

ROOF WATER CATCHMENT AND FILTRATION SYSTEMS

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ABSTRACT

Many municipalities are encouraging the design of buildings with rainwater cistern storage as an economical and environmentally conscious means of accessing and recycling water. These systems provide an on-site source of water for landscaping, agriculture, and fire suppression. When combined with new filtration and ultraviolet sterilization systems, roof catchment water can also be filtered and purified for use as potable water. This presenter will demonstrate different issues associated with roofing materials used with water catchment systems for potable water. Discussion will focus on the history of stormwater catchment systems from around the world, methods of calculating volume of stormwater collectable per sq. ft. of catchment area, understanding of stormwater filtration and new purification techniques, and conservation value of water catchment in arid climates.

SPEAKER

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JOHN BARTON often designs domestic roof water catchment systems for the high desert area of Northern New Mexico. He is an award-winning registered architect and roof consultant with 25 years of experience. Barton's work has encompassed a range of artistic and technical projects for educational, governmental, private, and nonprofit agencies. He is past president of the Santa Fe Chapter of the American Institute of Architects.

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INTRODUCTION

Roof rainwater harvesting (RWH) has been practiced for thousands of years. It is a technique through which rainwater is captured from roof catchments and stored in reservoirs for home or irrigation use. Human settlements in all climatic zones have incorporated roof RWH in a myriad of creative ways.

Today, with more advanced material and construction techniques, the industry is expanding how code-sanctioned RWH can be incorporated into buildings. Architects and roof consultants serve as important spokespeople for the continuing adoption and normalization of RWH. Its environmental impact and both personal and public cost-saving benefits, as well as its low-cost implementation make RWH a necessary topic.

HISTORY AND BACKGROUND

Rainwater catchment is a cornerstone of human civilization. The ability to capture and store water enabled the development of irrigation agriculture and improved quality of life on many levels. There are 15 types of rainwater harvesting, most with agricultural implications (Boers, 1982). See *Table 1*.

Of these techniques, rainwater harvesting was unique in that it typically provided the cleanest water, having touched only an uncontaminated roof surface before being stored in earthen or metal cisterns. Examples of early roof RWH technology can be seen in the tankas in India; the clay pot cisterns in Sri Lanka; roof vernaculars of Kenya, Indonesia, Thailand, Vietnam, Southern China, Persia, and the Sub-Sahara; antiquity roofs in the Mediterranean; and colonial roofs in Mexico (see *Figures 1-5*, Akpinar, 2014). See *Table 2*.

Since the commodification of water and the development of centralized distribution systems in the nineteenth and twentieth centuries, many in the industry have turned away from rainwater harvesting, seeing it as an ancillary expense.

Impending climatic pressures, as well as cultural trends towards green building, will soon force those who have disregarded

Pitting	Pits are dug and planted with cultivars on flat or sloping surfaces. Pitting conserves soil moisture and increases groundwater recharge. Pitting reduces velocity of precipitation-engendered runoff if built along a contour.
Cisterns	Runoff is collected and stored in underground storage reservoirs. Ancient cisterns may range from natural or excavated depressions in solid rock to lined structures.
Contouring	Contouring involves stone or earthen banks along a contour in a cultivated hill-slope. Hedgerows typically involve vegetation planted along a contour or cross-slope barriers of grasses and herbs. Contouring helps retain soil moisture, reduce soil erosion, and shorten slope length.
Dams	Stored and regulated flow of rainwater, runoff, and ephemeral streams behind large storage systems that are constructed around foots of hill slopes.
In-situ RWH	Designed for increasing rainfall infiltration and reducing soil evaporation through practices such as ridging, mulching, broad bed and furrowing, hoeing, and conservation tillage.
Large reservoirs	Precipitation and runoff collection in large-scale human-made basins.
Micro-basins	Different shapes of small basins, surrounded by stone or earth bunds to infiltrate precipitation-related runoff.
Micro-dams	Stored and regulated flow of rainwater runoff for infiltration behind stone/earthen banks in a landscape with gradient. Some micro-dam surfaces are planted after drainage to utilize silt deposition and higher soil moisture.
Open ponds	Precipitation and runoff are collected in open ponds through a catchment system. Ponds may or may not have lining. Absence of lining may lead to seepage.
Pit courtyards	Pit courtyards act as an impluvium to capture rainwater, surrounded by walls and impervious surfaces.
Rooftop RWH	From rooftops, water is collected and stored in storage tanks on the perimeter or else built into buildings.
Runoff	Diversion and spread of seasonal floods to agricultural plots from discrete rainfall events. These kinds of systems can be connected to terraces, reservoir systems, and dams of different sizes.
Shallow wells	Shallow wells dug in low depressions or ponds to collect surface runoff after percolation to extract water.
Terracing	Bunds in association with a trench along a contour on a sloping surface. Terracing reduces velocity of runoff during precipitation events, conserves soil moisture, and reduces erosion.
Underground wells	A proximate horizontal channel network or gallery excavated into an alluvial fan aquifer at the base of a mountain or foothill, recharged by precipitation.

Table 1

Semitropics	Semiarid, Mediterranean	Arid
Tankas (India); motka & kalshi rooftops (Bangladesh); rooftop practices in Kenya, Indonesia, Thailand, Vietnam, Southern China	Colonial rooftops (Mexico); traditional rooftops (NE Brazil); antiquity rooftops (Mediterranean); jojo & djabir tanks (Sub-Sahara); clay pot rooftops (China)	Traditional rooftop practices (Canary Islands); soufirs/tkhabit (Algeria)

Table 2

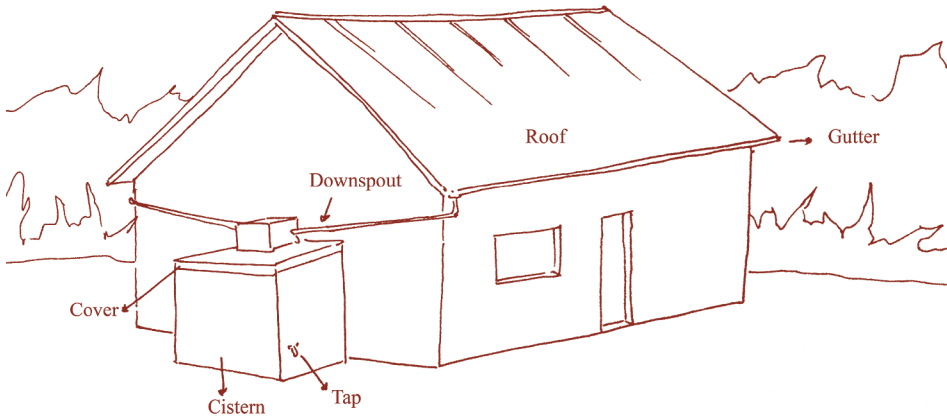


Figure 1 – Schematic of a typical rainwater catchment system.



Figure 2 – Tanka, a traditional Indian roof water catchment system. Source: P.C. Chatterji. “Status of Ground Water in Rajasthan.” Institute of Dev. Studies, Volume I, pp. 96 (1993).



Figure 3 – Traditional rainwater harvesting jar in Sri Lanka. Source: Roar Media, Inc.

RWH to embrace it in their own practices. Of course, this may seem obvious in regions like the arid Southwest and other areas with seasonal water shortages. However, even in cities like New York, with robust urban water distribution systems, and areas in Florida that receive over three feet of rainwater annually, a strong case can be made for using rainwater harvesting.

Rainwater harvesting is also essential in areas with no available potable groundwater. In Bermuda, for example, groundwater aquifers have high salt content because of their proximity to the ocean. The building vernacular that evolved since Bermuda’s colonization has had to incorporate roof rainwater harvesting. The iconic white roofs (see Figure 6) are made of limestone, which makes them heavy and resilient in hurricanes. Historically, the roofs were covered in a lime mortar, which has antibacterial properties (Terry, 1998). Today, the mortar has been replaced by white paint, which still reflects ultraviolet light and helps purify water. Water runs off these roofs into basement cisterns that supply up to a year’s worth of water for the building’s occupants. This technology, along with a culture of conservation on the island, has enabled residents to thrive in a water-poor environment for over 400 years.

BENEFITS, NEED, AND BARRIERS

The main objective of roof rainwater harvesting is to make water available for future use. Capturing



Figure 4 – Chand Baori Stepwall in India.
Source: Wikimedia Commons.

Figure 5 – Traditional rainwater catchment channel from Mughal Empire.
Source: Wikimedia Commons.



and storing rainwater for use is particularly important in dry-land, hilly, urban, and coastal areas (Ali, 2007). RWH can help meet the ever-increasing demand for water, reduce stormwater runoff that puts stress on drainage and transportation infrastructure, augment groundwater storage, control the decline of water tables, improve the quality of groundwater, and reduce soil erosion.

Additionally, RWH can earn up to six LEED points and state-dependent tax breaks (see Figure 7, USGBC, 2017); lower household water bills; increase property values; provide users with a softer, potable water for domestic use; save cities money; and contribute to overall resiliency of individual households and the broader community.

Despite the numerous benefits of roof RWH and the national building incentives in place, successful adoption of RWH systems is still largely dependent on state regulations. Many states, particularly out West, stipulated for years that rain needed to flow to join its rightful water drainage. In other words, water falling out of the sky did not belong to those whose property it hit; rather, it belonged to those who owned rights to water bodies farther downstream (Meehan, 2017). What these lawmakers did not consider is that the

amount of water lost due to evaporation generates a net loss of water. When rainwater is harvested and used for irrigation, it both decreases the amount of surface water that evaporates after a storm and can recharge surface water and groundwater aquifers downstream at higher rates (WaterAid, 2011).



Figure 6 – Typical roof in Bermuda. Source: Wikimedia Commons.

While most states have forgone these outmoded and nonsensical water laws over the past few years, many states still impede RWH practices. For example, Colorado, which banned roof RWH until 2016, now allows 110 gallons of collection at a time from residential buildings only. To put that in perspective, given that the average person uses 80 to 100 gallons of water per day (USGS, 2017), this new law allows for enough water collection to satisfy one person's needs for one day. In 19 other states, including Florida, rainwater harvesting is not illegal, but regulations effectively de-incentivize installation. Often this is done by legalizing



LEED v4 for BD+C: New Construction and Major Renovation

Project Checklist

Project Name:
Date:

Y ? N

Y	?	N	Credit	Integrative Process	1
0 0 0 Location and Transportation 16					
Credit				LEED for Neighborhood Development Location	16
Credit				Sensitive Land Protection	1
Credit				High Priority Site	2
Credit				Surrounding Density and Diverse Uses	5
Credit				Access to Quality Transit	5
Credit				Bicycle Facilities	1
Credit				Reduced Parking Footprint	1
Credit				Green Vehicles	1

0 0 0 Sustainable Sites 10					
Y			Prereq	Construction Activity Pollution Prevention	Required
				Site Assessment	1
			Credit	Site Development - Protect or Restore Habitat	2
			Credit	Open Space	1
			Credit	Rainwater Management	3
			Credit	Heat Island Reduction	2
			Credit	Light Pollution Reduction	1

0 0 0 Water Efficiency 11					
Y			Prereq	Outdoor Water Use Reduction	Required
Y			Prereq	Indoor Water Use Reduction	Required
Y			Prereq	Building-Level Water Metering	Required
			Credit	Outdoor Water Use Reduction	2
			Credit	Indoor Water Use Reduction	6
			Credit	Cooling Tower Water Use	2
			Credit	Water Metering	1

0 0 0 Energy and Atmosphere 33					
Y			Prereq	Fundamental Commissioning and Verification	Required
Y			Prereq	Minimum Energy Performance	Required
Y			Prereq	Building-Level Energy Metering	Required
Y			Prereq	Fundamental Refrigerant Management	Required
			Credit	Enhanced Commissioning	6
			Credit	Optimize Energy Performance	18
			Credit	Advanced Energy Metering	1
			Credit	Demand Response	2
			Credit	Renewable Energy Production	3
			Credit	Enhanced Refrigerant Management	1
			Credit	Green Power and Carbon Offsets	2

0 0 0 Materials and Resources 13					
Y			Prereq	Storage and Collection of Recyclables	Required
Y			Prereq	Construction and Demolition Waste Management Planning	Required
			Credit	Building Life-Cycle Impact Reduction	5
			Credit	Building Product Disclosure and Optimization - Environmental Product Declarations	2
			Credit	Building Product Disclosure and Optimization - Sourcing of Raw Materials	2
			Credit	Building Product Disclosure and Optimization - Material Ingredients	2
			Credit	Construction and Demolition Waste Management	2

0 0 0 Indoor Environmental Quality 16					
Y			Prereq	Minimum Indoor Air Quality Performance	Required
Y			Prereq	Environmental Tobacco Smoke Control	Required
			Credit	Enhanced Indoor Air Quality Strategies	2
			Credit	Low-Emitting Materials	3
			Credit	Construction Indoor Air Quality Management Plan	1
			Credit	Indoor Air Quality Assessment	2
			Credit	Thermal Comfort	1
			Credit	Interior Lighting	2
			Credit	Daylight	3
			Credit	Quality Views	1
			Credit	Acoustic Performance	1

0 0 0 Innovation 6					
			Credit	Innovation	5
			Credit	LEED Accredited Professional	1

0 0 0 Regional Priority 4					
			Credit	Regional Priority: Specific Credit	1
			Credit	Regional Priority: Specific Credit	1
			Credit	Regional Priority: Specific Credit	1
			Credit	Regional Priority: Specific Credit	1

0 0 0 TOTALS				Possible Points: 110	
Certified: 40 to 49 points, Silver: 50 to 59 points, Gold: 60 to 79 points, Platinum: 80 to 110					

Figure 7 - LEED points. Source: USGBC.

catchment only on residential buildings or by requiring a professional engineer to design the system (Meehan, 2017). Of the 16 states that offer statewide incentives and tax breaks, only Texas requires that all new public buildings incorporate RWH system technology. Other states often forbid RWH for potable purposes or leave this decision up to individual counties.

The legal imperatives for RWH are further obfuscated by county- and municipality-level ordinances. In Santa Fe, NM, for example, Ordinance 2003-6 states that a water harvesting plan should capture drainage from a minimum of 85% of the roofed area and that the captured water should be used for landscape irrigation (Santa Fe County, 2003-6). The wording of this ordinance makes unclear the size of cistern required and—if water can be used for potable purposes—what the requirements are to ensure it is purified. As a result, many builders do not follow ordinance guidelines and property owners

are rarely “red-tagged.”

Other counties do a better job articulating the requirements of RWH ordinances. Torrance County, New Mexico, requires explicitly:

A roof drainage plan shall be submitted. Cisterns shall be sized to hold 1.15 gallons per sq. ft. of heated area to be captured (e.g., a 2,000-sq.-ft. home is required to capture a minimum of 85% of drainage, which is 1,700 sq. ft. The cistern shall be sized at 1.15 x 1.700 = 1,955 gallons). This figure may be adjusted based on landscaping.

A pump and drip irrigation system shall be connected to the cistern. The drip irrigation system shall serve all landscaped areas. A maintenance plan shall be provided identifying cleaning schedule. All systems shall be installed by a licensed contractor or other qualified

individual as approved by the board of supervisors of East Torrance SWCD before construction. All systems shall include a level indicator. Provide manufacturer specifications for piping and cisterns. All systems shall include an overflow outlet. Cistern covers or lids shall be locking. Any spigots/outlets connected to these systems shall be marked ‘non-potable water.’

All piping shall be underground to prevent freezing and shall be at a minimum depth of 24 inches. All systems shall install a screen/sediment trap/filter to prevent particles entering the system. All systems shall be designed to drain away from footings/foundations. Only black cisterns shall be permitted to prevent algae from growing or deterioration of the cistern. If cisterns are used, it is advisable to enclose or bury them to prevent algae from

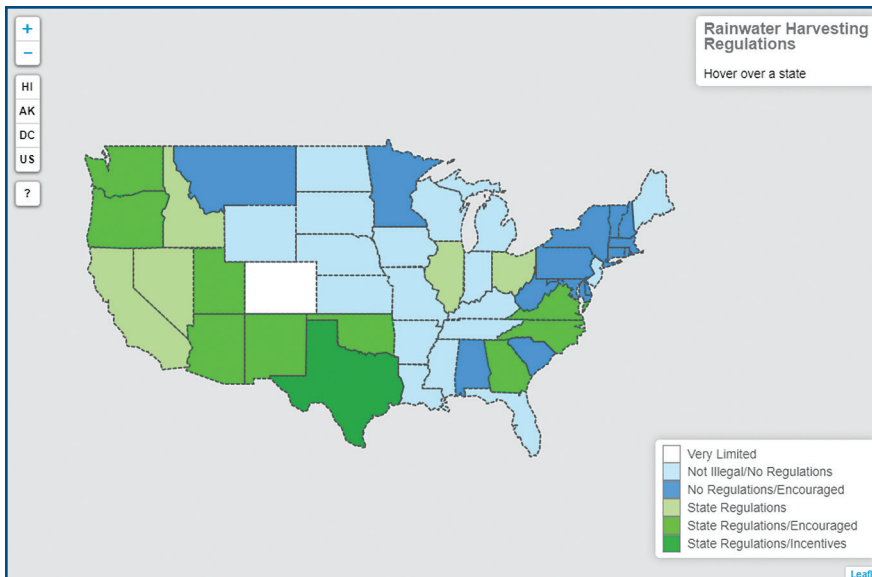


Figure 8 – Rainwater harvesting regulations map. Source: U.S. Dept. of Energy.

Figure 9 – Cisterns outside of Sprouts Grocery Store in Santa Fe, New Mexico.

growing, deterioration of the cistern by UV rays, or freezing of the system. Partially buried cisterns should be buried a minimum of 30 inches to prevent freezing.

If a rain barrel catchment is submitted with a plan, it **MUST** capture water from a minimum of 85% of the roofed area being proposed, and it must have a hose bib attachment to be utilized. All rain barrels/cisterns shall be covered by a screen or lath for support and by a fine gauge mesh to prevent mosquito breeding or other unwanted elements.” (East Torrance SWCD, 2016)

While many local governments and industry professionals have already identified RWH as an important priority in conserving water and lowering costs, states need to update their laws to facilitate the adoption of RWH systems. As this is being done, researchers and advocates within the industry have an obligation to promote case studies of successful RWH systems and lay out the potential savings so that clients can make smarter decisions about their buildings.

CALCULATING SAVINGS

Water savings can be calculated using this equation:

$$\text{Total} = \text{Roof area} \times \text{average annual rainfall} \times \text{efficiency coefficient}$$

See *Figure 10* to identify the climatic region your city falls within. Data are



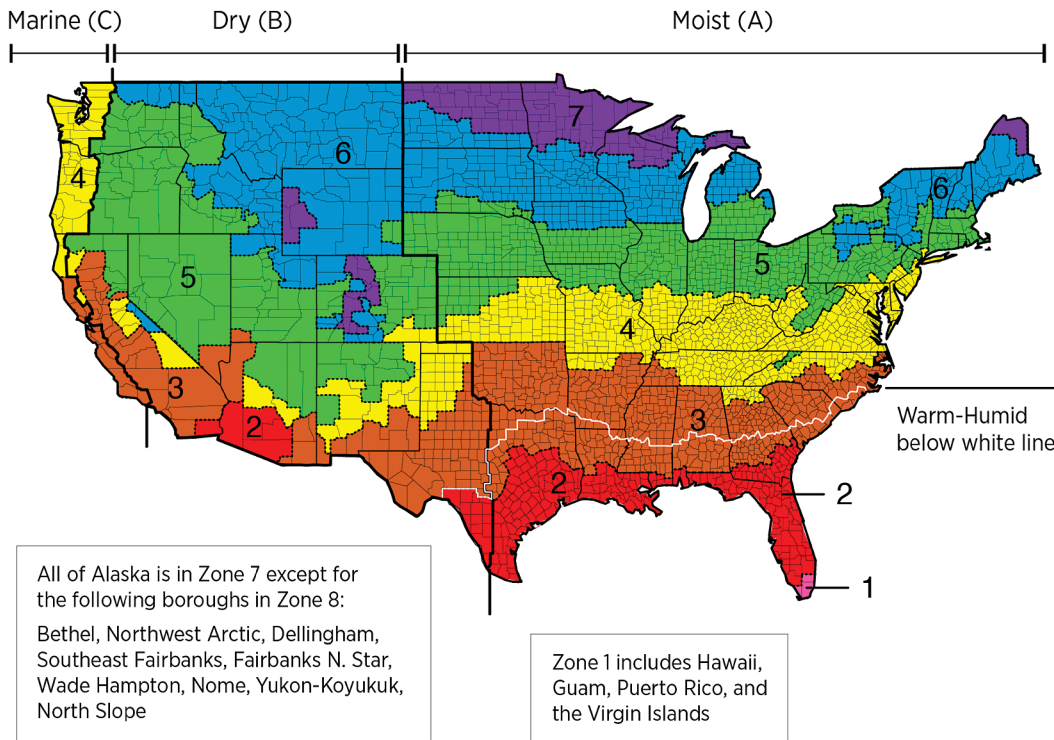


Figure 10 – U.S. climate zones. Source: ASHRAE 90.1.

sourced from USClimateData.com. These water savings can have substantial impacts on domestic water bills. See *Table 3*.

According to the United States Geological Survey (USGS), per capita daily water usage is 80 to 100 gallons (Maupin, 2014). The average household has just under three people, meaning that each household uses between 240 and 300 gallons per day, or 87,600 to 109,500 gallons per year. Depending on location, incorporating roof rainwater harvesting into domestic building systems can save 10 to 31% of surface water and groundwater. It can also substantially lower water bills and is well worth the initial capital investment in RWH materials.

RECOMMENDATIONS FOR EXISTING STRUCTURES

If the roofing material is not too degraded and the roof is not too flat, RWH systems can be incorporated into almost any building typology.

Rain barrels or cisterns can be hooked up to existing systems of gutters and downspouts and can even be routed to feed into buildings' water supply systems. Otherwise, rain barrels and tanks with taps can be

(often rain chains), which feed into cisterns or barrels that become integrated into the landscaping.

When designing RWH systems in new buildings, it is important to consider the

used and manually collected for either domestic use or irrigation. It is important that catchment systems not be located close to possible sources of contamination such as wood-burning stone exhaust flues (common sources of ash and creosote). Storage tanks must also be located below the roof to ensure that they fill easily and have overflow piping.

RECOMMENDATIONS FOR NEW ROOFS AND BUILDINGS

New buildings enable direct integration and filtration of water into the building itself. Some modern roof RWH systems have inverted roofs (see *Figure 11*) to allow water to pool and feed directly into the home. Others incorporate more aesthetic gutter and drainpipes



Figure 11 – Rainwater harvesting prototype in Iran. Source: Inhabitat.

Region	Annual water collected (gal m ³)	Roof Top Area (ft ² m ²)	Average Annual Rainfall (in mm)	Efficiency Coefficient
Coastal climates (FL)	27,474 gal 104 m ³	1076 ft. ² 100 m ²	51.2 in. 1300 mm	0.8
Arid Southwest (NM)	7,608 gal 28.8 m ³	1076 ft. ² 100 m ²	14.2 in. 361 mm	0.8
Temperate zone (NY)	23,036 gal 87.2 m ³	1076 ft. ² 100 m ²	42.9 in. 1090 mm	0.8

Table 3

Roof Material	Climate	Optimal Roof Slope	Notes
Single-ply membrane	All climates	¼ - ½ in./ft.	Includes EPDM, TPO, and PVC
Metal	All climates	3 - 6 in./ft.	Includes galvanized steel, aluminum, and copper
Shingle	Wet	3 - 6 in./ft.	Zinc and titanium
Built-up	All climates	¼ - ½ in./ft.	For irrigation use only
All	Wet	3 - 6 in./ft.	If steeper, efficiency coefficient increases
All	Snow	6 - 12 in./ft.	If too shallow, snow load compromises structure

Table 4

roof's slope. Flat roofs are not ideal for RWH, as water tends to pool for longer and can become a breeding ground for mosquitoes, algae, and bacteria. Roofs that are too steep can be materially inefficient and can lead to splashing because of the speed with which water hits the gutters. Optimal roof slopes for rainwater collection are explored in *Table 4*.

Roof material is also an important consideration when designing for RWH. Built-up roofing (BUR), which is a common choice for commercial buildings, contains layers of bituminous materials that release polycyclic aromatic hydrocarbons (PAH) and diethylhexyl phthalate (DEHP)—hazardous endocrine disruptors (ECY, 2014). Even if there is no direct harvesting of rainwater from these roofs, phthalates can leach into runoff water and end up in soils and water bodies, ultimately being consumed by humans and other species (Arcadi, 1998). Elevated concentrations of cadmium, lead, and other additives have been found in ceramic and concrete tile roofs. Thatched and other organic roof surfaces are also not ideal, as debris can run off and easily clog filters.

Metal, liquid applied membranes, EPDM, TPO, and PVC roofing are the cleanest options for RWH and are easily maintainable. However, there are still some concerns with these materials. Metal roofs have been found to leach levels of zinc and copper far greater than is recommended for consumption by the World Health Organization (ECY, 2014). TPO and PVC roofing can also release DEHP, although at lower levels than BUR. To prevent consumption of heavy metals and phthalates in rainwater, two courses of action should be taken. First, rainwater collected during the first season of a roof's installment should only be used for irrigation, and not for domestic purposes. Second, a robust purification system should be installed to filter and treat water as it enters the building.

Pre-Filtration Systems		
Filter Type	Typical Cost	Description
Industrial filters	\$400-\$2000	Meet the performance needs found in large-scale rainwater collection systems
Downspout diverters	\$100-\$800	High-performance cleaning devices typically used with underground cisterns
In-tank filters	\$50-\$750	Can be installed inside or on top of water tanks, cisterns, and rain barrels
Floating filters	\$150-\$500	Ensure that the cleanest, most oxygenated water is supplied to the system
First flush filters	\$50-\$400	Remove the fine impurities (think pollen and dust) from the initial rush of water
Downspout filters	\$15-\$200	Installed into downspouts, eliminating leaves, etc., in order to send clean water to the tank
Post-Filtration and Purification Systems		
Purification Type	Typical Cost	Description
UV disinfection	\$500-\$1000	Used to disinfect rainwater for indoor water usage; only effective if the water has been filtered to 10 or fewer microns prior to entering the UV disinfection product.
Chemical and dye injection	\$300-\$1000	Used to add chlorine or dye to rainwater to disinfect the water or signify that rainwater is being used
Ozone injection	\$100-\$350	The major difference between ozone and UV is that ozone is a very powerful oxidizer and kills all known microorganism, whereas UV typically just inactivates them. Ozone injection is rapidly gaining popularity in rainwater harvesting systems.
Sediment filtration	\$50-\$200	Used to remove the fine sediment, color, taste, and odor that may remain in your rainwater after pre-filtration; typically used in conjunction with a UV sterilizer to disinfect rainwater for indoor uses. Off-the-shelf filters work well to remove chlorine taste and odor.
Reverse osmosis	\$500-\$1000	Produces highly purified water and can remove up to 98% of contaminants. Filters last a year or more for 2000 gallons' worth of filtration. Usually requires 110-volt AC electrical connection. Not good for high-volume production; best used at kitchen sink for drinking water.

Table 5

Item	Cost
(3) 1700 gallon cisterns	\$5000
UV filter	\$500
5 + 7 micron filters	\$200
Labor	\$4000

Table 6

PURIFICATIONS SYSTEMS

Rainwater is a naturally soft water and is preferable for pipes, washing clothes, bathing, and drinking. However, harvesting rainwater for domestic consumption can be dangerous if the proper purification system is not in place. Pollutants such as algae, air pollution, bird excrement, leaves, sand and dust, and leaching from roof surfaces can affect the potability of rainwater for domestic consumption (WHO, 2017). Bird droppings, for example, are a source of bacterial contamination, such as *E. coli*. Traditional methods for dealing with pollutants include charcoal, gravel, sand, and fabric (Boers, 1982). Today we have far more sophisticated filtration and sterilization techniques, which must be implemented if water is intended for domestic consumption. Water should also be tested regularly to ensure its potability.

Because of the contemporary prevalence of man-made contaminants, especially in cities and areas with significant industrial presence, there are many synthetic filtration and purification systems on the market. These products are typically distinguished as pre-filtration and post-filtration purification. Post-filtration is the filtration that takes place after the collected rainwater has left the tank. A post-filtration system is typically a pressurized system that filters to

a much lower number of microns than typical pre-filters. Post-sediment filtration and disinfection is usually required anytime the water will be used for domestic use, such as drinking, cooking, flushing toilets, washing clothes, or shower usage. See *Table 5*.

COMMON ISSUES ASSOCIATED WITH COLLECTION AND STORAGE

There are several factors that can impact the quality of rainwater. If the house has a chimney, rainwater or snow can become smoky as it is intercepted on its way to the gutters. High chimneys (above three feet) are therefore better. Additionally, the quality and material properties of the roof are important considerations. Metal and PVC roofs are preferable over asphalt composition shingles, wood shingles, and other natural or conversely synthetic materials that might off-gas and contaminate the water supply. However, metal roofs and gutters can corrode over time and must be monitored.

Water quality can also become compromised if the cistern or rain barrels are not properly covered. Uncovered barrels can let in light, insects, and dirt, all of which contribute to the growth of algae, mosquitoes, and harmful bacteria—ultimately increasing the danger of vector-borne disease. Concrete lids are ideal.

Particularly in areas with significant rainfall or areas that experience seasonal heavy rains (monsoons), incorporating an overflow pipe is important (Daily, 2007). An overflow pipe empties into a non-flooding area, and excess water can in this way be used to irrigate and recharge the water table. Some components of roof RWH systems are likely to fail more frequently. The foul-flush diverter, the tap, and synthetic

filters should be checked every six months or as specified by equipment user manuals.

CASE STUDY: OJO CALIENTE STUDIO

One of John Barton's projects that integrated a comprehensive RWH system was an old adobe studio in Ojo Caliente, New Mexico. When he first purchased the building, it was a rough shell with adobe walls and an unconventional wood-frame roof. There was no plumbing, and the floor was dirt. Barton decided to keep the outer adobe walls, but to demolish the roof and interior. He wanted to create a "great space," with one main studio area surrounded by smaller support spaces, including the bathroom, storage, and mechanical areas.

The design called for two porches, and courtyards on either end of the house, both for the views and to create outdoor living areas. Wing walls were added to improve privacy from the road and to protect from the wind. These also integrated the building into the hill on which it sits and gave it a monumentality that its otherwise small footprint would not normally have. It ties into the Western "false-front" architectural tradition also, where a large street-facing façade covers a smaller building behind it.

Water conservation was a key design element, as the property has no well. Wastewater is separated into "gray" and "black" drain lines. The toilet and kitchen sink "black" wastewater runs to a conventional septic tank and leech field. The "gray" water from the tub, shower, bathroom sink, and washing machine is piped outside to water a cottonwood tree, which was chosen not only for its beauty, but also for its ability to take water with a high alkaline content



Figure 12 – Studio designed by John Barton Architects in Ojo Caliente, NM.


from soaps.

The budget for the roof rainwater catchment was as shown in *Table 6*.

The roof was made as large as possible and finished with galvanized steel 24-gauge metal panels to collect rainwater and snow-melt. This water is carefully drained with gutters and downspouts on either side to two catch basins. These are filled with gravel, which provides an initial stage of filtration. Drains at the bottom of these basins lead to another, finer filter screen and to three 1,700-gallon buried water storage cisterns. The cisterns are located on the south side of the house to minimize freezing issues in the winter and are connected in series to each other. The water from these cisterns is then pumped into the mechanical room and runs through two more 5- and 7-micron filters. Finally, it is sterilized as it runs through a UV system on its way to normal domestic use.

See *Figures 12-15* for detailed diagrams and photos of the system. With these water conservation and creation measures, the Ojo Studio was awarded the USGBC's 2012 Best Water Conservation Award.

CONCLUSION: MOVING FORWARD IN DESIGN AND INNOVATION

This paper has addressed the social, economic, and environmental benefits of roof RWH, elaborated on the rich history of the practice worldwide, laid out calculations for determining water savings, and explored the various ways in which RWH systems can be incorporated into new and existing structures. Ultimately, this analysis serves to emphasize the importance of adopting RWH practices into everyday design and building practices. When done right, RWH systems can be not only good for the planet and our pocket books, but beautiful as well. 

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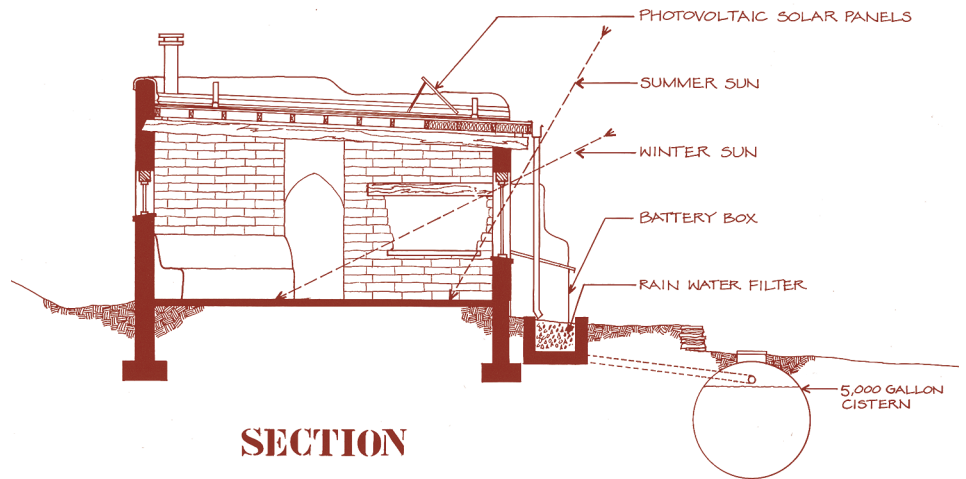


Figure 13 – Section of Ojo Caliente Studio.

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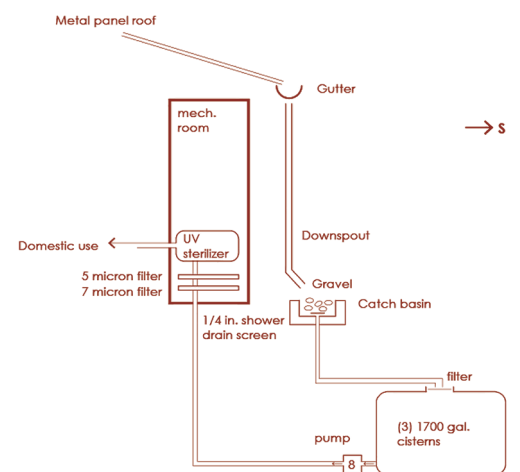


Figure 14 – Diagram of rainwater harvesting system at Ojo Caliente Studio.

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Figure 15 – Top left: Micron and UV filters; top right: catch basin and rock filter; bottom left: buried cistern on south side of house; bottom right: gutters on western façade.

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