



**GREEN
RESERVE**

The American Recovery and Reinvestment Act (ARRA), Green Project Reserve of 2009, through the State Revolving Fund, provided funding for a wide variety of qualifying projects in the categories of: *green infrastructure, energy efficiency, water efficiency, and other innovative projects.*

Green Infrastructure in Arid and Semi-Arid Climates



Adapting innovative stormwater management techniques to the water-limited West.



“Green infrastructure” may seem incongruous with the landscapes of the arid and semi-arid West, but forward-thinking communities in these water-limited regions are increasingly recognizing green infrastructure as a cost-effective approach to stormwater management that conserves water supply.

In arid and semi-arid regions, many green infrastructure practices will not be green at all.

When rain falls on undeveloped landscapes in the arid and semi-arid West, much of it is absorbed into the soil, and only a small portion flows into washes, arroyos, creeks, or streams. The rain that is absorbed into the soil either percolates to the groundwater or is evapotranspired into the atmosphere. By armoring the land with rooftops, roads, and parking lots, we dramatically change this balance. Much less precipitation infiltrates into the soil, and much more becomes stormwater runoff. “Gray” stormwater infrastructure

channels urban runoff into conveyance systems and receiving waters, increasing pollutant delivery and flood flows. These changes, in turn, increase erosion and degrade water quality. Green infrastructure refers to a set of practices that recognizes the connection between runoff quantity and water quality, and seek to maintain the natural water balance. By promoting infiltration and evapotranspiration as well as storage, green infrastructure reduces, retains, and treats runoff at its source.

Although many green infrastructure practices were first developed and applied in temperate, coastal states, green infrastructure approaches can restore hydrology and water quality in arid and semi-arid regions as well. Indeed, forward-thinking communities, researchers, and design professionals in these water-limited regions are increasingly recognizing green infrastructure as a cost-effective approach to both stormwater management and water conservation. This guide discusses how green infrastructure can be adapted to arid and semi-arid climates, reviews potential legal

In the 1920s, approximately 5% of precipitation in the Los Angeles region flowed to the sea. Today, extensive impervious cover and massive stormwater conveyance systems deliver 50% of the rain falling in the region to the sea. (Green, 2007)

constraints, and describes the myriad benefits of green infrastructure approaches.

ADAPTING GREEN INFRASTRUCTURE TO CONSERVE WATER SUPPLY

Water is a precious and limited resource in the arid and semi-arid West. As populations expand, groundwater resources are depleted, and climate variability increases, communities are increasingly struggling to balance water supply and demand. Green infrastructure can conserve water resources while preserving water quality. The following sections describe several green infrastructure practices that may be appropriate in arid and semi-arid regions, and review design adaptations that promote water conservation.

PASSIVE RAINWATER HARVESTING

Passive rainwater harvesting refers to the design of developed sites to collect runoff generated by impervious areas and direct it to nearby landscaped areas. These techniques can significantly improve water quality while dramatically reducing water demand. In the arid and semi-arid West, water use for landscape irrigation constitutes a large proportion of municipal water demand—particularly in the summer months. In Tucson, AZ, for instance, 40% of potable water usage is allocated to landscape irrigation.

Passive rainwater harvesting can be simple or complex, and can be designed for large-scale landscapes such as commercial sites and parking lots, or small-scale landscapes such as homes and gardens. All designs, however, are based on three simple components: a catchment area that collects rainwater, a distribution system that connects the catchment to the receiving landscape area,

and a receiving landscape area that can retain and infiltrate rainwater.

- The catchment area is any impervious area from which rainwater can be harvested—typically a roof, street, or parking lot. The volume of water harvested will depend on the surface area, texture, and slope.
- Distribution systems are generally based on the thoughtful siting and design of building components and landscape features, and are seldom highly engineered. Homeowners can distribute rooftop runoff to landscape areas by directing gutters and downspouts to these areas, while larger sites can connect catchment areas to landscape areas with standard or perforated pipes. In large parking lots, the topography can be manipulated to drain water to landscaped areas throughout the site. Slightly more complex systems include curb cutouts and channel systems.
- Receiving landscape areas are generally concave, planted areas with edges that retain runoff. If a layer of precipitated calcium carbonate, or caliche, occurs in site soils, some excavation may be required to increase rooting depth and infiltration capacity. If site soils are poor, soils may be amended with organic matter to increase water retention. The principles of xeriscaping should be applied to reduce the amount of water required to maintain a healthy landscape. Although all planted areas will likely require one to three years



Passive rainwater harvesting in Tucson, AZ. Photo courtesy of Watershed Management Group.



Active rainwater harvesting at Taxi Redevelopment in Denver, CO. Photo courtesy of Wenk Associates.

ADAPTING GREEN INFRASTRUCTURE TO CONSERVE WATER SUPPLY

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Active Rainwater Harvesting in Tucson, AZ.



Subsurface Infiltration Basin in Rancho Mirage, CA. Photo courtesy of RGA Landscape Architects.

of irrigation after planting, subsequent water requirements can be dramatically reduced, if not eliminated, by selecting native or desert-adapted plants and controlling plant densities. Organic mulch can also increase water retention, while building soil structure and suppressing weeds. Because arid and semi-arid regions often experience infrequent, high intensity storms, receiving landscape areas should be able to accommodate too much water as well as too little. The ponding depth should allow all stormwater to infiltrate within 12 to 24 hours, and overflow mechanisms should be provided to allow excess stormwater to overflow safely to other locations.

- Two variations on the receiving areas described above are French drains (trenches filled with gravel) and pervious paving materials. Water directed to French drains and areas covered with pervious paving materials can infiltrate into the soil to irrigate plants with large, extensive root systems. Note that accumulated sediment can potentially diminish the performance of both of these techniques, and regular maintenance will be required to maintain infiltration rates.

The principles above are most effective when they are designed as a system and applied across a neighborhood or watershed. One example of a neighborhood-scale system is the development of “green streets.” Green streets integrate a series of distribution systems and landscaped areas into the street design to retain and treat stormwater while beautifying streets and slowing traffic. Rainwater can be drawn into landscaped rights-of-way, medians, traffic circles, and chicanes by cutting existing curbs or installing curbs flush with the ground.

For more information on passive rainwater harvesting, see the City of Tucson’s comprehensive Water Harvesting Guidance Manual, available at <http://dot.tucsonaz.gov/stormwater/education/waterharvest.php>

ACTIVE RAINWATER HARVESTING

Active rainwater harvesting reduces stormwater runoff and municipal water demand by storing rainwater from rooftops or other impervious surfaces for later use. Rainwater may be stored in rain barrels, above-ground cisterns, or below-ground tanks for outdoor or indoor uses compatible with local codes. The appropriate storage volume will depend on roof area, rainfall, available space, and site-specific conditions, as well as the system objectives. Whereas smaller rain barrels can provide modest reductions in runoff volume and irrigation demand, larger rain cisterns or tanks can capture most rooftop runoff and supply much of the irrigation demand. A 2007 study prepared for the Colorado Water Conservation Board, for instance, found that a 5,000-gallon cistern paired with water-wise landscaping could provide 50% of the irrigation demand for a 7,000-square-foot lot in Douglas County, CO. The cost of storage systems, however, increases significantly with storage volume—particularly for underground storage construction. In sizing rainwater harvesting systems, site owners must balance the multiple benefits of stormwater retention and water conservation against the costs.

SUBSURFACE INFILTRATION BASINS

Subsurface infiltration basins represent another approach to green infrastructure that manages stormwater while potentially conserving water supply. Subsurface infiltration basins are large storage structures (often tens of thousands of gallons) installed below the ground that receive stormwater runoff from nearby sites and allow the stormwater to percolate into the soil. These structures require soils with adequate percolation rates. Although not appropriate for all urban areas, where soils are adequate and land is expensive, these structures are cost-effective. Subsurface infiltration basins may also conserve water supply by recharging groundwater reserves. The potential groundwater recharge benefits of green infrastructure practices is discussed in the section, “The Multiple Benefits of Green Infrastructure.”

ADAPTING GREEN INFRASTRUCTURE TO CONSERVE WATER SUPPLY

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Green roof atop the EPA Region 8 office in Denver, CO. Photo courtesy of Greg Davis.

GREEN ROOFS

When designed appropriately, green roofs may offer a water-efficient approach to urban stormwater management in arid and semi-arid regions. As in temperate regions, green roofs in arid and semi-arid regions reduce and treat stormwater runoff. The green roof installed atop the EPA Region 8 Office in Denver, CO, for instance, retains more than 80% of the rainfall it receives. Though green roofs in arid and semi-arid regions will require irrigation throughout their lifetimes, water efficiency can be significantly increased by adapting green roof designs. Irrigation requirements can be dramatically reduced by increasing growing media depth, planting native and drought-adapted species, and applying drip irrigation. Municipal water demand can be further reduced by installing systems that irrigate green roofs with harvested stormwater runoff or AC condensate.

When installed in appropriate settings, green roofs may also represent a cost-effective approach to urban stormwater management. The cost-effectiveness of a given green roof

installation depends on the benefits offered by the green roof, as well as the value placed upon those benefits. Green roofs not only retain and treat stormwater, but conserve energy, reduce heating and cooling costs, reduce the urban heat island effect, sequester CO₂, provide habitat, and extend the lifetime of the roof. While conventional roofs typically require replacement every 10-20 years, green roofs typically require replacement every 40-50 years. In dense, urban settings, green roofs also provide valuable recreational space and can reduce stormwater management costs by reducing or eliminating the need for stormwater vaults or ponds. The green roof atop the EPA Region 8 Office in Denver, CO, for instance, reduced the cost of the below-ground stormwater detention vault from about \$363,800 to \$150,000.



RAINWATER HARVESTING AND WATER RIGHTS

Green infrastructure approaches in the arid and semi-arid West must adapt to legal as well as technical constraints. In many western states, water law is based on the doctrine of prior appropriation. According to this doctrine, the diversion and use of state waters requires a water right, and water rights are allocated based on the time of appropriation (“first in time, first in right”). The application of this doctrine to rainwater harvesting raises several questions. Does the state have jurisdiction over precipitation? Does active rainwater harvesting require a water right? The answers are different for each state, and in many states the answers continue to evolve. While some states have developed laws and policies that promote

rainwater harvesting, others are extremely restrictive, and still others have no formal policy at all. The table below summarizes the present stance of 11 western states toward rainwater harvesting.

The table identifies the agency responsible for the administration and enforcement of state water law, reviews whether the state has jurisdiction over atmospheric rainwater, reviews whether a permit would be required to harvest and use rainwater, and states who may apply for rainwater harvesting permits if they are required. The final column lists relevant state policies and incentives.

State	Responsible Agency	Jurisdiction over Atmospheric Water?	Permit Required?	Who May Apply for Permit
Arizona	Arizona Department of Water Resources	No	No	N/A
California	California Environmental Protection Agency, Division of Water Rights	No	No	N/A
Colorado	Colorado Division of Water Resources	Yes	Yes. Colorado law identifies properties that may apply for a permit.	1. Residential properties that are supplied by a well (or could qualify for a well permit) and that are not served by a municipality or water district. 2. Developers wishing to apply for approval to be one of 10 statewide pilot projects.
Idaho	Idaho Department of Water Resources	No	No	N/A
Montana	Montana Department of Natural Resources & Conservation, Water Resources Division, Water Rights Bureau	Yes	Yes	No formal policy.
Nevada	State of Nevada, Department of Conservation & Natural Resources, Division of Water Resources	Yes	Technically, yes	Applications not accepted.
New Mexico	New Mexico Office of the State Engineer	No	No	N/A
Oregon	Water Resources Department	Yes	No. Oregon law exempts “the collection of precipitation water from an artificial impervious surface” from permit requirements.	N/A
Utah	Utah State Engineer	Possibly	Yes	No formal policy.
Washington	Washington Department of Ecology	Possibly	No	N/A
Wyoming	State Engineer and Wyoming Board of Control	Yes	Technically, yes, but residential rainwater harvesting is regarded as de minimus	No formal policy.

RAINWATER HARVESTING AND WATER RIGHTS

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Many states and municipalities recognize the vast gains in water efficiency that rainwater harvesting can provide, and have decided to play an active role in promoting this practice to

conserve water supply. The table below reviews some of the innovative policies and incentives that Western states and municipalities have adopted to promote rainwater harvesting.

State	State/Municipal Policies and Incentives
Arizona	<p>A state tax credit is available for plumbing stub outs and water conservation systems (including rainwater harvesting) through 2011.</p> <p>The city of Tucson mandates that commercial developments meet 50% of their landscaping water requirements with harvested rainwater.</p>
California	<p>A draft Los Angeles ordinance would require builders to employ rainwater storage tanks, permeable pavement, infiltration swales, or curb bumpouts to manage 100% of the runoff from a 3/4" storm, or pay a mitigation fee.</p>
New Mexico	<p>The New Mexico State Engineer issued a Rainwater Harvesting Policy encouraging "the harvesting, collection, and use of rainwater from residential and commercial roof surface for on-site landscape irrigation and other on-site domestic uses."</p> <p>Santa Fe County's Water Harvesting Ordinance mandates the use of rain barrels, cisterns, or catchments for small residences, and the use of buried or partially buried cisterns for large residences and commercial buildings.</p> <p>The Albuquerque Bernalillo County Water Utility Authority offers rebates for rainwater harvesting systems based on the amount of water that can be stored.</p>
Oregon	<p>Building Code OPSC 08-01 allows rainwater harvesting systems for residential, potable uses as a statewide alternative method.</p>
Washington	<p>The Washington Department of Ecology issued an Interpretive Policy Statement clarifying that a water right is not required for rooftop rainwater harvesting.</p> <p>Kitsap County offers a 50% reduction in stormwater management fees to new or remodeled commercial buildings that utilize rainwater harvesting.</p>



THE MULTIPLE BENEFITS OF GREEN INFRASTRUCTURE



Although this guide emphasizes the stormwater quality benefits of green infrastructure practices, green infrastructure can provide myriad environmental, social, and economic benefits.

ENVIRONMENTAL BENEFITS

- Provide habitat: Native and drought-adapted plants that thrive on infrequent precipitation can provide habitat for native birds and insects.
- Reduce the urban heat island effect: Removing pavement and planting vegetation can cool and shade urban neighborhoods in the hot summer months.
- Increases groundwater recharge: In many cities and towns in the arid and semi-arid West, impervious cover and engineered conveyance systems reduce the amount of precipitation that enters the groundwater store. Green infrastructure practices that reduce impervious cover and enhance infiltration can increase the flow of water to the groundwater store. The Los Angeles Basin Water Augmentation Study or WAS

(2010) offers a particularly comprehensive analysis of the potential for distributed, infiltration-based practices to enhance groundwater recharge. The Los Angeles WAS estimates that green infrastructure practices that infiltrate the first $\frac{3}{4}$ " of rainfall on each parcel could increase groundwater recharge in the Los Angeles region from 16% of annual rainfall to 48%. Monitoring results from six study sites also suggest that the infiltration of stormwater does not degrade groundwater quality. Local conditions will shape the effect of green infrastructure on groundwater recharge in each region, but the impact of extensive implementation can be substantial.

SOCIAL BENEFITS

- Beautify neighborhoods: Private gardens and public rights-of-way irrigated with passive and active rainwater harvesting can create beautiful landscapes.
- Calm traffic: By reducing street widths and introducing curves, green street techniques can slow traffic.

In Los Angeles, enhancing groundwater recharge through green infrastructure practices could supply approximately \$310 million worth of water per year.

THE MULTIPLE BENEFITS OF GREEN INFRASTRUCTURE

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- **Build communities:** By beautifying neighborhoods and creating a unique sense of place, green infrastructure practices can increase neighborhood interaction. Neighbors may even work together to integrate green infrastructure into their neighborhood.

ECONOMIC BENEFITS

- **Reduce landscape maintenance costs:** Passive rainwater harvesting and drought-adapted plants will reduce the cost of irrigation and maintenance.
- **Reduce energy use:** The use of rain that falls on site can reduce the energy required to treat and distribute municipal water.
- **Increase groundwater resources:** In the arid and semi-arid Southwest, groundwater sources comprise approximately 55% of the water supply. Green infrastructure practices that increase groundwater recharge could provide significant cost savings by averting increased pumping costs or increased water imports. The Los Angeles WAS concluded that infiltration-based practices distributed across the region could increase groundwater recharge by 384,000 acre-feet per year—more than 1.5 times the volume captured by centralized spreading grounds. Based on the cost of the current water supply, the study estimated the corresponding value at approximately \$310 million per year.

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