THE UNIVERSITY OF ARIZONA
Cooperative Extension

az1916 June 2021

Landscape Management Practices to Optimize Passive Rainwater Harvesting and Plant Health

Ursula K. Schuch and B. Grant McCormick

Rainwater harvesting is a sustainable way to augment or offset water for landscape irrigation and mitigate stormwater impacts in Arizona and the desert southwest. Annual evaporation in Arizona's low deserts is 70 to 80 inches, and precipitation ranges from 4 to 12 inches per year (AZMET), which creates the need for supplemental water to insure healthy plant growth for non-native plants and for native plants in challenging settings such as hardscape-intensive urban areas. Longer, hotter summers, increasingly unreliable patterns of rainfall (National Oceanic and Atmospheric Administration (NOAA) 2017), and increasing population (US Census Bureau, 2018) will require more water conservation measures to ensure sustainable growth and development of urban trees and forests. Water harvesting is an important water conservation method that can supplement other water sources, and is increasingly seen as a discrete supply of water.

Most landscape plants, especially trees planted in urban areas of arid regions, require supplemental water to establish and remain healthy under high heat loads of parking lots, buildings, and hardscapes. Trees are especially important in urban landscapes for their multiple environmental services, including shade, mitigating high temperatures, absorbing stormwater, filtering dust and noise, slowing wind, and giving shelter and food for wildlife. Choices made during the design and implementation of water harvesting landscapes impact the health and success of plants. This article focuses on designing, installing, and caring for passive rainwater harvesting systems to optimize plant success.

Water Harvesting Overview

Rainwater harvesting systems generally fall into one of two categories: passive water harvesting and active water harvesting.

Active water harvesting systems use a cistern or barrels to store water for later use (Fig. 1). This water is often harvested from roofs or other impervious areas and may require filters and other components to prevent debris from entering the system. Water can be distributed with a hose by gravity, or a pump may be installed if the water is used in a conventional irrigation system.

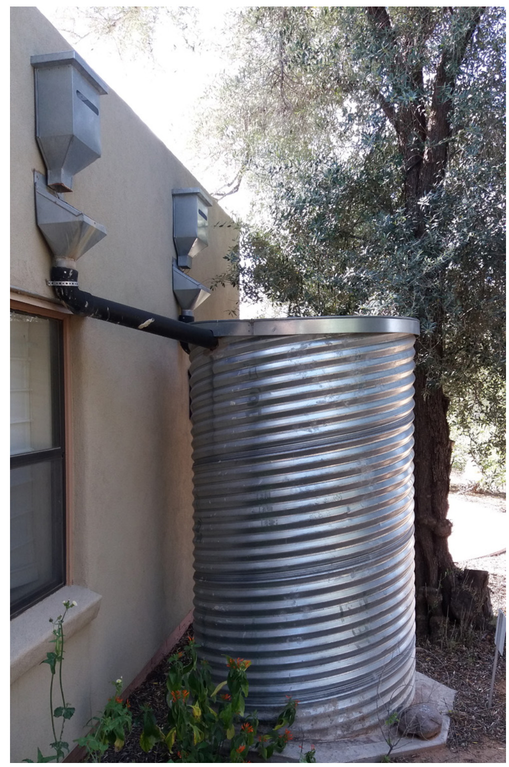


Fig. 1. Active water harvesting system.

Passive water harvesting systems use earthworks and other structures to create features such as basins and berms, facilitating water infiltration into the soil where plants can access it. In addition to infiltration features, other structures are used to guide water movement to desired locations, such as swales to move water to infiltration areas, and check dams that create a barrier to hold water in a basin while allowing it to overflow where desired. Passive water harvesting relies on gravity for water movement. Where properly implemented, it slows and spreads runoff, prevents erosion, and infiltrates the water on-site to be utilized for plant growth. In the example of passive water harvesting (Fig. 2), water runs off a roof into a gutter system, flows through a downspout, lands on a splash pad, flows into a basin, and infiltrates into the soil where plant roots can access it.

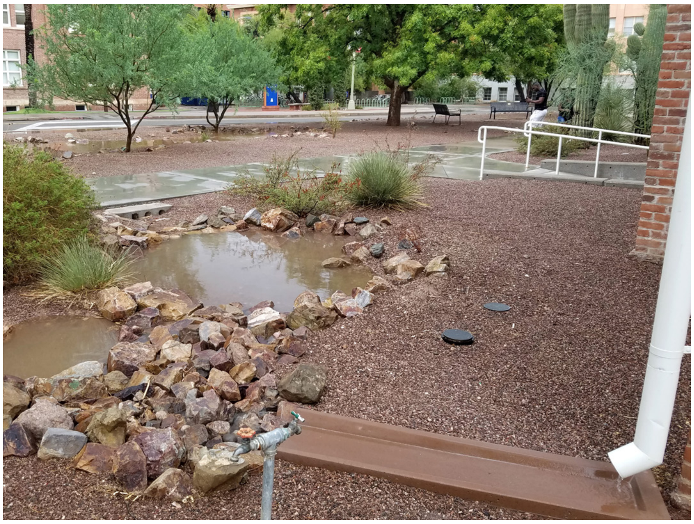


Fig. 2. Passive water harvesting system

Rainwater harvesting systems have been installed in the low desert in many public projects, neighborhoods, private residences, and commercial properties to supplement or replace their landscape irrigation and, in turn, use less potable water. The City of Tucson is a water conservation leader and was the first city in the United States to establish an ordinance requiring mandatory rainwater harvesting for commercial properties. This ordinance applies to commercial properties established after June 1, 2010. It mandates the capture of rainwater such that 50% of the landscape irrigation needs can be fulfilled from rainwater harvesting after a period of plant establishment (City of Tucson, 2008). Along with the building plans and the landscaping plan, a rainwater harvesting plan is submitted for approval, including a landscape water budget and an implementation plan on how water is captured and distributed. Successful rainwater harvesting in landscapes requires configuring impermeable surfaces and the soil grade to collect and direct water to areas where it will infiltrate and provide moisture in the root zone of plants strategically placed along the basins or conveyances.

Although a growing number of passive and active rainwater harvesting systems are being installed, landscape professionals and property owners may not be aware of best practices for installing and maintaining these systems to ensure proper functioning. Improper installation or maintenance of systems contributes to issues such as standing water, which may lead to mosquitoes breeding, water overflowing into undesired areas, water infiltrated in locations plants can't access, and erosion due to water velocity or steep slopes. Water may move eroded soil and gravel into streets, sidewalks, or other areas in the landscape, creating maintenance and safety issues and potentially damaging plants when excess soil is deposited around their base. Awareness of common problems causing rainwater harvesting inefficiencies or damage to trees and other vegetation can reduce future issues in landscapes and increase returns on investments in water harvesting systems.

Water Harvesting Issues Related to Plant Health

The following facts about plant root systems are relevant to optimize the health of plants supplied with harvested rainwater. Roots expand horizontally from the base of a plant, and for trees and large shrubs they grow primarily between the surface to a depth of 2-3 feet below the surface. Feeder roots, which are primarily located at the root system's growing edge, take up the majority of water and nutrients from the soil. They are often found near and beyond the drip line of the plant canopy. Supplemental irrigation water or harvested rainwater is ideally infiltrated where feeder roots can access it.

When trees are watered only near the trunk base even several years after planting, an extensive root system often does not develop and makes the plant vulnerable to blowing over. Ideally, a well-developed horizontal and vertical root system safely anchors the tree. Supplying irrigation throughout the root zone, especially where feeder roots are located, will promote further root growth in that area.

Moist soil, sediment, or organic matter accumulating at the base of a plant trunk can seriously compromise plant health. Plants have generally evolved with the below-ground woody root tissue adapted to being wet and in contact with the soil. The above-ground portions of plants are generally not adapted to constant contact with wet soil or water. Plant placement in landscapes where rainwater is harvested needs to ensure that the base of stems or trunks do not remain wet for long periods after rain events to prevent possible rot or plant failure. Take note of conditions where a particular plant grows naturally to inform decisions on placement of that plant relative to soil accumulation and moisture conditions. Some plants can thrive in areas where the soil stays moist, and sediment accumulates around the base, and their natural growing conditions are the best indicator of this.

The volume of soil available for tree roots to grow into is critical to allow trees to reach their full growth potential at maturity. Small planting cutouts, especially in parking lots, limit the tree root zone and the surface area for harvested rainwater to infiltrate. Tree roots need sufficient space to grow and expand, and water directed into infiltration areas should wet as much of the anticipated mature tree root zone as possible while not causing damage to the trunk base.

Guidelines for Healthy Plants in Water Harvesting Landscapes

- The plant palette of a water harvesting landscape should be suitable to the arid climate and available rainfall. Higher water use plants require supplemental irrigation on a separate valve to provide additional water.
- Choose appropriate positions for plants relative to the infiltration basin, e.g., on the rim, halfway on the slope, or upslope of the basin where appropriate. Some

plants can tolerate growing in basin bottoms, but that is generally not recommended for many plant types, especially trees.

- Place trees where their mature root system will be served by harvested water in basins at or beyond the mature canopy.
- Species selection needs to accommodate pedestrian, bicycle, and vehicle traffic, such that large or fast-growing, multi-trunk desert trees are placed far enough from sidewalks, bicycle paths, and roadways to prevent interference when they are mature.
- Rock and organic mulch should be kept away from the base of tree trunks or large shrubs to avoid physical damage and prevent susceptibility to disease.
- Program irrigation to turn on only if the irrigation needs of the plants are not met by rainwater harvesting.
- Rain gauges or soil moisture sensors connected to the irrigation system ensure that controllers are set to stop watering if there has been a rain event with sufficient water captured to infiltrate into the plant root zone. Program irrigation cycles to match seasonal evapotranspiration demand.

Examples of Rainwater Harvesting Best Practices and Possible Improvements

Many plants used in Southwestern urban landscapes require low or medium amounts of supplemental irrigation water and are well suited for water harvesting landscapes. Irrigation should be based on the plant's evapotranspiration, which is an estimate of how much water evaporates from the soil and transpires from the plant. Some trees are adapted to the Southwest's dry climate and may grow with harvested rainwater only once they are successfully established. The best chances for successful growth and health of trees occurs when there is a sufficiently large root growth zone where harvested water infiltrates throughout much of that root zone. The size, shape, depth, and location of basins, plant placement, grading at the site, and maintenance of the infrastructure influence how well a rainwater harvesting system will work.

The following are visual examples with descriptions of best practices and areas that would benefit from modifications for optimal rainwater harvesting and plant health.

This shallow infiltration basin (Fig. 3) is at and beyond the tree canopy's dripline to maximize access to harvested water for the roots. The tree's base is set slightly higher than the surrounding basin to avoid keeping the trunk base wet for too long.

A broad, shallow basin spreads the water over a large soil area to maximize infiltration (Fig. 4). Ideally, the barrel cacti would have been placed higher up on the slope so that they would receive less water and avoid the risk of rotting.

A number of rock check dams were added to an existing swale (Fig. 5), which previously allowed all the water to flow to one low point in the distance. The check dams slow the water flow and allow infiltration near plants rather than letting all the water runoff quickly.

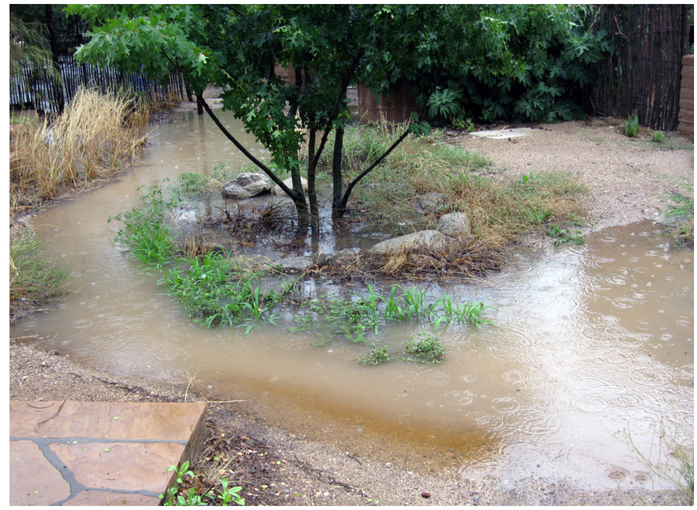


Fig. 3. Passive rainwater harvesting to store moisture in the tree root zone

Fig. 4. Plant placement adjacent to infiltration basins

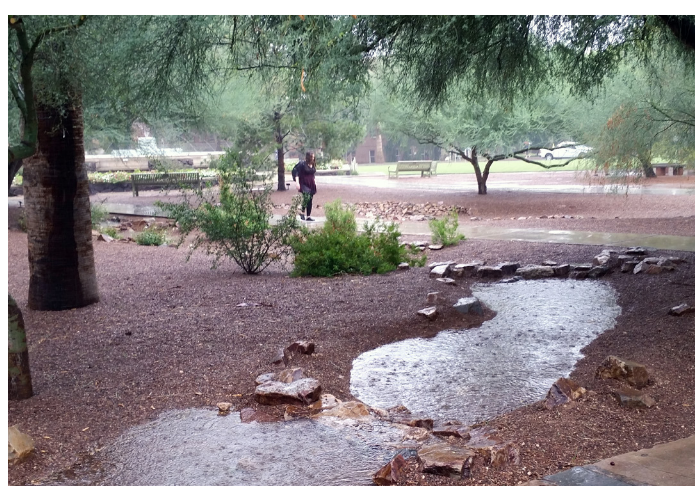


Fig. 5. Check dams separate infiltration basins.

This street without curbs is sloped to allow water to drain into the landscaped median, where there is a broad, shallow basin that spreads the water out in a large area for infiltration and root growth (Fig. 6).

A street edge basin fed through a curb core opening (Fig. 7). A small number of herbaceous perennials and a shrub occupy the small basin that corresponds to the limited water flow accommodated through the curb core opening.

This planting area in a commercial development receives rain runoff from the parking lot on the right (Fig. 8). Rip rap rock is used where water flows into the basin to slow the water and prevent erosion, while the basin bottom is relatively level and broad to allow the water to spread out and infiltrate over a large area. Plants are positioned for roots to reach infiltrated water but are not planted in the basin's lowest spot.

The broad, shallow basin (Fig. 9), allows a large volume of parking lot runoff to infiltrate over a large area of landscape, utilizing the full right-of-way. The design could be further enhanced through subtle undulations in the grade and introducing plants within the basin. Runoff from parking lots

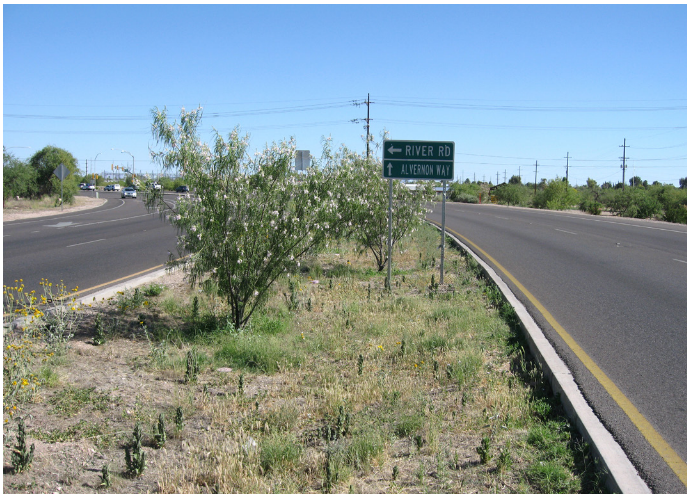


Fig. 6. Rainwater harvesting from street surfaces

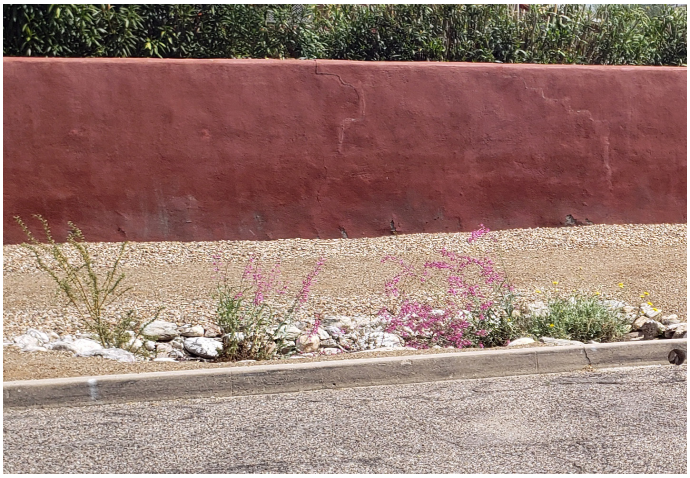


Fig. 7. Curb core inlet channels water from the street into the basin.

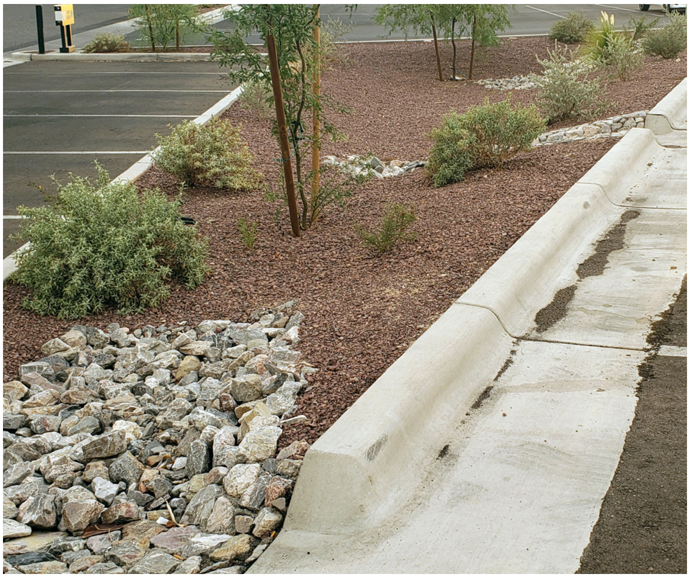


Fig. 8. The design and installation of this infiltration basin captures runoff from the parking surface through several curb inlets which are secured with rocks to prevent soil erosion.

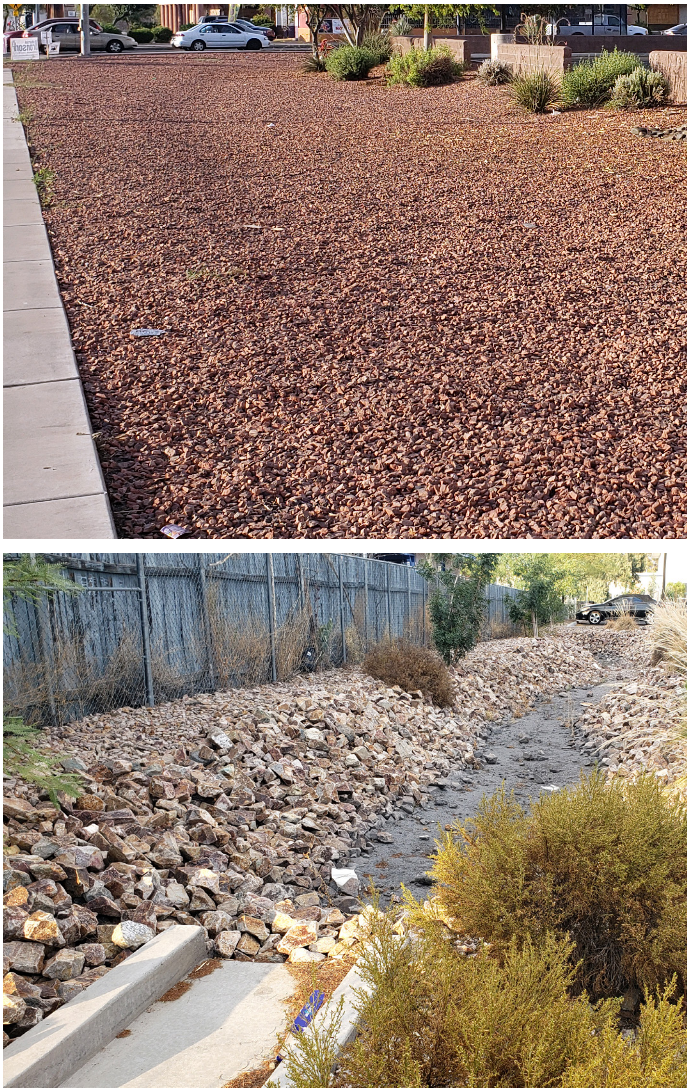


Fig. 9. Runoff from the parking lot flows into a large, shallow basin (above) and into a smaller basin (below).

includes pollutants from the parking lot surface. Plant roots can help break down pollutants and generally are not harmed.

Shallower basins between 6″ and 12″ depth are safer in areas of high pedestrian traffic such as this public plaza (Fig. 10). Depending on the plant types and density, and the amount of runoff, basins often do not need to be very deep.

Missed opportunity in this large stormwater detention basin to capture rainwater for plants (Fig. 11). Although a significant amount of water can infiltrate in the bottom of the basin (circled with a black line), much of the vegetation is too far away to access the water. Placement of smaller water infiltration areas on the slopes would allow roots of nearby plants to reach collected water before it spills over to the bottom during larger storm events.

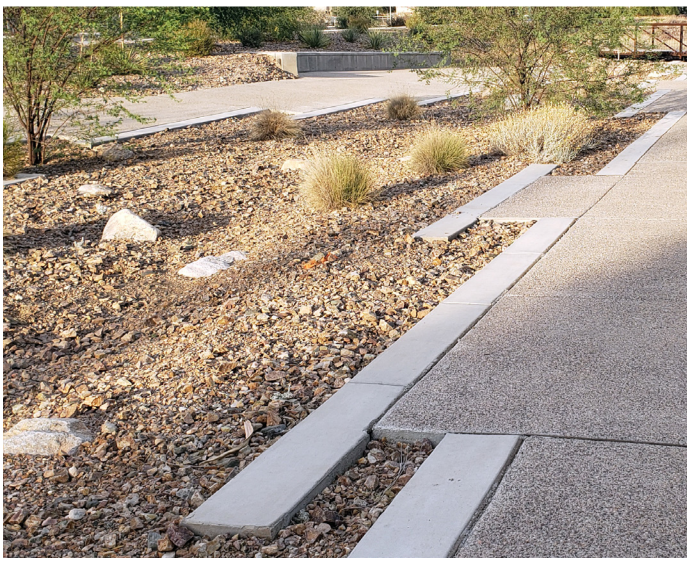


Fig. 10. Shallow basin in public pedestrian area

Fig. 11. Infiltration basin (inside black line) with scarce access by plant roots.

An example of street edge curb cut allowing water to flow into a basin (Fig. 12). The tree placement would be better to the left or right of the curb cut, either within or above the basin, which would allow roots to grow into the basin to access water, providing a more sustainable root structure. As planted, the tree will receive runoff before the rest of the basin even during small rain events and will stay wet longer.

This, combined with accumulation of sediment and organic matter around the base of the trunk increases the likelihood of tree failure.

This tree, now only present as a stump, grew too large and partially blocked large trucks servicing this business (Fig. 13). Because of extensive branch damage, it was eventually removed. Although the planting area and infiltration area are generous, the final spread of this palo verde tree canopy was interfering with traffic, emphasizing the importance of considering the final tree size at planting time and tree placement in relation to driveways or roads.

Fig 12. Street edge basin with large curb cut

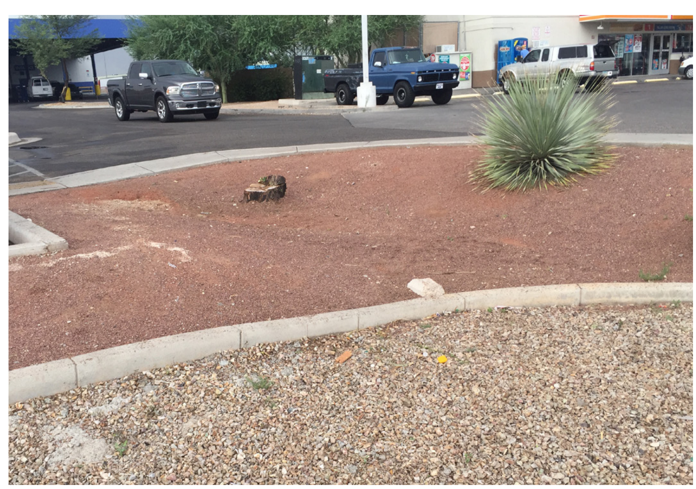


Fig. 13. Stump indicating former presence of palo verde tree.

Cause of tree removal is unknown, but the parallel curb cuts, which drained water quickly from the basin, may have contributed (Fig. 14).

Riprap around the base of trees can damage trunks, especially of fast-growing species (Fig. 15). Placement of the tree directly where water moves into a basin is not ideal because the trunk will tend to stay wet and accumulate sediment around the base. Placing the outflow from the basin not across the inflow may retain water longer in the area.

Two views of the same basin, one dry and one wet (Fig. 16). This large water infiltration basin receives drainage from multiple sources, surface runoff, and a drainage pipe. Trees are planted on the slope of the basin and are thriving. Their roots can reach infiltrated water while the position of the trunks allows them to not remain wet, thereby avoiding potential rot issues. The basin bottom is bare soil. The water infiltration function of the basin bottom would be enhanced by the addition of appropriate plants, such as grasses, which can withstand such moist conditions. Habitat and aesthetic values could also be promoted through addition of such plants.

This shallow wide basin with rock gravel mulch captures runoff from adjacent hardscape surfaces (Fig. 17). The infiltration surface area and root zone area for trees and shrubs is large. Due to shallow side slopes, the basin did not need edging with larger rocks.

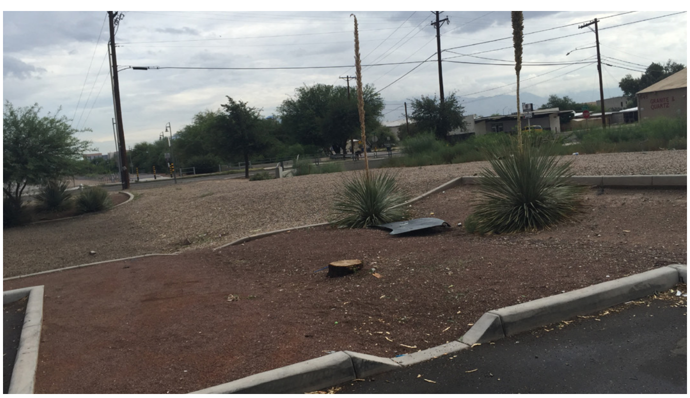


Fig. 14. Stump indicating previous tree in planting area.

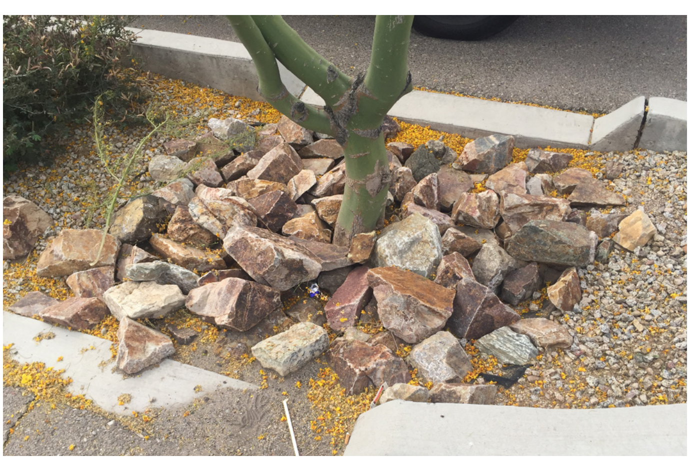


Fig. 15. Parallell curb cuts in a small planting island and riprap on top of the tree root zone.

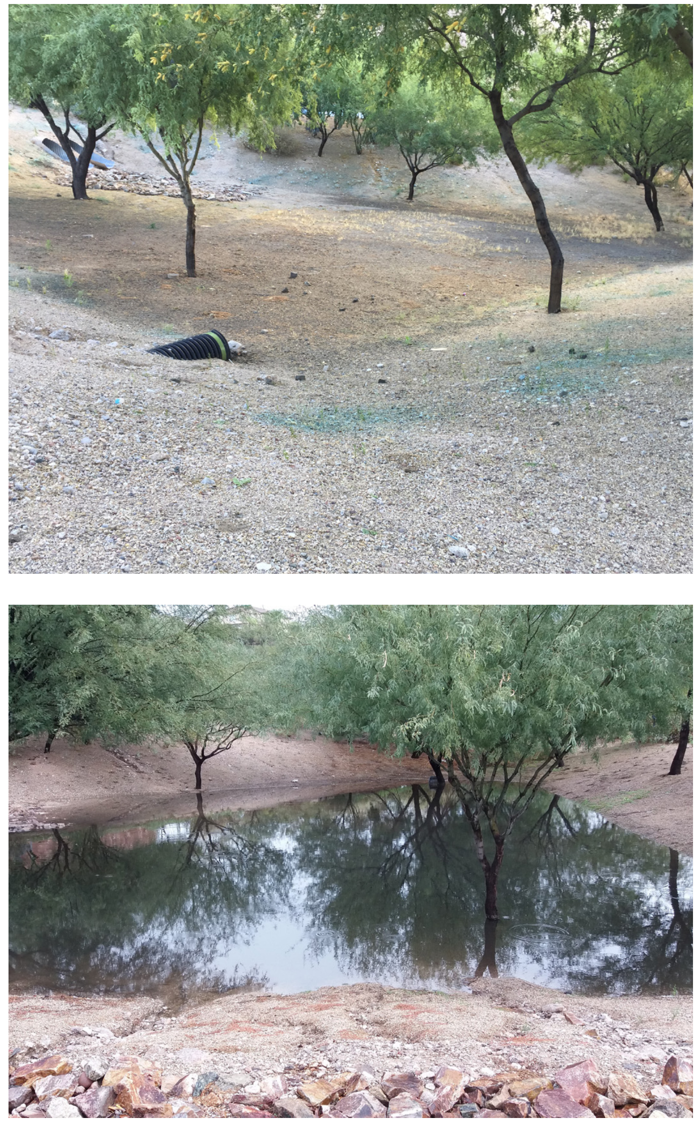


Fig. 16. Large detention basin without (above) and with runoff (below) after a rain event.

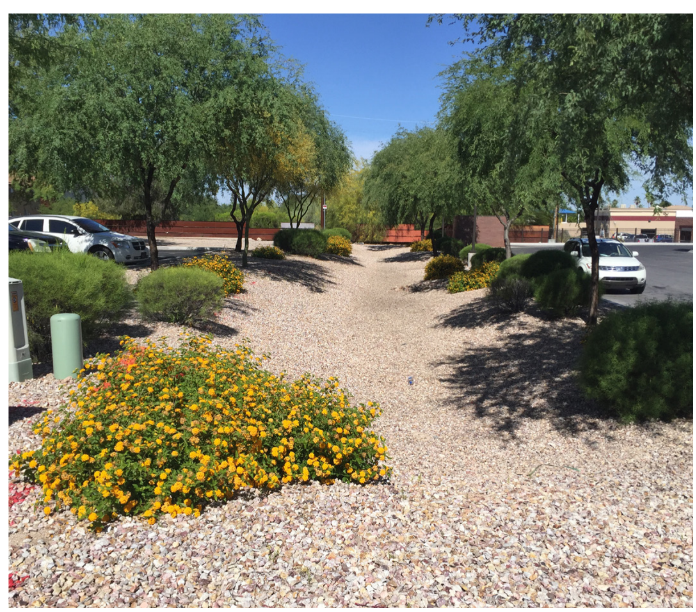


Fig. 17. Effective harvesting of runoff from multiple sources.

Drainage volume cannot move fast enough into the rainwater harvesting infiltration area on the other side of the wall (Fig. 18). Redesign of flow from the parking lot to basins could enhance the design, allowing the water to pond in the landscape instead of the parking lot.

The inlets of surface runoff from two parking areas are secured with large rocks to prevent erosion, although one shows signs that maintenance is needed (Fig. 19). The water infiltration area, once full, will drain into a culvert just below street level. This area could be enhanced by making the basin bottom a few inches lower as well as planting grasses or other flood-tolerant plants in the basin bottom along with trees and other xeric plants on the slopes of the basin.

Trees, shrubs, and other plants can be planted at the slope, the top, or parallel to the infiltration basin (Fig. 20, 21). Plants will thrive as long as their roots have access to the soil moisture and are not inundated for long periods of time, especially if they cannot tolerate those conditions.

Rainwater harvesting basins have appropriate inlets to capture runoff, however, in both cases the soil surface is too high on the basin side, preventing water from flowing into

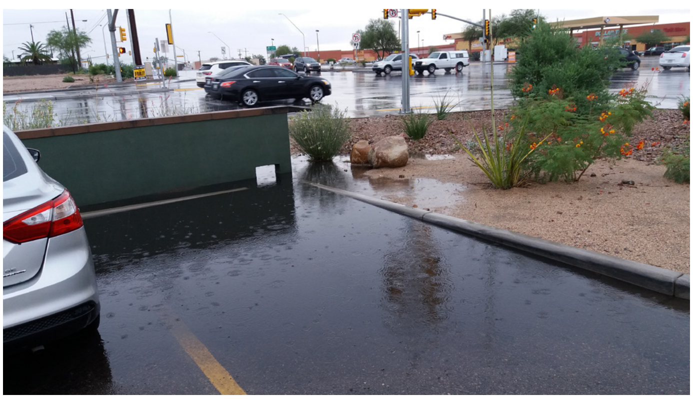


Fig. 18. Insufficient drainage into the basin.

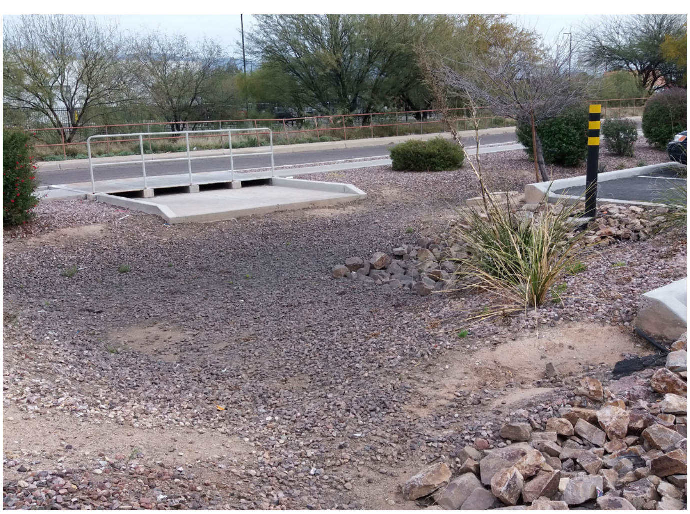


Fig. 19. This large, deep basin will overflow into a culvert to prevent flooding of the adjacent street.

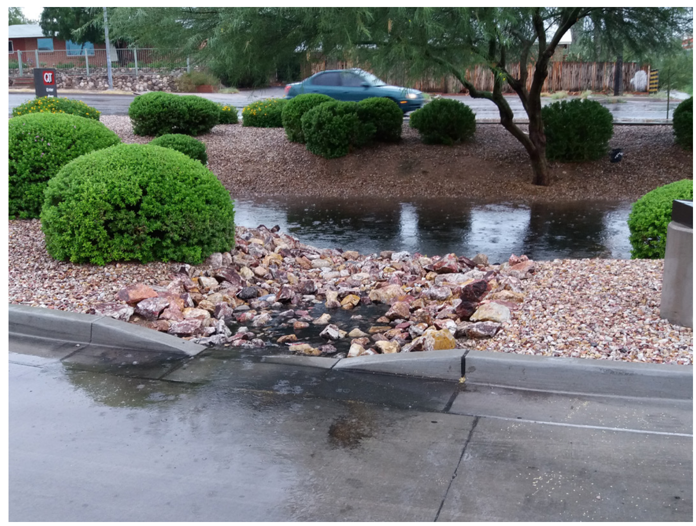


Fig. 20. Trees and other plants thrive on the slopes and the top of these infiltration basins shown after a rain event.

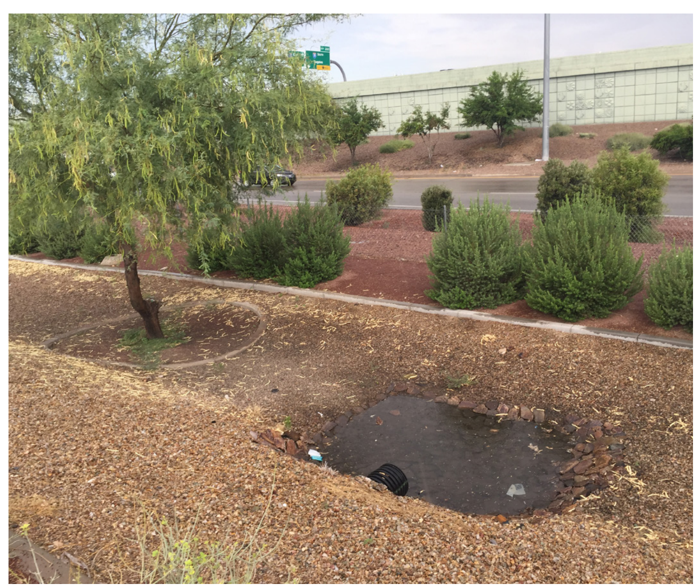


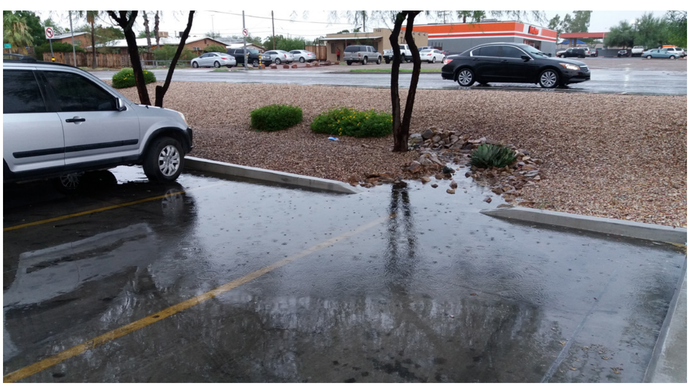
Fig. 21. Parallel placement of the infiltration basin to the tree supplements the root zone of the tree without excessive moisture at the trunk base.

the basin and infiltrate (Fig. 22). Rock mulch on top of the soil may contribute to a shallow or incorrect grade of basins. Regrading would be necessary to make these water harvesting areas functional.

These are examples of missed opportunities for more effective rainwater harvesting. The basins could have been much wider to take advantage of the large area within the street right-of-way (Fig. 23). More water could infiltrate in wider basins and more plants could be installed.

Curb cuts can be narrow or wide, with wide ones accommodating greater volumes of water to enter the infiltration area. Planting islands in parking lots have one, two or three inlets/outlets (Fig. 24). The amount of captured water that can infiltrate into the soil depends on the grading of the water harvesting area directing water into the island, grading of the surface inside the planting island, depth of the island retaining water and placement of the outlets in addition to soil texture and structure.

Although runoff water in this design flows (blue arrow) across soil, very little water will be harvested due to the higher elevation of soil throughout most of the planter (Fig. 25). For effective water infiltration, the majority of the soil (yellow oval) should be lower than the curb inlet and outlet, except where the tree trunk meets the ground, which should be elevated slightly. The green arrows indicate how water could spread if the infiltration basin (yellow oval) would be lower than both



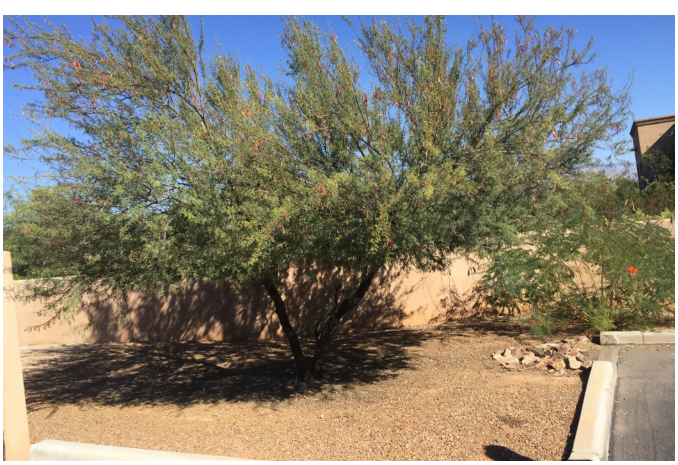


Fig. 22. Improper grading of the infiltration area prevents effective water harvesting

Fig. 23. Narrow infiltration basins

curb cuts.

Appendix 1: Tips for Design, Construction, and Care for Passive Water Harvesting Systems

- The location of water infiltration areas should not interfere with pedestrians, vehicles, building foundations, or other structures.
- An estimate of how much water will be collected from roofs or other impenetrable surfaces, such as driveways or roads, assists in planning the appropriate size of:
  a. active water harvesting systems, including how to distribute the water in the landscape
  b. the extent of passive water harvesting systems such as basins and conveyances to collect and direct the flow of water for optimal landscape benefits.
- Grading of impervious surfaces and landscape runoff collection surfaces on the site needs to direct water to

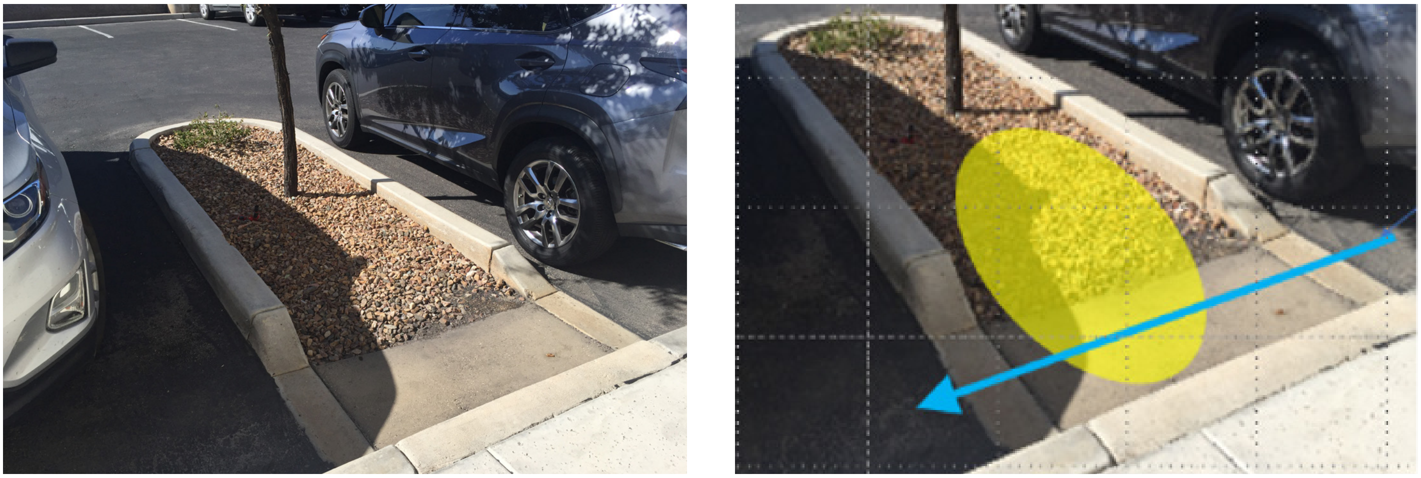


Fig. 24. With this design, water flows (blue arrow) past the planter due to the elevation of the concrete slab and the soil. For effective water infiltration, the concrete slab and soil (yellow oval) should be lower than the curb inlet and outlet.

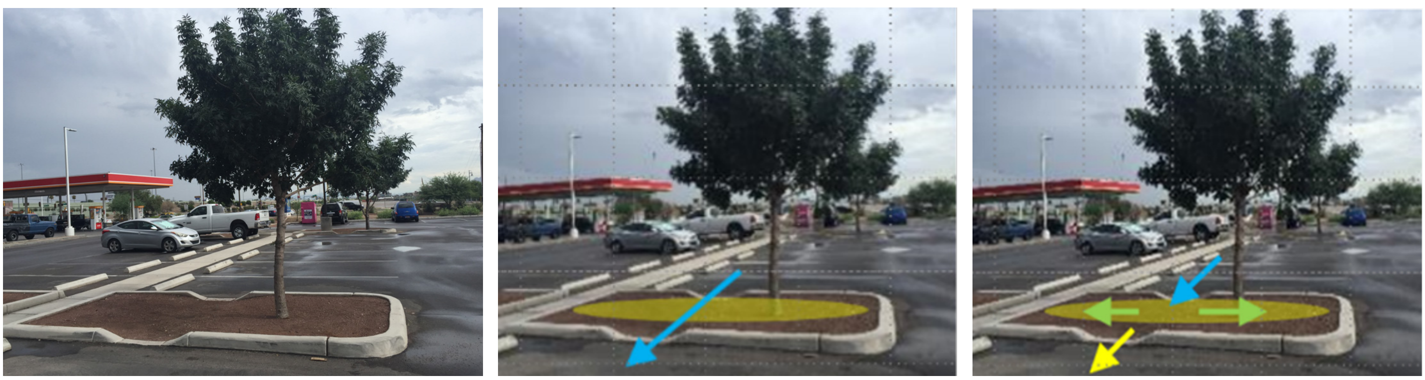


Fig. 25. Water harvesting in this planter is not effective and can be optimized by lowering the soil surface level.

flow by gravity to the infiltration areas.

- The ponding depth of basins (the difference between basin bottom and spillway) and their horizontal extent can be used to estimate basin storage volume. Basin volume should be designed to hold and infiltrate expected runoff and allow excess runoff to overflow into other downstream basins. The extent of basins and conveyances will be property-specific and depend on where the water will be distributed, where plants will be located, and the infiltration rate of the soil.
- Channels, swales, and other conveyance features that direct water from runoff areas and infiltration features, and between infiltration features, may be lined with rocks if necessary to mitigate high-velocity water flow or steep slopes. Check dams at grade transitions can convert a sloping channel or swale into a series of level basins, allowing improved infiltration and accommodating overflow along the expected flow path. In such cases, larger rocks are not needed on the basin bottom since the erosive force of water is focused at the armored check dams, and rocks on the basin bottoms can inhibit infiltration.
- Lining inlets, spillways, and conveyances with rocks can prevent erosion or scouring.
- Basins should be at least 6 inches deep to effectively collect water and up to 12 to 18 inches in areas where large volumes of water need to be concentrated in a small area. Basins with a depth of one foot or greater may present safety issues, including drowning or mosquito breeding in poorly drained soil, and may restrict access to the landscape. For example, in Tucson's Commercial Water Harvesting requirements, the ponding depth of water in a rainwater harvesting basin cannot be more than 8 inches. Check whether there are specifications regarding basin depth or depth of standing water in your area.
- Water from basins has to drain within 24 hours after a rain event; otherwise, soil must be treated to improve infiltration. Infiltration rate requirements vary by jurisdiction, so be sure to check your local building standards.
- To ensure proper infiltration, fine sediment should be kept from washing into the basin, and the bottom of basins should be free of larger rocks, which can allow

sediment to clog pore spaces between rocks.

- Organic mulch can be used in the basin bottom at a depth of 2-4 inches, provided it will not be washed away during heavy rains and will not reduce the water holding capacity of the basin.
- Basin bottoms should be level throughout in order to evenly distribute collected water through the soil surface.
- Basin sides should be sloped and secured with rocks 4 inches or larger to maintain the integrity of the slope and prevent erosion except for cases where the side slopes are very gentle.
- Overflow structures such as check dams, which direct flow out of basins, should be placed at least 6 inches above the bottom of the basin to allow water to slow down, pond, and infiltrate. Overflow needs to pass below the top of the basin rim to prevent damage to the basin and prevent overflow into undesired areas.
- To ensure optimal water collection and infiltration, periodically inspect and maintain water harvesting infrastructure to identify issues such as erosion or overflow occurring where not desired. Erosion of soil particles into the water harvesting infiltration area will reduce the effective harvested volume of water over time, especially during heavy rains.
- Removing debris from culvert inlets and fixing rock lining of basins, inlets, spillways and conveyances is key to maintaining functionality of the water harvesting system.

References

Arizona Meteorological Network. AZMET. https://cals.arizona.edu/AZMET/

City of Tucson, 2008. Rainwater Harvesting Ordinance No. 10597.

Lancaster B. 2014. Rainwater Harvesting for Drylands and Beyond Vol. 1, 2nd Edition. Tucson, AZ: Rainsource Press. 281p.

National Oceanic and Atmospheric Administration 2017. State climate summary Arizona. September 27, 2019. https://statesummaries.ncics.org/chapter/az/

US Census Bureau. 2019. Quickfacts Arizona. September 27, 2019. https://www.census.gov/quickfacts/AZ.

Watershed Management Group. 2017. Green Infrastructure for Desert Communities. Vers. 2.0. https://watershedmg.org/learn/resource-library

Waterfall P., 2006. Harvesting Rainwater for Landscape Use. Univ. of Arizona Cooperative Extension, 2nd. Ed., Publication 1344. https://extension.arizona.edu/sites/extension.arizona.edu/files/pubs/az1344.pdf.

Acknowledgement

The Arizona Department of Forestry and Fire Management and the U.S. Forest Service supported this work with grant CCG 18-101. We thank Tucson Water for their collaboration.

Image 1, 16b, 18, 20, 21, and 22a are courtesy of Jeffrey Gilbert.

THE UNIVERSITY OF ARIZONA
Cooperative Extension

AUTHORS

URSULA K. SCHUCH
Professor and Specialist, Environmental Horticulture, School of Plant Sciences

B. GRANT MCCORMICK
Adjunct Professor, Water Harvesting & Green Infrastructure, Department of Environmental Science

CONTACT
URSULA K. SCHUCH
uschuch@arizona.edu

This information has been reviewed by University faculty.
extension.arizona.edu/pubs/az1916-2021.pdf

Other titles from Arizona Cooperative Extension can be found at:
extension.arizona.edu/pubs