Turning Drains Into Sponges and Scarcity Into Abundance

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INTRODUCTION

As communities grow and develop, formerly vegetated and porous earthen watersheds are paved over and made impervious. Over 25% of the land area in my hometown of Tucson, Arizona is now paved, roofed, or otherwise turned to hardscape.[1] In more densely populated communities, such as Los Angeles, California, over 60% of the land surface is paved.[2] This urban phenomena dehydrates landscapes, increases downstream flooding, increases the heat island effect, degrades water quality, and creates sterile living environments (unless you like kayaking in urban runoff).

A recent report prepared by American Rivers states that rapid expansion of paved-over and developed lands in communities across the U.S. is worsening the effects of drought. For example, development in Atlanta, Georgia, and surrounding counties contributes to a yearly loss of rainwater infiltration ranging from 57 to 133 billion gallons. If managed on site, this rainwater— which could support the annual household needs of 1.5 to 3.6 million people—would filter through the soil to recharge aquifers, and increase underground flows to replenish rivers, streams, and lakes.[3]

In association with creating hardscapes, the remaining exposed earth is often denuded and increasingly compacted. Tucson's overconsumption of groundwater (exceeding the rate of net natural recharge), along with the paving and dehydration of its watershed, has contributed to the severe degradation of the once perennially-flowing Santa Cruz River. Water tables have dropped over 300 feet (90 meters) since the early 1900s, and many springs and wells have dried up. While 12 inches (304 mm) of rain falls on Tucson in an average year, we are lucky if a fraction of this rainfall infiltrates into the soils of the city's urbanized watershed and our household landscapes. In these desiccated landscapes, automatic irrigation systems frequently turn on just hours after a downpour or even while the rain is pouring from the sky.

Figure. Santa Cruz River, Tucson, Arizona 1904. Note the meandering flowing river and the rich sponge of vegetation throughout the watershed—especially where the native forests are still intact. Such a watershed absorbs more rainfall than it drains away. Water moves slowly and consistently through the forested watershed and meandering waterway. Figure. Santa Cruz River, Tucson, Arizona 2007. On the same stretch of river today, note the dry channelized riverbed and the replacement of the watershed's vegetative sponge with pavement, buildings, or bare compacted earth. The watershed now drains away more rainfall than it absorbs. Stormwater erosively rips through the watershed and straightened river channel, flooding land downstream. Summer temperatures are increasing due to heat absorbed by exposed pavement.

Figure. Landscapes of hydrophobic impermeable pavement
Figure. Flooded street
Figure. Kayaking in street runoff
Figure. Water to stormdrain

CHOOSING WATER ABUNDANCE OVER WATER SCARCITY

It does not have to be this way. We have a choice. We can choose to either dehydrate or rehydrate our watersheds. We can choose between water scarcity and water abundance.

Figure. Water scarcity
Figure. Water abundance

Hardscapes that drain water away can be turned into sponges that hold water in place. Unnecessary hardscape can be reduced, and runoff from the remaining hardscape can be harvested in soil to passively irrigate native vegetation. The soil is our largest and least expensive "tank", while the vegetation is the living pump that allows us to access the water in the form of beauty, windbreaks, medicines, and a canopy of shade. This process can begin to rehydrate landscapes, decrease downstream flood peaks, reduce stormwater pollution and counteract the heat island effect. In addition, rehydration of landscapes creates dynamic, sustainable living environments that produce food, create wildlife habitat and control erosion.

Figure. An excessively wide, exposed, heat absorbing street in Tucson, Arizona. Such urban design has contributed to a 10°F rise in temperatures in Phoenix, Arizona and a 6°F rise in Tucson, Arizona since the 1940s.[4]
Figure. A narrow, mature, shady tree-lined street in the Village Homes Community, Davis, California. Such urban design and forestry has contributed to a 10°F drop in summer temperatures compared to built-out areas without such natural shading.[5] *Appropriately-selected vegetation, once established, can be irrigated entirely by harvested rainfall and runoff from the adjoining hardscape.*

“Draining” landscapes—consisting of vegetation placed at the top of earthen mounds—can be replaced with creative undulating landscapes consisting of water harvesting depressions and plants placed within or adjacent to water collection areas. Besides harvesting water, these landscapes harvest organic leaf drop and reduce soil erosion. Water-draining landscapes can create mosquito problems when runoff pools at the bottom of the system and stands the three days necessary for mosquitoes to develop from eggs to adults. In contrast, water-harvesting landscapes create a mosquito solution by distributing water evenly over multiple small basins in the landscape. Water-harvesting earthworks should be designed to infiltrate standing water within 12 hours, though water often infiltrates much quicker in well-designed water harvesting landscapes. The more organic mulch and vegetation contained in the depressions, the faster the rate of water infiltration.

Figure. A landscape on “life support” drains its resources away. Note the mounded

planting areas and the design of hardscape and landscape that drains all runoff to the street.
Figure. A sustainable landscape harvests and recycles on-site resources. Note the sunken water-harvesting areas planted with native vegetation and mulched to reduce evaporation. The sidewalks and roof are designed to beneficially drain runoff into the landscape's soil. The earthworks overflow from one to another, infiltrating as much water as possible and passively irrigating the landscape, until only surplus water flows to the street.

SUSTAINABLE HIERARCHY OF WATER USE

With the construction of harvesting landscapes, we can move away from the unsustainable practice of using costly potable water (or reclaimed water that has been treated off site and pumped back to the site) to irrigate landscapes. Instead we can move towards a sustainable hierarchy in household and community water management in which:

- Rainwater and localized runoff are the *primary* water sources for our landscapes and gardens.
- Greywater is the *secondary* water source for landscapes, with greywater consisting of on-site household "wastewater" drained from sinks, clothes washers, showers, bathtubs, reverse-osmosis water filters, evaporative cooler bleed off, and condensate from air conditioners. Greywater does not include the drainwater from toilets, which is considered blackwater.
- Municipal/well water that must be pumped to a site is strictly a *supplemental* source used for landscape watering *only* in times of great need such as drought.

Outdoor irrigation conducted on standard, non-harvesting landscapes consumes about 30% of the potable water used at single-family residences in the U.S.[6] In hot, dry climates the potable water consumed for irrigation can be much higher. In Albuquerque, NM irrigation constitutes 40% of potable water demand.[7] In San Diego, CA, Denver, CO, and Phoenix, AZ, outdoor water use is well over half the water consumed at single-family residences.[8] In contrast, outdoor irrigation in water-harvesting landscapes typically constitutes 5% or less of the potable water consumed at a single-family residence.

Even in dry climates, rain can constitute an abundant water source. Studies have found that over 70% of the average residential water use of 165 gallons (625 liters) per person per day (gpcd) in Tucson's urban core could be met by direct rainfall (averaging 12 inches or 304 mm per year).[9] In addition, recycling greywater can provide up to 40 gpcd (152 liters) of greywater for landscape irrigation.[10] The easiest place to begin harvesting rainwater and greywater is in the landscape, where the quality of these water sources is appropriate for the intended use.

WATER HARVESTING PRINCIPLES

The Eight Universal Principles of Successful Water Harvesting listed below provide guidance on how to implement both the sustainable hierarchy of water use, and the stewardship path to abundance, within our community's landscapes.

1. **Begin with long and thoughtful observation**.
Observe where water flows, where it collects, where it drains to, and where it drains from. Careful observation informs you of site resources and challenges. Observe what is working and build on that. Observe what is not working and change it.

2. **Start at the top (highpoint) of your watershed and work your way down**.
It is easier to harvest water high in the watershed because the volume and velocity of flow is relatively small, in contrast to the difficultly of harvesting and managing water at the bottom of the watershed where flow is concentrated and fast-moving. Harvesting water at the top of the watershed also allows the use of gravity to distribute harvested water downslope.

3. **Start small and simple**.
Small, simple systems of appropriate scale are easier to create and maintain than complex, extensive systems. As an added benefit, large numbers of small earthwork structures distributed throughout a watershed will be far more effective at hydrating the land than a small number of large-scale earthwork structures placed in just a few areas of the watershed.

4. **Slow, spread, and infiltrate the flow of water**.
Zig-zag the flowpath of water to calm the flow, reduce destructive erosion, and increase the time and distance water flows. This will increase infiltration into the soil from *source* (high point) to *sink* (low point). This practice achieves *waterspread* throughout the watershed.

5. **Always plan an overflow route, and manage that overflow as a resource**.
You can’t turn off the rain once your water harvesting earthworks and cisterns fill up, so always be prepared for overflow. Design cistern overflow so it fills a vegetated earthwork nearby, which overflows to the next earthwork, and the next, passively irrigating sheltering vegetation. Route water in a zig-zag pattern that follows the fourth principle–slow, spread, and sink.

6. **Maximize living and organic groundcover**.
Plant vegetative groundcover and spread organic mulch over the surface of the soil to create a living sponge that combines with harvested water to grow more resources. As roots expand and soil life increases, the soil's ability to infiltrate and hold water steadily increases as well.

7. **Maximize beneficial relationships and efficiency by "stacking functions**."

Design your water harvesting strategies so they do more than hold water. Cisterns and earthworks provide high quality irrigation water and serve as on-site stormwater control strategies. In turn, rain-irrigated vegetation and above-ground cisterns can passively shade and cool the east and west sides of buildings in summer, while the plants clean the air, produce food, create wildlife habitat, and add beauty to our lives.

8. **Continually reassess your system: the "feedback loop."**
The value of long and thoughtful observation extends throughout the life of your system. How is the land responding to your work? How are your strategies performing? What still needs to be addressed? Make any needed changes using the principles to guide you.

WATER HARVESTING IN INTEGRATED SITE DESIGN

Solar Arc

Design sites to work with the seasonally changing sun angles to increase the site's functionality and comfort. Harvesting water should support perennial vegetation planted west, north and east of a home in a "solar arc" helps to passively heat the home in winter by retaining winter sun access, and helps cool it in summer when vegetation shades out the rising and setting sun. Studies have found the shade cast by such plantings can reduce summer temperatures around buildings by as much as 20°F, while maintaining access to winter sun can help passively meet 50% or more of the building's heating needs.[11, 12]

Figure. Solar arc
Figure. Solar arc planted within a building's oasis zone

Hardscape design

Raise pathways, accessways, and gathering areas and direct water running off these surfaces to adjoining sunken, mulched, and vegetated basins. The mulch and vegetation help bioremediate contaminants in the runoff while the runoff boosts vegetation growth. This vegetation then matures to passively shade, shelter, and cool the hardscape of the accessways and gathering areas.

Figure. Raised pathways, sunken planting areas.
Figure. Trees naturally grow taller beside roadways, when the extra runoff is allowed to gather and promote more growth. 1-10 highway near Benson, Arizona.

Food production

Use rainwater and greywater to grow food. The average meal in America travels 1,500 to 2,500 miles (2,413 to 4,022 km) from farm to plate.[13] but much of this could be produced right outside the kitchen door. One hundred fruit trees scattered throughout a neighborhood of 1,000 people are as productive as 100 trees in a 1-acre (0.4-ha) irrigated orchard, and 1,000 such neighborhoods yield as much as 1,000 acres (404 ha) of orchard.[14] Neighborhood orchards serve multiple functions when integrated with homes and neighborhoods as a whole—providing food, passive cooling, beauty, living playgrounds, windbreaks, erosion control, and stronger local economies. In addition, watering these trees and other food plants with harvested rainwater and on-site greywater drastically reduces the strain that distant groundwater-irrigated orchards put on community resources, and saves the fossil fuel otherwise needed to harvest, package, transport, and sell the distant orchard's produce to us.

Figure. Rainwater- and greywater –irrigated bounty of white sapote fruit, Tucson, Arizona.

Single-family residence

The Lancaster household in Tucson, Arizona has turned a sterile lot into an oasis providing 15 to 25% of its food needs on site by irrigating over 95% of the landscape and garden using harvested rainwater and greywater. The bulk of the water is harvested within passive earthworks.

Figure. Site before water harvesting
Figure. Site after water harvesting
Figure. Roof runoff is caught in a 1,200-gallon (4,548-liter) cistern and used for irrigation. The sunken, mulched garden basins harvest direct rainfall, runoff from raised pathways, and overflow from the cistern. Ten out of the past 11 years this garden and landscape has been irrigated entirely with rainwater.
Figure. A greywater-generating washing machine can be discharged to one of multiple greywater drains enabling the user to direct greywater to whichever fruit tree needs water most. Higher-water-use exotic fruit trees are only planted where they get harvested greywater to supplement harvested rainwater.
Figure. Greywater to landscape diagram
Figure. Food grown with rainwater and greywater

The rainwater harvesting earthworks and plantings extend beyond the property into the public right-of-way and the community at large.

Figure. Dunbar/Spring neighborhood, Tucson, AZ. Public right-of-way before water harvesting in 1994
Figure. Dunbar/Spring neighborhood, Tucson, AZ. Public right-of-way after water harvesting in 2006
Figure. Existing curbs are cut to allow street runoff to enter mulched basins and passively irrigate street-side plantings of native trees, shrubs, and ground cover. One curb is cut per basin so the cut can serve as both the inflow and overflow for street water. This pattern creates a very stable, self-maintaining system of "eddies" or "backwater" locations along the flowpath of street runoff. Water "settles" into the basins rather then flowing through them, so there is no erosion. Mulch floats up with the incoming water, then sinks back down as the water quickly infiltrates into the soil. Using this strategy, native-plant landscapes thrive on harvested street water alone once plants are well established. These systems reduce street flooding, decrease the need for more flood control infrastructure, reduce urban heat island conditions, beautify neighborhoods, create wildlife habitat, and naturally filter pollutants from soil and air. In this example a small dirt berm placed just downgradient of the curb cut helps direct additional street runoff through the curb cut and into the basin. Curb cuts will also work without the

added dirt berm. These curbcuts and plantings have reduced runoff from this street by over 90%.

We harvest over 100,000 gallons (379,000 liters) a year of rainwater and greywater in the soils of our property and surrounding right-of-way, while using less than 20,000 gallons (75,800 liters) per year of municipal water inside the house. We give back to the watershed more than we take from it.

Figure. Neighborhood-grown mesquite pods, along with neighborhood honey and mesquite flour.
Figure. Rodd Lancaster eating runoff-irrigated neighborhood cactus fruits and pads.
Figure. Chi Lancaster with backyard- and neighborhood-grown foods irrigated solely by harvested rain and runoff. Note the curb cut that directs street runoff to the mesquite tree.
Figure. Desert Harvesters mobile community hammermill for quick and easy grinding of locally harvested mesquite pods.
Figure. Enjoying mesquite pancakes with prickly pear syrup at a Desert Harvesters milling event.

Multifamily residence

The 28-unit Milagro co-housing site in Tucson, Arizona has no conventional detention or retention basins at the low end of the site. Instead dozens of small infiltration basins are grouped and scattered throughout the site's landscape and watershed. These small basins are the foundation of the landscape, harvesting direct rainfall and rooftop runoff, and household wastewater that is distributed subsurface to the basins via pipes after being treated at the on-site constructed wetlands. The salt-free rainwater helps leech salts from the root zone of plants that has been introduced there by treated wastewater. Once plants are established, no additional potable water is used for irrigation. At this cluster development only 5 acres (2 ha) of the 43-acre (17-ha) site is developed. The remaining 38 acres (15 ha) have been set aside as natural open space to preserve the native desert ecosystem. Here intact plants, leaf drop and undisturbed native soil create a natural sponge in the watershed. The photos below illustrate a range of strategies in use at this site.

Figure. Milagro co-housing site, Tucson, AZ. Rainfall collects in infiltration basins minutes after a large summer storm hits the site. The newly constructed basins were not yet mulched or planted when this photo was taken. Credit: Natalie Hill.
Figure. Milagro co-housing site, Tucson, AZ. The newly constructed basins shown above are now mulched and vegetated. These basins, with their spongy mulch and soil-burrowing plant roots, absorb all water within 20 minutes, preventing mosquito breeding and problems resulting from anaerobic soils.
Figure. Milagro co-housing site plan. Tucson, AZ. On this plan, only basins in the common area are marked. Most residents went on to construct mulched and vegetated basins, and installed covered cisterns in their private backyards. Trees in the common area were selected and placed to maintain winter solar access to south-facing windows.

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Figure. Milagro co-housing site, Tucson, AZ. Gravelpave2 geocells with landscape fabric backing are shown being installed at the Milagro co-housing parking lot. Flush concrete curb is installed to strengthen the edge between the surface of the geocells and the incoming stabilized-earth road.
Figure. Milagro co-housing site, Tucson, AZ. The completed Gravelpave2 parking lot with geocells filled with gravel will produce no runoff so no detention basin or other drainage infrastructure is needed.

Neighborhood streets

Installation of water harvesting, vegetation-growing traffic circles and other traffic-calming strategies can reduce impervious asphalt and calm traffic in residential neighborhoods. If located at the high point of a crowned road, a traffic circle should have a solid curb surrounding the sunken planting area to prevent direct rainfall from flowing out of the planting area. If a traffic circle is located in the low point of a sunken road, the circles' curb can be cut with periodic openings or constructed flush with surrounding asphalt to allow street runoff to flow into the circle's planting area. The same approach applies to road medians.

Figure. A traffic circle with a raised curb and curb cuts can be used where runoff flows toward the center of concave-shaped intersections. Raised curbs keep cars out while curb cuts allow water to flow in.
Figure. Midtown neighborhood, Tucson, Arizona. A traffic circle with curbs built flush with the street elevation is appropriate at sites where the center of the road or intersection is at the low point of the street and runoff can flow across the flush curb into the planting area. Boulders and bollards keep cars out.
Figure. Midtown neighborhood, Tucson, Arizona. "Chicanes" or pullouts with flush curbs can be used where a road is crowned in the center so runoff drains to street-side curbs. Flush curb allows runoff to flow into planting areas, while surplus runoff can continue flowing down the street.
Figure. Dunbar/Spring neighborhood, Tucson, Arizona. Intersection before and after construction and planting of a traffic circle. Sunken plantings and raised curb, but no curb cuts, is appropriate for use where the center of the road or intersection is raised or crowned to drain water away. The raised curb and sunken basin retain rainfall that would otherwise run off. Construction of this circle reduced impervious paving at this intersection by 26%.
Figure. Community members get involved planting the traffic circle and painting the intersection around the circle.
Figure. The painted intersection celebrates the seasons, water harvesting, and the neighborhood.

CONCLUSIONS

Throughout our urban, suburban, and rural watersheds lets strive to create multi-functional sponges to passively and naturally enhance and hydrate landscapes, communities, and lives for the better. Using the water-harvesting principles, begin at the top of watersheds and subwatersheds, and continue all the way to the bottom to create the most effective water--harvesting designs. Every home site, business site, school ground, park, farm, and ranch is a subwatershed of the larger community watershed. Harvest water throughout each. Create organic sponges in the landscape using primarily native vegetation. These plants naturally survive in native soils under local rainfall conditions, and thrive when planted within or beside water-harvesting structures that increase soil moisture and extend its availability into dry seasons and periods of drought. When exotic vegetation, such as fruit trees is desired, focus its placement close to buildings where harvested greywater and roof runoff can easily meet the trees' higher water needs, and the people inhabiting the buildings can conveniently supply the trees' higher care needs, while enjoying the fruit.

Where streets act as urban ephemeral waterways, build on this role by planting the native vegetation found along natural ephemeral waterways along these urban waterways. Water-harvesting earthworks placed within public rights-of-way can create self-sustaining, flood-controlling, “greenfrastructure” that doubles as neighborhood-enhancing, pedestrian and bicyclist-friendly, cool-island green belts.

Lets harvest more water throughout the soils of our watersheds than we pump out. Let's give back more than we take. That's the stewardship path to abundance, and we begin by planting the rain.

RESOURCES

• *Rainwater Harvesting for Drylands, Volume 1: Guiding Principles to Welcome Rain Into Your Life and Landscape* by Brad Lancaster, Rainsource Press, 2006. www.HarvestingRainwater.com

• *Rainwater Harvesting for Drylands and Beyond, Volume 2: Water-Harvesting Earthworks* by Brad Lancaster, Rainsource Press, 2007. www.HarvestingRainwater.com

• Desert Harvesters. www.DesertHarvesters.org

• *City of Tucson Water Harvesting Guidance Manual* edited and illustrated by Ann Audrey, June 2003. http://dot.ci.tucson.az/stormwater/

• Seattle, Washington Public Utilities SEA Streets Project. Website: http://www.ci.seattle.wa.us/util/About_SPU/Drainage_&_Sewer_System/Natural_Drainage_Systems/index.asp. Progressive multi-use water harvesting/beautification/flood

control strategies in the public rights-of-way.

• Portland, Oregon Sustainable Stormwater Program featuring Natural Drainage Systems and more. Website: http://www.portlandonline.com/bes/index.cfm?c=34598 Progressive multi-use water harvesting/beautification/flood control strategies in the public rights-of-way and beyond.

• The Keeling Neighborhood Greenway in Tucson, Arizona. Website: www.drachmaninstitute.org. This greenway has yet to be implemented, but the plan can be found at the listed website under the "portfolio" section. It includes a lot of passive water harvesting off streets and sidewalks to irrigate native shade trees.

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