Rainwater Harvesting

Rain Barrel set up for watering planters
(Source: Flickr Creative Commons)

Small, low-profile cisterns

Purpose & Benefits

- Reduce runoff from the property
- Provide non-potable water source for reuse
- Provide additional water storage for slow release to Conservation Landscapes and Rain Gardens

Description

Rainwater Harvesting is a term for the age-old concept of capturing runoff and storing it in a Rain Barrel, cistern or other container for future use. Rain Barrels and cisterns are similar in function and design, but the cistern is a larger tank than a Rain Barrel. Rainwater that falls on a rooftop is collected and conveyed into an above- or below-ground storage tank for non-potable water uses such as irrigation, exterior washing (e.g., washing cars, building exteriors, etc.), operating water features (ponds and fountains), and possibly some interior reuse options like flushing toilets or laundry (indoor uses may require additional treatment of the water as per local health codes). In many instances, Rainwater Harvesting is combined with Conservation Landscapes (**Chapter 1**), Rain Gardens (**Chapter 2**), or landscaped areas to allow stormwater stored temporarily in the tank to be used to water these practices and infiltrate into the ground.

What to Expect

Normally, the tank cannot hold the entire runoff volume from a rain event. An overflow should be designed to send any extra water to a stable place, like a stone or concrete pad, to prevent erosion. If the rain water is not used for irrigation, a recommended approach for stormwater management is to leave the spigot slightly open at the bottom of the tank so that it slowly releases any water that is stored in the tank, and empties the tank for the next rainfall event. This is especially effective when the Rainwater Harvesting system is used in conjunction with a Conservation Landscape or Rain Garden. However, homeowners or businesses may have other uses in mind that suggest other methods to operate the system.

Other important considerations include: (1) creating a plan for the winter when the water may not be used, and (2) preventing mosquitoes from breeding in the summer.

Figure 5.1. *Examples of residential Rainwater Harvesting cisterns*

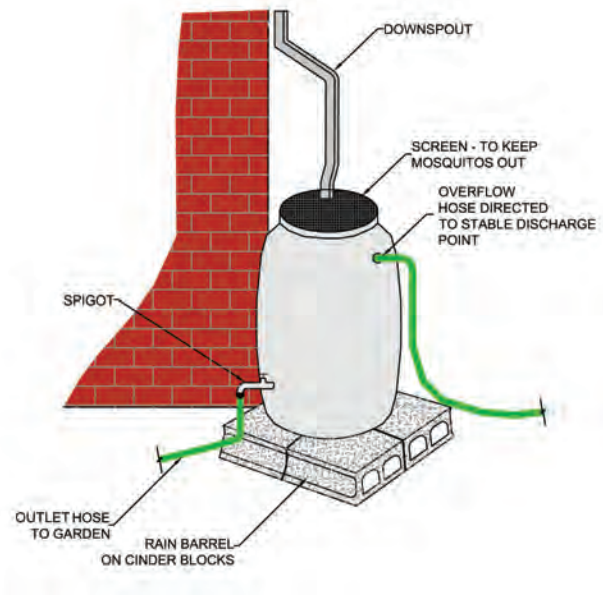

Figure 5.2. *Single Rain Barrel system, with overflow*
(Source: MDE, 2000)

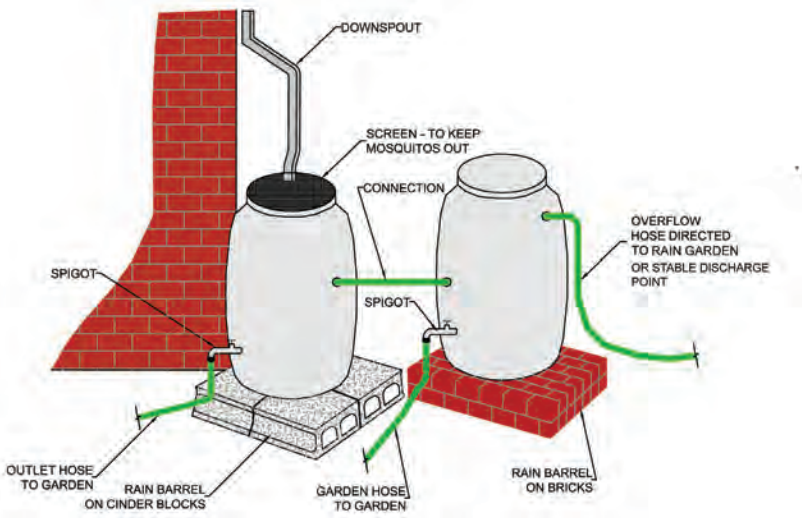

Figure 5.3. *Interconnected Rain Barrel system, with overflow*
(Source: MDE, 2000)

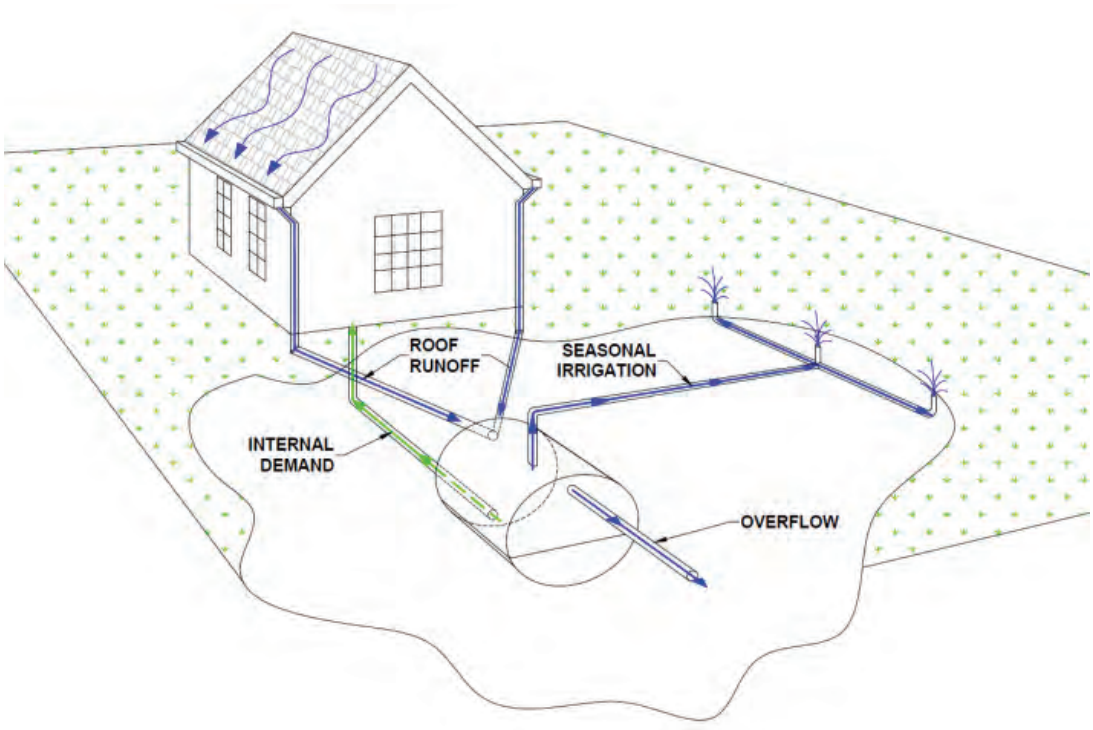

Figure 5.4. *Underground cistern for year-round indoor use and seasonal outdoor use*
(Source: VADEQ 2013, original graphic by Alex Forasté)

5.1. Complexity

A simple Rain Barrel or single above-ground tank system is quite simple, and with a few commonly available tools, most people can assemble and install a perfectly usable system. Larger systems are inherently more complicated. Design features that add complexity include multiple, separate vessels that must be connected together, a more extensive system of gutters and collection pipes, and some type of pre-treatment system to keep leaves and debris out of the vessel. More complex designs will likely require some assistance from a professional, or at least an experienced installer (see **Table 5.1**). For underground cisterns or storage tanks, a backhoe or excavator will be needed. For underground work, utilities and groundwater depth become considerations, raising the complexity and likely necessitating additional professional assistance.

Understand the Complexity of the Rainwater Harvesting Project

The intent of this guide is for practices in the SIMPLE, or low end of MODERATE categories. If the practice is in the moderate or complex category, consider consulting with an appropriate design professional or experienced installer.

A Steward or homeowner can usually install a simple Rain Barrel. Consult a landscape contractor for cistern installations, or where Rain Barrel installations are complex or uncertain.

Table 5.1. Design Complexity for Rainwater Harvesting Systems

Design Complexity	Description	Guidance
Simple	• Rain Barrels or simple above-ground tank • 50-300 gallons in size • Each tank collects from one downspout • Gravity-fed outflow • Has basic screening or filtration (e.g., leaf screens on gutters), but not greater treatment system at the tank • See **Figures 5.2 & 5.3**	• Design and construction is simple and can be done by handy homeowners, volunteers, or contractors with a little guidance • Most difficult part of assembly may be cutting and re-routing downspouts and installing hardware at bottom end of Rain Barrel
Moderate	• Larger home-scale storage systems • see **Figures 5.4 & 5.5** • 300-1000 gallons, above or below ground • Collect from multiple downspouts • May include pump distribution, and pre-screening, first-flush diverters (**Figure 5.6**), which add complexity	• Elevation of tank(s) with respect to downspouts, inlets, and outlets are the primary complicating factors • Many tank materials available to best meet desired application • Design should include basic drawings with elevations to ensure flow and storage are aligned • Construction likely requires professional assistance, such as an experienced plumbing contractor
Complex	• Larger commercial or institutional applications • Large above-ground or underground systems • Will likely include large collection pipes, filters, pumps, sensors, and valves	• Will usually require a professional architect, engineer, or landscape architect, and adherence to stormwater manual design specifications (MDE, 2000, Ch. 5;VDEQ, 2013, Specification #6) • Requires contractor with capabilities for general site development and plumbing contractor with specific experience in Rainwater Harvesting

Figure 5.5. *A residential system with a large underground tank adds complexity*
(Source: Rainwater Management Solutions, Inc.)

5.2. Location & Feasibility

At the simpler end of Rainwater Harvesting, above-ground storage (Rain Barrels or small cisterns) are typically located in close proximity to the house, garage, or shed where the runoff is coming from. The downspout is then directed to the storage vessel. For an underground storage and distribution system, selecting the location is more complicated. Here are some factors to consider:

Location of Downspouts To avoid unnecessary piping, plumbing, or other conveyance, the storage tank or reservoir is typically located where the downspouts come down from the roof. However, aesthetics or the location of the intended water use may be considerations. If the house has several downspouts, consider whether the project will interconnect the downspouts or interconnect storage vessels. The simplest option is to have each tank only collect water from a single downspout.

Location of Water Use and/or Drawdown It is important to consider the pathways by which water enters and exits the system. For example, it may not be the best option to put a Rain Barrel right under an existing downspout on one side of a house, where the homeowner will need to run a large amount of hose to reach a garden or Rain Garden on the other side of the house. Sometimes it will make more sense to put the container away from the structure entirely and to convey the water farther from the downspouts to the container via gravity flow.

The relative elevations of downspouts and storage tanks will also affect pumping requirements. Locating storage tanks in low areas will make it easier to route roof drains from buildings to cisterns. However, it

Do:

- Have a use or uses of the water in mind before installing the system
- Empty Rain Barrel between rain events, ideally into another practice

Don't:

- Underestimate the weight of a barrel or cistern full of water
- Allow water to overflow that will sit against the house foundation or structure

can make gravity flow out of the tank more difficult and increase the likelihood that pumping will be necessary to distribute the water to areas situated on higher ground. Conversely, placing storage tanks at higher elevations may require building a pedestal or foundation and securing the tanks, but will reduce or eliminate the amount of pumping needed for distribution.

Setbacks from Buildings The overflow from a storage tank should not cause standing water or saturated soil within 10 feet of any building foundation. Tanks must be watertight to prevent water damage near a building, and in general, underground tanks should be at least 10 feet from any building. Both the overflow outlet pipe and the drawdown outlet pipe should steer water well away from the foundation, with the ground sloping gently away from the building.

Rooftop Material The quality of the harvested rainwater will vary according to not only how much debris gets into the tank, but also based on the roofing material over which it flows (see box below).

Water Table The water table depth is only a concern for a buried cistern. Underground storage tanks are only appropriate where they can be placed entirely above the water table. Special considerations may allow a tank to be partially or entirely submerged in the groundwater, but a professional engineer must design this system due to the necessary structural calculations and water quality concerns.

Consider the Rooftop Material and Water Quality

Water harvested from certain types of rooftops may pick up toxic compounds. Carefully consider the eventual use of water coming off roofs covered with asphalt sealcoats, tar and gravel, paint, treated wood, metal that contains lead, or any material that may contain asbestos. Due to possible toxicity concerns, avoid using water that is questionable for watering food gardens or for any purposes that involve significant body contact.

5.3. Design

There are six primary components of a Rainwater Harvesting system:

- Roof surface
- Collection and conveyance system (e.g., gutter and downspouts)
- Pre-screening/filter
- Storage tank
- Overflow
- Distribution system

Rooftop Surface The rooftop surface should be made of relatively smooth material with good drainage, either from a sloped roof or an efficient roof drain system. Slow drainage of the roof leads to poor rinsing and more accumulation of debris (leaves, sticks, etc.) in gutters, which can decrease the quality of water collected in the system. As mentioned before, some materials may leach toxic chemicals making the water less desirable for certain uses.

Collection and Conveyance System The collection and conveyance system consists of the gutters, downspouts and pipes that channel stormwater runoff into the storage tank. Gutters and downspouts should be designed as they would for a building without a Rainwater Harvesting system. Aluminum, round-bottom gutters and round downspouts are generally recommended for Rainwater Harvesting, although most retrofit systems simply utilize the existing gutters and downspouts. Gutters and downspouts should be kept clean and free of debris and rust.

Pre-Screening Pre-screening of water before it enters the tank is required to keep sediment, leaves, contaminants and other debris from the system. Leaf screens and gutter guards meet the minimal requirement for pre-screening of small systems. Larger or more complex systems may require a pre-fabricated first-flush diverter (see **Figure 5.6**). All pre-filtration devices should be designed to have relatively low maintenance requirements, such as cleaning the screening material several times per year or after significant storm events. The purpose of pre-screening is to significantly cut down on maintenance of the tank itself by preventing debris and organic buildup in the tank, thereby decreasing bacterial growth in the tank.

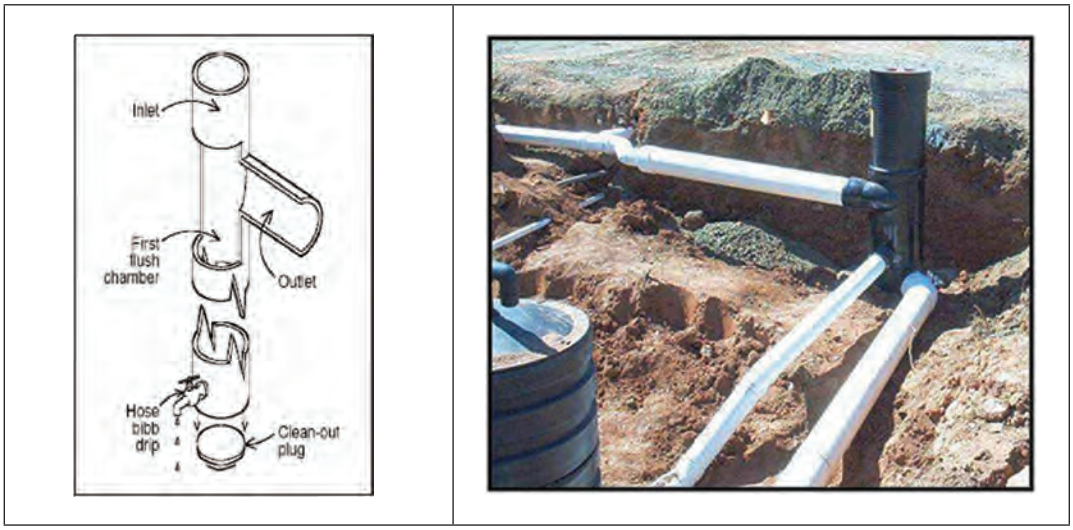

Figure 5.6. *Schematic & photo of pre-screening first-flush diverters designed to remove leaves, grit, and debris before water enters the cistern – applicable for moderate or complex Rainwater Harvesting projects.*
(Source: VADEQ 2011)

Tanks Will Be Heavy

Water weighs 8 pounds per gallon. A full 50-gallon Rain Barrel will weigh approximately 400 pounds. A full 275-gallon cistern will weigh over a ton, at approximately 2,200 pounds!

Storage Tanks The storage tank is the most important and typically the most expensive component of a Rainwater Harvesting system. Typical cistern capacities range from 50 to 250 gallons, although some commercial applications can be over 30,000 gallons. Multiple tanks or barrels can be placed together and connected with pipes to balance water levels and increase overall storage, as needed. The tanks can be made of many materials and configured in various shapes, depending on the type used and the site conditions where the tanks will be installed. For example, configurations can be rectangular, L-shaped, or cylindrical.

Storage tanks should be placed on a solid foundation of tight or compacted soil. The load-bearing capacity of the soil must be considered, since full cisterns can be very heavy. This is particularly important for above-ground cisterns, as significant settling could cause the cistern to lean or potentially topple. A gravel, cinderblock, or concrete base may be appropriate depending on the size of the tank and the existing soils. A strong base is especially important if the tank needs to be raised up to allow for more elevation change for gravity-fed distribution of the water.

Figure 5.7. *Larger above-ground tank made of opaque and durable material.*



Additional factors to consider when designing a Rainwater Harvesting system and tank include:

- Above-ground storage tanks should be UV-light and impact resistant.
- Underground storage tanks must be designed to support any anticipated loads (e.g., coverage soil, vehicles, pedestrian traffic, etc.).
- Underground Rainwater Harvesting systems should have an opening to allow access for cleaning, inspection, and maintenance purposes. This access point should be secured/locked to prevent unwanted access.
- Rainwater Harvesting systems may be ordered from a manufacturer or can be constructed on site from materials, such as ferro-cement.
- Storage tanks should be opaque or otherwise protected from direct sunlight to inhibit algae growth.
- Rain Barrels or cisterns that have an open top should utilize 2 layers of windows screen secured to the top to prevent mosquitoes from getting in and to keep leaves and debris out.

Sizing the Tank(s) For water quality improvement, a 1 inch rainfall event is a typical recommended amount to capture in a Rainwater Harvesting tank. This is the standard for most of Maryland, including Annapolis and the Eastern Shore. Use the following formula to determine how many gallons a roof area will produce in a 1-inch rain event:

Storage volume (gallons) = Area of the roof (square feet) that drains to the tank X 0.625

For a home with a 1200 square foot roof footprint divided equally between 4 downspouts, the area going to one downspout is:

1200 square feet ÷ 4 = 300 square feet

The minimum tank volume needed to capture 1 inch of runoff from that section of roof is:

300 square feet x 0.625 = 187.5 gallons

Given that most Rain Barrels hold approximately 50 - 75 gallons, capturing a full 1 inch of runoff at this downspout will require connecting multiple barrels together (**Figures 5.8 and 5.9**) or using a larger tank (for example, **Figure 5.7**). Most homeowner systems that use only one Rain Barrel are significantly undersized for the 1 inch storm. This is not a problem, but careful consideration of the overflow routing is in order.

Figure 5.8. *Two Rain Barrels connected together to capture more roof runoff*

Water storage below the outlet (e.g., spigot, with hose to garden), called dead storage, and an air gap at the top of the tank should be considered when factoring the total volume of the barrel or cistern. For gravity-fed systems, a minimum of 6 inches of dead storage should be provided. For systems using a pump, the dead storage depth will be based on the pump specifications. For example, in a typical gravity-fed 55-gallon Rain Barrel, 6 inches of storage at the bottom will be approximately 10 gallons and the air gap at the top will be approximately 5 gallons. The actual usable volume of the barrel will be around 40 gallons. Note that 6 inches of standing water at the bottom of the tank is a prime condition for mosquito breeding, so it is essential to make sure the tank system is mosquito proof.

Overflow As mentioned earlier, the overflow at the top of the tank must carry extra water away from the tank and about 10 feet away from any adjacent buildings once the tank fills up. The diameter of the overflow outlet and pipe should be adequate to carry overflow water without the tank overtopping, typically 1 to 3 inches for a small-scale system. Place a screen over the end of the overflow pipe to prevent rodents and insects from

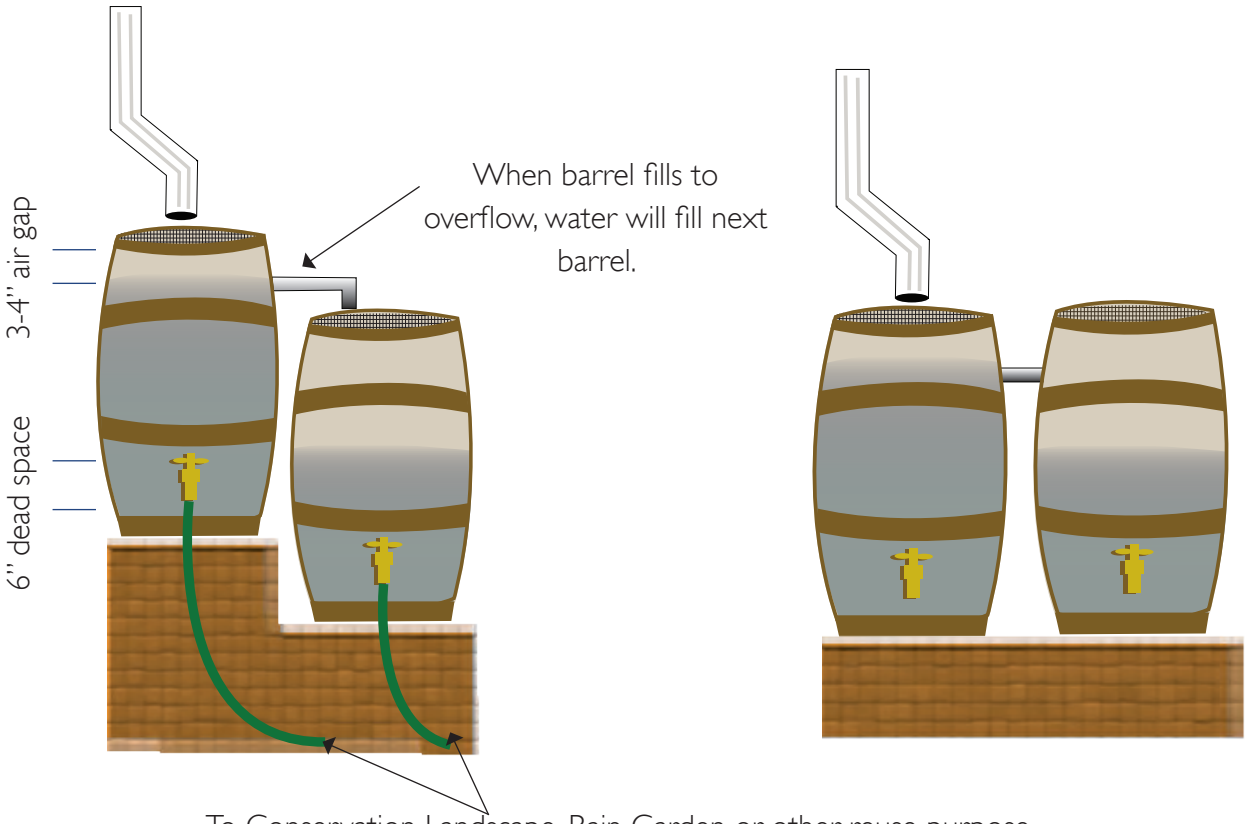

Figure 5.9. *Possible two-barrel configurations for Rainwater Harvesting. This allows more storage while still using small vessels. If more than two barrels are required, a larger tank or cistern is recommended.*

getting into the tank. If possible, lead the overflow pipe to a Conservation Landscape, Rain Garden, or other site that will allow water to infiltrate into the ground.

Outlet For simple gravity-fed Rainwater Harvesting systems, place an outlet spigot near the bottom of the tank (above the dead storage). A regular hose-bib spigot is the easiest type of outlet to use because a garden hose or soaker hose can be directly attached. Ideally, for stormwater management purposes, this outlet would be left open in order to draw down the tank so that it is empty for the next rain event. If the homeowner desires to have some water stored for later use for irrigation, for example, the tank should be emptied before the next storm or at least the spigot left open during non-irrigation months. As with the overflow pipe, drain the outlet/hose to a nearby Rain Garden, Conservation Landscape or other location where the water can soak into the ground.

Figure 5.10. *Rain Barrel with open top, 2 layers of screen, and downspout entering above. This allows for some pre-screening of leaves and debris as well as a strategy to prevent mosquitoes from entering.*



5.4. Materials

Materials for a basic, gravity-fed system are outlined in **Table 5.2.** Note that Rain Barrel kits are readily available from certain vendors, watershed groups, and soil and water conservation districts. These may contain most of the needed materials. See **Table 5.3** for typical components of a simple Rain Barrel.

Table 5.2. Materials Specifications for Rainwater Harvesting Systems

Material	Specifications	Notes/Comments
Downspout	• Match existing gutters and downspouts	• May need elbows or extensions to reach from existing downspouts into to the tank
Pre-screening for simple tank	• Typical leaf screens or gutter guards • Can also use basic, fine-mesh metal or plastic insect screen for top of tank	
Pre-screening first-flush diverter for more complex systems	• Vortex filters or first-flush diverters	• Some simple first-flush diverters for small-scale systems can be made from gutter/downspout materials • More complex vortex filters are pre-fabricated from various vendors
Base/foundation for tank	• When needed, gravel, block or pavers to stabilize the surface under a tank	• The base must be made level • Loose/soft soils must be compacted
Tank/barrel/cistern	• 50-65 gallon food grade plastic barrels • 250-275 cube-shaped plastic tanks in cages	• Variety of materials and configurations possible – should be impact resistant, UV resistant, and able to support any loads above or around it
Spigot and hose	• Typical garden hose, and readily available spigots and connectors from hardware store	• Installing a spigot in bottom of a Rain Barrel may require long reach or long-handled pliers
Overflow outlet/pipe	• Flexible pipe or PVC pipe sections • Connector to secure pipe to tank	• Reduce erosion by allowing water to release at ground level
Erosion control	• 3 inches of gravel, stone, or a splash block	• This will prevent erosion at the opening of the overflow and outlet pipes or hoses
Miscellaneous hard-ware	• *Possible:* downspout extension or adapter, screws, fasteners to hold components together • Non-toxic caulk to seal pipe connections	• This will depend on the specific components of the system, but a hardware store representative will likely be able to advise do-it-yourself efforts
Tools	• *Likely:* adjustable wrench, screwdriver • *Possible:* drill, hole saw bit for drill, hack saw, long-handled pliers, shovel, rake, tamper	• A kit may not require any tools • More tools will be necessary for custom systems



Table 5.3. Materials for a Rain Barrel

Item	Approximate Price	Notes
Screen – a few square feet	$2-7	• If the Rain Barrel has an open top, use a double layer in a crisscross pattern (e.g., the small square holes *not* aligned) secured to the top to prevent mosquito breeding • See **Figure 5.10**
Rain Barrel	$25-100	• The lower price is for the barrel only • Rain Barrel kits may come with spigots, connections, hardware, and/or diverters
Overflow outlet/pipe	$2-5	• Flexible pipe or PVC pipe sections
Hose bib/spigot, ¾ inch with ¾ inch nut, rubber gasket, and washer	$5-10	• Should be water tight, with gasket and washer on inside of barrel
Garden hose	$5-50	• Price depending on length and quality
Self-drilling sheet metal screws	$2-5	• To hold the screen to the lid of the barrel
Tools required: • drill (hole for spigot, starter hole in lid for keyhole saw) • keyhole saw or hole saw for drill attachment (to cut hole in lid) • screwdriver (to secure screen) • pliers (to hold nut in place to secure hose bib) • adjustable wrench (to tighten hose onto spigot)		
General notes: Total cost for this system can be as little as $40 and take only a couple hours to construct. As shown, it does not have a dedicated overflow, but assumes that the ground beneath the barrel is stable and will not erode, like concrete or gravel for example. Pre-assembled kits are readily available, as well.		



5.5. Construction

The following are instructions for constructing a basic, gravity-fed system located close to a downspout:

Step 1 – Prepare the Ground Level the ground where the tank will be located, using rakes or shovels. Test soil compaction by stomping on it or chopping into it. If it is firm, the tank may possibly be placed directly on the ground. If the soil is loose or unstable, tamp it down and build a foundation using gravel and pavers or block. Foundations raise the elevations of the tanks, and clearance under the downspouts should be re-measured to know where to cut off the downspouts.

Step 2 – Check Final Height Measure the height of the tank and make sure there is enough clearance to get the tank under the downspout connection point. Don't forget to account for the height of the foundation below the tank, if applicable.

Step 3 – Assemble Tank Assemble the tank and any necessary connection hardware. Pre-built kits, may have this step partially or fully completed. Otherwise, cut a hole in the lid if necessary, and affix the screen to the lid. Alternatively, connect the downspouts to another screening device or first flush diverter. Install a hose bib 6 inches from the bottom of the tank, if there isn't one already. Attach additional hardware as necessary if the system will have multiple tanks or a dedicated overflow hose. An interconnecting hose between tanks will equalize the water level in the tanks if the water level is above this bridge. An overflow outlet point should be installed near the top, leaving at least 2-6 inches from the top of the tank for the air gap. See the diagram in **Figures 5.2 and 5.3** for examples of barrel-based systems.

Do:

- Make sure the ground beneath the barrel/cistern is solid, and level
- Make sure that wherever the water is directed is several inches below the spigot
- Ensure any overflow is directed away from the house, and to a stable surface like a splash block or gravel with the ground sloping gently away from the house

Don't:

- Use materials easily damaged by sunlight
- Leave the Rain Barrel full after it gets filled – it can only do its job in a storm if it is empty when the rain comes!

When Using Pumps

If the system involves a pump inside the tank, or an underground tank, install any in-tank components and an observation/access port if the tank does not already have one.

Step 4 – Install Tank & Route Downspouts Put the tank in place on the ground or on its foundation and confirm that it is stable and level. Route the downspout into the top of the tank. This will likely involve cutting off a section of the downspout with a hacksaw and attaching a curved downspout section to lead the downspout into the inlet. Connect any filtration or diversion devices to the downspout, if applicable.

Step 5 – Install Overflow Pipe Connect the overflow pipe to the overflow point of the tank and seal it properly. Lead the end of the pipe to where it can release water at ground-level away from the building. The ground at the outlet may need gravel, stone or a splash block to prevent erosion.

Step 6 – Connect Distribution Pipe Connect the hose to the outlet at the bottom of the tank. If the system is intended to have a constant slow-release from the tank, put the open end of the hose in place and make sure the spigot is slightly open. If the system is intended to have the hose ready for use, but with no particular destination in mind, connect a hose and leave it coiled next to the tank.

5.6. Maintenance

Table 5.4. Recommended Maintenance for Rainwater Harvesting Systems

Maintenance Task	Frequency
• Keep gutters and downspouts free of leaves and other debris • Inspect and clean storage tank lids, paying special attention to vents and screens on inflow and outflow spigots	At least once/year
• Inspect and clean pre-screening devices	At least four times/year
• Inspect condition of overflow pipes, overflow filter path and/or secondary runoff reduction practices • Inspect tank for sediment buildup • Inspect structural integrity of tank, pump, pipe and electrical system (as applicable based on the system)	Every third year
• Replace damaged or defective system components • Check mosquito screens and patch holes or gaps immediately	As needed
• Check Rain Barrel or tank regularly to see if mosquito larvae are present • Use mosquito dunks or similar for short-term control and repair any openings allowing mosquitoes to enter	Summer, as needed
• Drain tank after growing season if used for seasonal irrigation use only • Add empty plastic soda bottles (with tops affixed) to the water if some winter use is desired, so that if the tank freezes, it will not crack	Winter, as needed

5.7. Resources

American Rainwater Catchment Systems Association
http://www.arcsa.org/

Cabbell Brand Center. (2009). *Virginia Rainwater Harvesting Manual*, 2nd ed.

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Texas Water Development Board. (2005). *The Texas Manual on Rainwater Harvesting*, 3rd ed.
Virginia Department of Environmental Quality. 2013. *Virginia Stormwater BMP Specifications – Rev. 2013 (DRAFT).* Richmond, VA. Available at: http://www.deq.virginia.gov/Programs/Water/StormwaterManagement/Publications.aspx

Arlington Echo
http://www.arlingtonecho.org/restoration-projects/rain-barrels.html