and his brother created the first curb cut "illegally" in Tucson, AZ in 1996 – it is now a practice that has been adopted by cities around the world.

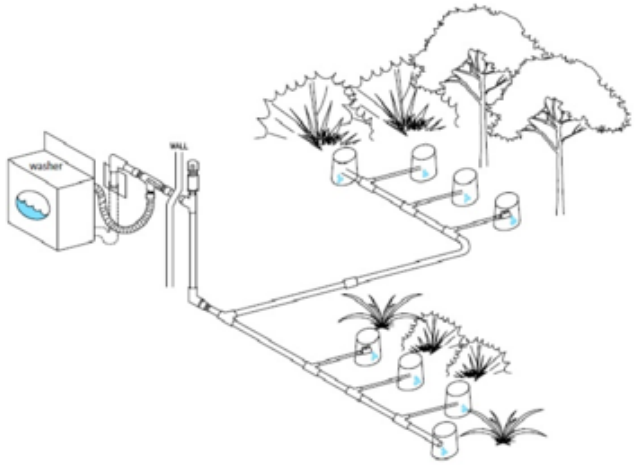


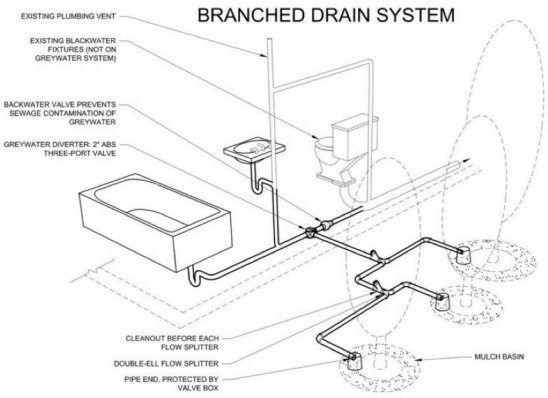
GREYWATER – LAUNDRY TO LANDSCAPE & BATHROOM SYSTEMS

Greywater is the relatively clean water from baths, showers, sinks, and washing machines. Currently in California you can legally install a laundry to landscape system (washing machine water to irrigation) and a bathroom graywater system (bath tub, shower, & bathroom sink) to a mulch basin or infiltration basin. Greywater systems must use biodegradable soaps and they must be properly designed, sized, and maintained. The greywater will typically first enter a mulch basin (a organic sponge), where the water is then soaked up by the roots of greywater-loving fruit trees or perennial plants such as certain types of berries. Kitchen sink water is currently considered *blackwater* and is not legally allowed to be used as graywater. This pivotal greywater legislation was made possible by the hard work of groups like Greywater Action (Laura Allen), Oasis Designs (Art Ludwig), and others.

Laundry-to-Landscape (L2L)

A L2L system connects your laundry washing machine to a 3-way diverter valve which allows you to divert the water to a greywater irrigation line. The 3-way diverter is legally required – in times of high rainwater saturation or if non-biodegradable soaps are being used, you want to divert the graywater back into the sewer line. The L2L line is pressurized because of the washing machine pump. When converted to a ½" irrigation tube it can typically irrigate six different plants or trees. Certain plants and trees do better with graywater – check the greywater books and resources for more info on plant selection.





Bathroom Greywater Systems – Branched Drainage Mulch Basin

Bathroom sinks, tubs, and showers can be legally used for graywater irrigation. In these systems, the 3-way valve is installed directly onto the bathroom outlet pipe. The greywater pipe will go into the yard and can irrigate several fruit trees or perennial plants (a "branched drain"). CA regulations state that the greywater must exit the pipe below ground – a bucket or upside-down flower pot protects the graywater pipe from being filled with mulch. The greywater enters the mulch basin in a location close enough to irrigate certain fruit trees and perennial plants. The size of the greywater basin depends on the human use / greywater supply and also on the plant demands and percolation rate of the soil.

Greywater Do-Nots:

- No standing greywater
- No storage (can store for 24 hours, but can be stinky)
- No salts / chlorines / bleach / etc.

Other Greywater Considerations:

- Most active soil biota is in top of soil, so ideally drop greywater near top
- Plants play critical function in successful greywater systems! Without healthy plants the system will not work optimally

Calculating Greywater Production:

Peak Greywater Discharge: max use/person/day **x** max number people in household

Annual Greywater Discharge:
gallons per use **x** number of uses/person/(week or day) **x** number people in household **x** (52 weeks or 365 days)

Average Greywater Rates:

- *Laundry ~20gals/load*
- *Shower ~2 gals/min (gpm)*
- *Sink ~1 gpm*
- *Bath ~80 gals/use*

Ex. L2L:
– Annual Laundry = 3 loads/week **x** 20gals/load **x** 52 weeks = 3120 gallons

Ex. Master Bathroom Greywater:
– Annual Master Shower = 10mins/day **x** 7 days/week **x** 2gpm **x** 52 weeks = 6240 gallons

– Annual Master Sink = 5mins/day **x** 7 days/week **x** 1gpm **x** 52 weeks = 1820 gallons

- Annual Master Bath = 1 use/week **x** 80 gals/ use **x** 52 weeks = 4160 gallons

- Total Annual Greywater (Master Bathroom) = 12,220 gallons greywater / year

Calculating Greywater Basin Size (minimum soil surface area)
(use Art Ludwig's Greywater book, table 2.3, pg. 13)

Ex. – What is the minimum soil surface area required to handle the daily peak discharge from the laundry machine? *This ensures the greywater can be safely handled by the soil.*

Daily peak laundry discharge = 120gals/day

Percolation Rate = 30min/in
2.5 Loading Rate (gal/day/sf)
0.4 Area Needed = sf/gal/day

120gals/day x 0.4 area needed (sf/gal/day) =48sf needed for greywater to be safely handled

WATER HARVESTING BUDGET

Water Harvesting Budgets help balance out our water harvesting supply with our water demand. By calculating how much greywater and rainwater will be harvested, and then calculating our rough estimate for plant water demand (and home water demand in certain cases), we can determine whether our water harvesting budget will be balanced. Ideally, the amount of water we harvest would be close to equal to the amount of water demand over the year. The Watershed Management Group in Tucson, AZ is able to meet all their water needs (including filtered drinking water) for 11 months out of the year, all from the 3 roofs that feed their 10,000 gallon underground rainwater tank. And this is in a place with less than half of our California annual rainfall – about 11 inches of rain a year.

HAPPY HARVESTING!

REFERENCES / RESOURCES:

1) Brad Lancaster, *Rainwater Harvesting for Drylands and Beyond*, Volume I, II, & III (https://www.harvestingrainwater.com/)

2) Art Ludwig, *Water Storage* & *Create an Oasis with Greywater* (http://oasisdesign.net/)

3) Laura Allen, *The Water-Wise Home* (https://greywateraction.org/)

4) Watershed Management Group, Tucson, AZ Water Harvesting Design Certification. (https://watershedmg.org/)

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