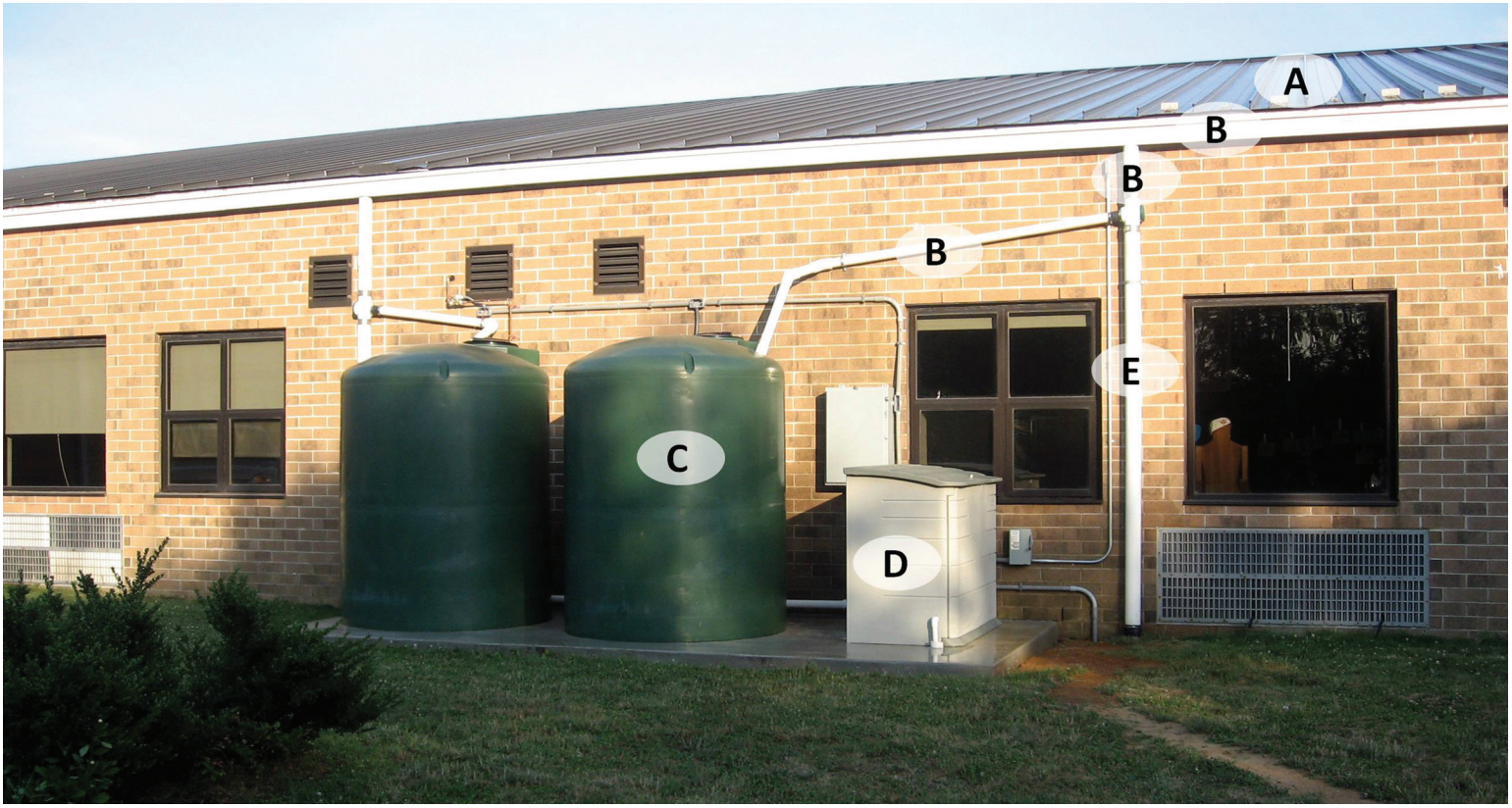
Rooftop Rainwater Harvesting For Plant Irrigation I: Design Concepts and Water Quantity

Fact Sheet FS1162

Cooperative Extension

Salvatore S. Mangiafico, Environmental and Resource Management Agent
Christopher C. Obropta, Extension Specialist in Water Resources
Elaine Rossi-Griffin, Program Coordinator, Environmental Science



Introduction

Rainwater harvesting is used as a primary source of domestic or irrigation water in less-developed countries and arid climates. This is often the case where water infrastructure is limited or rain is insufficient for crop production. However, rainwater harvesting is used increasingly in developed nations for the irrigation of crops and landscaped areas and other non-potable uses. Users include owners of municipal buildings, businesses, plant nurseries, and individual homes.

In New Jersey, there is interest in harvesting rain water from the roofs of buildings and greenhouses at businesses and farms. Benefits of harvesting rain water may include:

- reducing runoff during rain events
- conserving potable water
- having a source of relatively high quality water for supplemental irrigation
- avoiding state permits for additional water allocations

Reducing runoff and conserving potable water contribute to a wider goal of sustainable development, particularly in densely populated areas.

The most basic form of rainwater harvesting is simply diverting roof runoff away from stormwater infrastructure and onto permeable areas like lawns and landscaped areas. Small-scale storage of rain water can be accomplished with a rain barrel (See Bakacs and

RUTGERS
New Jersey Agricultural Experiment Station

Rutgers, The State University of New Jersey
88 Lipman Drive, New Brunswick, NJ 08901-8525
Phone: 732.932.5000

Haberland [2010]), which is suitable for homeowners or for demonstrations at businesses.

Collection Vessels

While rainwater can be harvested in a variety of vessels including stone cisterns or open basins, most commonly closed tanks are used. Plastic tanks in a variety of sizes and shapes are available commercially. Plastic tanks for above-ground use should be made from plastic that is resistant to ultraviolet light and opaque in color. For underground use, tanks manufactured for this application should be used. Larger commercially-available tanks are made from fiberglass, galvanized steel, or a variety of other materials when a plastic liner is used. If collection vessels are recycled from other uses, those used to store toxic materials must be avoided. Matrix systems which consist of modular milk-crate-like plastic forms are also available. They are pieced together to provide an underground storage space without the need for a single large open tank. These systems provide flexibility in size and shape of the reservoir area, and can be used where a load-bearing vessel is desired. Pre-packaged and modular systems are available commercially, and some manufacturers have certified contractors for their installation.

Collection tanks are often fitted with some method to facilitate draining and to remove any debris that may collect in the tank. A drain or manhole opening can be used for this purpose. For maximum collection efficiency, a spare tank can be connected to collect water while the main tank is taken offline for cleaning. The ability to drain or pump out stagnant water is also helpful. Tanks may need to be vented to allow filling with water, but all openings should be screened to prevent access by mosquitoes or small animals. Tanks should be located both as close to the collection surface and as close to where water will be used as is practical.

Collection Capacity

The capacity of a rainwater harvesting system can range from a single 55-gallon barrel to a series of cisterns capable of storing thousands of gallons. The desired capacity for a collection system will depend on many factors including:

- Anticipated demand – How much water is needed or desired for irrigation or other uses? What portion of that demand is to be satisfied by collected rainwater? In New Jersey, where rainwater harvesting is primarily for supplemental irrigation and stormwater management, matching collection capacity to demand may be less critical.
- The ability to use collected water for a specific purpose – Larger tanks will provide a greater capacity for storage. If only a small portion of collected water will be used, a smaller tank would achieve the same efficiency in the long run.
- Available collection area – Determine the roof area that is available and practical to be used as a collection surface.

Table 1. Average rainfall for select locations in New Jersey.*

	Average monthly rainfall (inches)							Average annual total precipitation (inches)
	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	
Atlantic City (marina)	3.25	3.16	2.46	3.36	4.16	3.02	2.71	38.37
Audubon	3.95	4.38	3.81	4.52	4.37	4.11	3.26	45.95
Belvidere	3.93	4.28	4.22	4.46	3.65	4.30	3.55	45.15
Cape May	3.31	3.65	3.01	3.39	3.78	3.31	3.41	41.39
Millville	3.53	3.94	3.27	3.59	4.35	3.47	3.04	43.20
Morris Plains	4.64	5.09	4.40	5.29	4.37	5.33	4.17	53.67
Sandy Hook	3.69	4.01	3.53	4.10	4.03	3.42	3.36	43.58
Somerville	4.00	4.34	3.98	4.63	4.39	4.58	3.69	47.71
Sussex	4.44	4.46	4.57	4.22	4.23	4.45	3.72	48.03
Toms River	4.02	4.17	3.52	4.56	5.00	3.95	3.55	48.81
Wanaque	4.23	4.54	4.34	4.31	4.25	4.58	3.67	48.78

* Adapted from NOAA 2002. Data are from 1971–2000. Note that local areas may receive more or less rain than indicated. Note that annual variations include periods of droughts or unusually wet weather, so that the indicated rainfall may not estimate actual rainfall for any given year.

- Water conservation or runoff management goals – Tanks could be sized to meet a specific need, for example capturing 10% of roof runoff, or collecting enough water to irrigate a specific garden.

Water Quantity and Demand

Average annual rainfall for New Jersey ranges from 38 to 54 inches, with an overall average of about 48 inches (30-year-normal values from 1971–2000) (NOAA 2002). While droughts and unusually wet weather occasionally occur, on average rain is relatively equally distributed across months. It should be remembered, though, that some months may have significantly more or less rain than average. Collection systems should be designed with regard to expected monthly rainfall (Table 1).

When designing rainwater harvesting systems, the possibility of periods of drought and wet weather should be considered. Additionally, the seasonality of water demand should be considered, particularly if the water will be used for supplemental irrigation, as irrigation demand is generally greater in summer months. Finally, it should be remembered that in winter months precipitation may fall as snow, which may or may not be collected with the rainfall harvesting system.

There are simple formulas that can be used to calculate the potential volume of rain water harvested from a storm. The volume of rainwater is equal to the area of the roof from which the rain is being collected multiplied by the depth of the rainfall, then multiplied by a unit correction factor:

volume (gal.) = roof area (sq-ft.) x depth of rainfall (in.) x 0.623

or

volume (L) = roof area (m^2) x depth of rainfall (cm) x 10

A 1-inch rain falling on a 1000-sq-ft. roof would yield 623 gallons. Or, a 3-cm rain falling on a 100-m^2 roof would yield 3000 L.

It is important to note that the roof area should be calculated as the footprint of the roof, or the area of the roof surface in the horizontal plane. In other words, the roof over a house with a 1200-square-foot footprint would have an "area" of 1200 square-feet for this calculation, no matter the pitch of the roof.

There may also be losses of water along the collection path. It is estimated that 75–95% of the total water falling on the catchment surface will make it to the collection vessel (Texas Water Development Board 2005, Council on the Environment NYC 2008). This should be factored into calculations of how much water will be collected.

If the collected water is going to be used for irrigation, similar calculations can be used to determine how large a crop area can be irrigated with harvested water. The depth of irrigation water that can be applied is equal to the volume of water collected divided by the crop area, with a factor to correct for units:

depth of irrigation (in.) = volume (gal.) ÷ crop area (sq-ft.) x 1.605

or

depth of irrigation (cm) = volume (L) ÷ crop area (m^2) x 0.1

For every 1000 gallons of collected water applied to a 500-square-foot garden would give 3.2″ of applied irrigation. Or, 4000 L of collected water applied to a 50-m^2 garden would give 8 cm of applied irrigation.

Rain Harvesting System Components

A basic rainwater harvesting system consists of:

- The catchment surface. For roof collection systems, this is the roof surface.
- Gutters and downspouts.
- The storage tank.
- A water delivery system. This may be a simple spigot and hose on a rain barrel or a pump system that supplies an irrigation system.

Leaf screens may be useful to keep debris out of the collected water. These may be simple mesh screens over the gutters. Such screens will need maintenance to prevent clogging as they collect leaves and other debris. Additionally, a first-flush diverter may be useful to remove the first flush of water after runoff begins. At the beginning of runoff from the collection surface, the initial volume of water may have elevated contaminant levels. One recommendation is to divert 10–20 gallons for each 1000 square foot of collection surface. First-flush diverters can have a variety of designs, including standpipes or boxes with baffles. See Texas Water Development Board (2005) and Council on the Environment NYC (2008) for more details on system design.

Other Design Considerations and Components

Overflow. Consideration should be given to the disposition of water that overflows the collection tank during large rain events. Because water flow may be concentrated, care should be taken that overflow does not cause erosion or negatively impact neighbors or nearby waterways. Overflowing water should not be diverted to septic drain fields. Consultation with a qualified engineer may be advisable.

If harvested rain water will be used for critical irrigation, it may be necessary to use municipal water or well water as a back-up source of water. This is sometimes called a dual supply system. In this case, caution should be taken to prevent cross-connection, and the use of proper anti-siphon procedures will prevent the possibility of collected rain water being siphoned into the potable water supply lines. Inspections or permits may be necessary for these connections.

Cross connection and backflow prevention. Cross-connection refers to any case where a water system with non-potable water is connected to a potable water system, and such connections can constitute a serious threat to public water supplies (USEPA 2003). Backflow occurs when an unexpected decrease in water supply pressure allows contaminated water to be siphoned into the potable water supply. The potential for backflow can be prevented by leaving a physical air gap between the potable water supply outlet and the potentially contaminated water or by installing anti-siphon devices such double check valves or vacuum breakers. It should be remembered that collected rainwater may have bacteria, heavy metals, or contamination by other substances, and so any potential of rainwater entering potable water supplies should be avoided. Additionally, it should be remembered that wells and groundwater also constitute potable supplies, and methods should be taken to prevent their contamination as well.

Winterizing. During the design phase, accommodations for winter conditions must be considered. Modifications may include a method to divert water from being collected during winter months and a valve to drain water from the tank before the onset of freezing temperature. Depending on location, local conditions, and materials used, tanks and their plumbing may not need any special preparations for winter weather. Valves may need testing the following spring as they are susceptible to damage by freezing water.

Local Regulations. In all cases, building codes, health department stipulations, and water supply company requirements should be followed in order to prevent cross connection. Obtaining permits, using certified plumbers, or allowing inspections of completed installations may be required.

Safety Considerations

It should be remembered that a gallon of water weighs more than eight pounds, so a 55-gallon drum of water will weigh over 400 pounds, and a 500-gallon cistern would weigh over 4,000 pounds. Any water collection vessel should be installed on a level and solid surface to prevent the possibility of anyone being crushed or trapped by an unstable tank. A base of soil, sand, or pea gravel may be a suitable platform for a collection vessel, but a concrete pad may offer a more stable surface less susceptible to erosion. Consulting a professional engineer to be sure of the stability of the soil or constructed base is advisable.

Legal Considerations

The authors know of no regulations at this time governing cistern installation for private use in New Jersey except that using cisterns in a drinking water system is typically not allowed (NJDEP 2004). Other states may have regulations stipulating, for example, the allowable size and material of storage tanks, or the maximum allowable amount of water that can be harvested. State laws and local ordinances should be consulted when designing any rainwater harvesting system.

Costs and Benefits

For sites serviced with municipal or well water, per-gallon savings of using harvested water are unlikely to offset the costs for the installation and maintenance of a rainwater collection system in the short-term. Instead, the most valuable benefits may be the environmental gains of water conservation and stormwater management, and, for businesses, the demonstration of good environmental stewardship. Additionally, rain water harvesting may be a good solution for sites without ready access to municipal or well water.

The costs of building a rainwater collection system will depend on the size of the system and collection vessel, the materials used, if labor for installation must be paid for, and if the system requires running pumps or other equipment. Some estimates are given by Council on the Environment NYC (2008). Self-installation of modular systems or custom-designed set-ups may be less expensive than installation by certified contractors.

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Photo Caption

A rainwater harvesting system installed at a school in East Greenwich, NJ: a) The catchment surface (building roof); b) Gutter, downspout, and pipe which deliver water to the tanks; c) Collection tanks; d) Housing for pumps which deliver water to an irrigation system for an ornamental garden; e) Overflow pipe which transports any water in excess of tank capacity to the pre-existing stormwater conveyance system.

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Rutgers, The State University of New Jersey
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Phone: 732.932.5000