# 4.6 Rainwater Harvesting

### *Introduction*

Rainwater harvesting systems store rainfall for future use. Rainwater that falls on rooftops is collected and conveyed into an above- or below-ground storage tank (also referred to as a cistern), where it can be used for non-potable water uses and on-site stormwater disposal/infiltration. Non-potable uses may include landscape irrigation, exterior washing (e.g. car washes, building facades, sidewalks, street sweepers, fire trucks, etc.), flushing of toilets and urinals, fire suppression (sprinkler systems), supply for cooling towers, evaporative coolers, fluid coolers and chillers, supplement water for closed loop systems, steam boilers, replenishment of water features and water fountains, distribution to a green wall or living wall system, laundry, and even delayed discharge to the combined sewer system.

In many instances, rainwater harvesting can be combined with a secondary (down-gradient) stormwater practice to enhance stormwater retention and/or provide treatment of overflow from the rainwater harvesting system. Some candidate secondary practices include:

- Disconnection to a pervious or conservation area (see “Disconnection”)
- Overflow to bioretention practices (see “Bioretention”)
- Overflow to infiltration practices (see “Infiltration”)
- Overflow to grass channels or dry swales (see “Open Channels”)

By providing a reliable and renewable source of water to end users, rainwater harvesting systems can also have environmental and economic benefits beyond stormwater management (e.g. increased water conservation, water supply during drought and mandatory municipal water supply restrictions, decreased demand on municipal or groundwater supply, decreased water costs for the end-user, potential for increased groundwater recharge, supply of water post storm/hurricane in case of failed municipal infrastructure etc.).

A Rainwater Harvesting Spreadsheet (RHS) is provided as a companion to this specification and is discussed in more detail in the Rainwater Harvesting Design Criteria section below. The spreadsheet is available for download at http://www.northinlet.sc.edu/LID/ .

## KEY CONSIDERATIONS: RAINWATER HARVESTING

**DESIGN CRITERIA:**

- Rainwater harvesting systems should be sized based on the contributing area, local rainfall patterns and projected demand for the harvested rainwater.
- Pretreatment should be provided upstream of all storage tanks to prevent leaves and other debris from clogging the system.

**BENEFITS:**

- Helps restore pre-development hydrology on development sites and reduces post-construction stormwater runoff rates, volumes and pollutant loads.
- Can be used on nearly any development site.
- Reduces demand on public water supplies, which helps to protect groundwater aquifers from drawdown and salt water intrusion.

**LIMITATIONS:**

- Stored rainwater should be used on a regular basis to maintain system storage capacity.

**SITE APPLICABILITY:**

- Rural Use
- Suburban Use
- Urban Use

- Construction Cost: Medium
- Maintenance: Medium
- Area Required: Low

**STORMWATER MANAGEMENT PRACTICE PERFORMANCE:**

**Runoff Reduction Credit Approach** (applies to Shellfish Bed, SMS4, and infiltration credit approaches)

- Varies[1]

**Coastal Zone Credit Approach**

- Equal to runoff reduction credit.

**Statewide Water Quality Requirement Credit Approach**

- Runoff Reduction credit applies to infiltration requirement.

**Pollutant Removal[1]**

Varies[1] - Total Suspended Solids
Varies[1] - Total Phosphorus
Varies[1] - Total Nitrogen
Varies[1] - Metals
N/A - Pathogens

*[1] = varies according to storage capacity of the rainwater harvesting system and demand for the harvested water.*

*Figure 4.6-1. Example Cistern Application (Photo: Marty Morganello)*

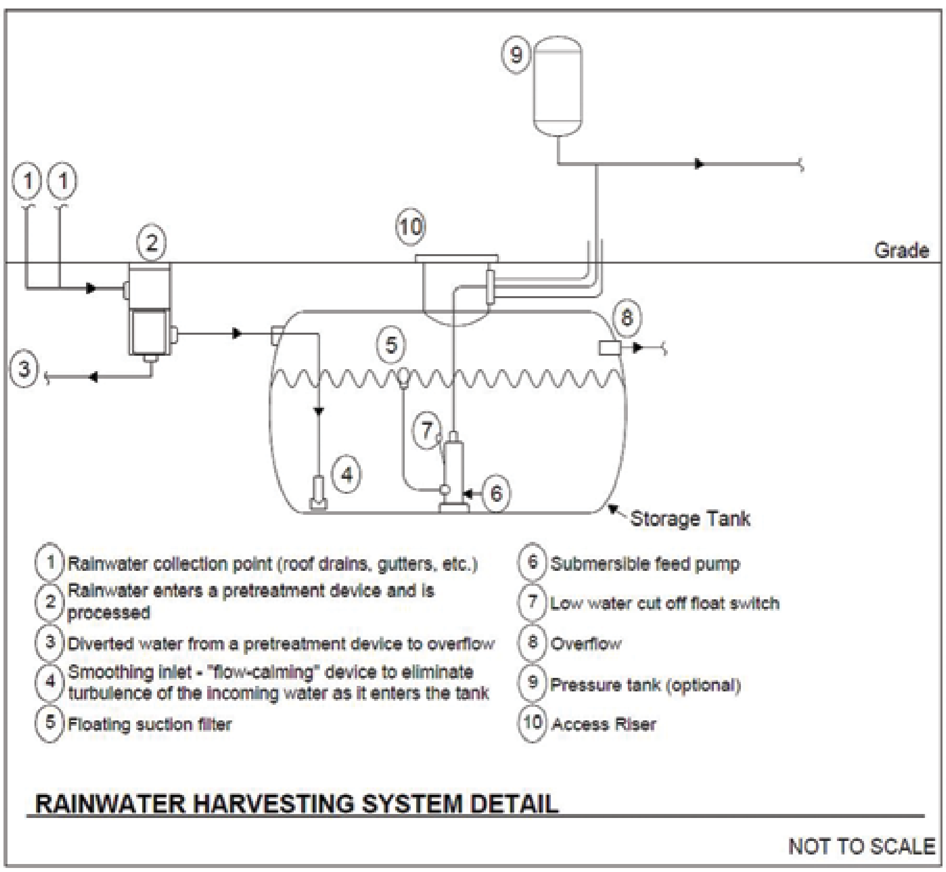


*Figure 4.6-2. Underground Rainwater Harvesting System Detail Example*

## *Rainwater Harvesting Case Study: Charleston County Consolidated 911 Dispatch Center*

Located in Ladson, the Charleston County Consolidated 9-1-1 Center and Emergency Operations Center was completed in 2013. Typically, the building is staffed by an average of 30 people 24 hours a day, 7 days a week; however, during an activation of the emergency response center, that number could swell to 200 people. Aside from being designed to handle extreme weather events, this building was planned with the goal of being Leadership in Energy and Environmental Design (LEED) certified.

To receive LEED credits for reduced water usage, the designers employed several low impact development best management practices across the site, including grassed parking spaces, xeric landscaping, vegetated stormwater ponds, and a rooftop rainwater harvesting system. Runoff from the 18,500 square foot roof is collected and channeled into pairs of inlets spaced around the periphery of the roof. One set of inlets conveys the stormwater into a 5,000 gallon cistern buried behind the building, and the other inlets act as an overflow bypass. A collar placed around the overflow inlet allows several inches of water to pond on the roof before it is diverted via the overflow into the storm drain system and into one of the three dry detention ponds on the property.

The harvested stormwater then passes through a vortex filter located in a mechanical room in the building's bottom floor, which acts as a pretreatment device to remove coarse sediment from the collected rainwater. This particular system is typically designed for outdoor applications, and was modified with an extended top to protect the interior of the building from splashing from the concentrator. This system separates "dirty" (i.e., sediment-laden) and "clean" stormwater, and dirty stormwater is conveyed to stormwater ponds on the property. The clean (i.e., filtered), stormwater is combined with air conditioning condensate and water flushed from 600-gallon potable water tanks, and then piped to the control panel system, where it undergoes final filtration and UV sterilization. This filtered and sterilized water is then conveyed in purple PVC piping (marked as non-potable water) to supply water for flushing 14 low-flow toilets (1.28 gallon per flush) in the building.



*From left to right: rooftop stormwater collection, screening system, and control system.*

### *Rainwater Harvesting Feasibility Criteria*

A number of site-specific features influence how rainwater harvesting systems are designed and/or utilized. These should not be considered comprehensive and conclusive considerations but rather recommendations that should be considered during the process of planning to incorporate rainwater harvesting systems into the site design. The following are key considerations for rainwater harvesting feasibility:

**Plumbing Code.** This specification does not address indoor plumbing or disinfection issues. Designers and plan reviewers should refer to the 2012 Uniform Plumbing Code - Chapter 17 Nonpotable Rainwater Catchment Systems, or local plumbing codes, as applicable. For sizing of conveyance systems refer to Uniform Plumbing Code (UPC) 2012 Edition, Chapter 11: "Storm Drainage" section 1101.11 Roof Drainage - Table D 1.1 Appendix D

**Mechanical, Electrical, Plumbing (MEP).** For systems that call for indoor use of harvested rainwater, the seal of an MEP engineer is typically required.

**Available Space.** Adequate space is needed to house the storage tank and any overflow. Space limitations are rarely a concern with rainwater harvesting systems if they are considered during the initial building design and site layout of a residential or commercial development. Storage tanks can be placed underground, indoors, on rooftops that are structurally designed to support the added weight, and adjacent to buildings. Designers can work with architects and landscape architects to site the tanks creatively. Underground utilities or other obstructions should always be identified prior to final determination of the tank location.

**Site Topography.** Site topography and storage tank location should be considered as they relate to all of the inlet and outlet invert elevations in the rainwater harvesting system.

The final invert of the outlet pipe from the storage tank must match the invert of the receiving mechanism (e.g. natural channel, storm drain system, etc.) that receives this overflow. The elevation drops associated with the various components of a rainwater harvesting system and the resulting invert elevations should be considered early in the design, in order to ensure that the rainwater harvesting system is feasible for the particular site.

Also, site topography and storage tank location will affect pumping requirements. Locating storage tanks in low areas will make it easier to get water into the cisterns; however, it will increase the amount of pumping needed to distribute the harvested rainwater back into the building or to irrigated areas situated on higher ground. Conversely, placing storage tanks at higher elevations may require larger diameter pipes with smaller slopes but will generally reduce the amount of pumping needed for distribution. It is often best to locate a cistern close to the building or drainage area to limit the amount of pipe needed.

**Available Hydraulic Head.** The required hydraulic head depends on the intended use of the water. For residential landscaping uses, the cistern may be sited up-gradient of the landscaping areas or on a raised stand (Raised stands for larger cisterns should be designed by a licensed structural engineer). Pumps are commonly used to convey stored rainwater to the end use in order to provide the required head. When the water is being routed from the cistern to the inside of a building for non-potable use, often a pump is used to feed a much smaller pressure tank inside the building, which then serves the internal water demands. Also, cisterns can use gravity to accomplish indoor residential uses (e.g. laundry) that do not require high water pressure.

**Water Table.** Underground storage tanks are most appropriate in areas where the tank can be buried above the water table. The tank should be located in a manner that does not subject it to flooding. In areas where the tank is to be buried partially below the water table, special design features must be employed, such as sufficiently securing the tank (to keep it from "floating"), and conducting buoyancy calculations when the tank is empty. The tank may need to be secured appropriately with fasteners or weighted to avoid uplift buoyancy (One form of hold down ballast is an automatic fill valve using municipal or well water supply to maintain a minimum depth of water in the underground tank to prevent it from floating). The combined weight of the tank and hold-down ballast must meet or exceed the buoyancy force of the tank. The tank must also be installed according to the tank manufacturer's specifications.

**Soils.** Storage tanks should be placed on a gravel or sand pad, and a concrete pad is recommended for cisterns over 2,000 gallons. The bearing capacity of the soil upon which the cistern will be placed must be considered, as full cisterns can be very heavy. This is particularly important for above-ground cisterns, as significant settling could cause the cistern to lean or have the potential to topple in some cases. Where the installation requires a concrete foundation, the foundation must be designed consistent with the bearing capacity of the soil to support the tank's weight when the cistern is full. Additionally, the pH of the soil should be considered in relation to its interaction with the cistern material.

**Proximity of Underground Utilities.** All underground utilities must be taken into consideration during the design of underground rainwater harvesting systems, treating all of the rainwater harvesting system components and storm drains as typical stormwater facilities and pipes. The underground utilities must be marked and avoided during the installation of underground tanks and piping associated with the system.

**Contributing Drainage Area (CDA).** The contributing drainage area (CDA) to the cistern is the impervious area draining to the tank. Typically, rooftop surfaces are the only allowable surface in the CDA. If paved areas or other surfaces will be part of the CDA, additional treatment of the collected rainwater will likely be required (such as oil/water separators and debris excluders). Areas of any size, including portions of roofs, can be used based on the sizing guidelines in this design specification. Runoff should be routed directly from the drainage area to rainwater harvesting systems in closed roof drain systems or storm drain pipes. Surface drainage should be avoided to prevent increased contamination of the water.

**Contributing Drainage Area Material.** The quality of the harvested rainwater will vary according to the roof material or drainage area over which it flows. Harvesting water from certain types of rooftops and CDAs, such as asphalt sealcoats, tar and gravel, painted roofs, galvanized metal roofs, sheet metal, or any material that may contain asbestos may leach trace metals and other toxic compounds and should be avoided. Wood/Cedar shake roofs should also be avoided as they may retain moisture between rainfall events, allowing for biological growth. If a sealant or paint roof surface is desired, it is recommended to use one that has been certified for such purposes by the National Sanitation Foundation (ANSI/NSF standard). This list can be found at the NSF Website under Protocol P151, "Health Effects from Rainwater Catchment System Components.

**Water Quality of Rainwater.** Designers should note that the pH of rainfall in Coastal South Carolina tends to be acidic, around 5.0, according to the National Atmospheric Deposition Program (NAPD, 2011), which may result in leaching of metals from roof surfaces, tank lining or water laterals, to interior connections. Once rainfall leaves rooftop surfaces, pH levels tend to be slightly higher, ranging from 5.5 to 6.0. Limestone or other materials may be added in the tank to buffer acidity, if desired or based on pH monitoring within the cistern.

**Pollutant Hotspot Land Uses.** Harvesting rainwater can be an effective method to prevent contamination of rooftop runoff that would result from mixing it with ground-level runoff from a stormwater hotspot operation, such as hydrocarbons, metals or pesticides. In areas where higher pollution loading is likely, rainwater harvesting should be avoided.

**Setbacks from Buildings.** Storage tank overflow devices should direct overflow away from buildings to avoid causing ponding or soil saturation within 10 feet of building foundations. Tanks must be designed to be watertight to prevent water damage when placed near building foundations.

**Vehicle Loading.** Whenever possible, underground rainwater harvesting systems should be placed in areas without vehicle traffic or other heavy loading; construction costs increase significantly if underground harvesting systems are designed to be subjected to these additional loads.

**Feasibility in Coastal South Carolina.** Rainwater harvesting systems are very well suited to the warm environment of Coastal South Carolina, and may help to relieve some of the pressure on drinking water aquifers if applied on a wide scale. As previously mentioned, the high water table in much of Coastal South Carolina may mean that above ground installations will often be more appropriate.

**Economic Considerations.** Rainwater harvesting systems can provide cost savings by replacing or augmenting municipal water supply needs.

### *Rainwater Harvesting Conveyance Criteria*

**Collection and Conveyance.** The collection and conveyance system consists of the gutters, downspouts, and pipes that channel rainfall into storage tanks. 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. If the system will be used for management of the 10-year storms, the gutters should be designed to convey the appropriate 10-year storm intensities.

Pipes connecting downspouts to the cistern tank should be at a minimum slope of 1.5% and sized to convey the intended design storm, as specified above. In some cases, a steeper slope and larger sizes may be recommended and/or necessary to convey the required runoff, depending on the design objective and design storm intensity. Gutters and downspouts should be kept clean and free of debris and rust.

**Overflow.** An overflow mechanism should be included in the rainwater harvesting system design in order to handle an individual storm event or multiple storms in succession that exceed the capacity of the tank. The overflow drain must not be equipped with a shutoff valve. Overflow pipes should have a capacity equal to or greater than the inflow pipe(s) and have a diameter and slope sufficient to drain the cistern while maintaining an adequate freeboard height, according to local regulations. The overflow pipe should be screened to prevent access to the tank by rodents and birds. All overflow from the system should be directed to an acceptable flow path that will not cause erosion during a 2-year storm event.

### *Rainwater Harvesting Pretreatment Criteria*

Pre-filtration is required to keep sediment, leaves, contaminants, and other debris from the system. Leaf screens and gutter guards meet the minimal requirement for pre-filtration of small systems, although direct water filtration is preferred. All pre-filtration devices should be low-maintenance. The purpose of pre-filtration is to significantly cut down on maintenance by preventing organic buildup in the tank, thereby decreasing microbial food sources.

Diverted flows (i.e. first flush diversion and overflow from the filter) must be directed to an acceptable flow path that will not cause erosion during a 2-year storm or to an appropriate BMP on the property.

Various pretreatment devices are described below.

- ✧ **First Flush Diverters:** First flush diverters direct the initial pulse of rainfall away from the storage tank (see Figure 4.6-3). While leaf screens effectively remove larger debris such as leaves, twigs, and blooms from harvested rainwater, first flush diverters can be used to remove smaller contaminants such as dust, pollen, and bird and rodent feces.
- ✧ **Leaf Screens:** Leaf screens are mesh screens installed over either the gutter or downspout to separate leaves and other large debris from rooftop runoff. Leaf screens must be regularly cleaned to be effective; if not maintained, they can become clogged and prevent rainwater from flowing into the storage tanks. Built-up debris can also harbor bacterial growth within gutters or downspouts (TWDB, 2005).
- ✧ **Roof Washers:** Roof washers are placed just ahead of storage tanks and are used to filter small debris from harvested rainwater (see Figure 4.6-4). Roof washers consist of

*Figure 4.6-3. First Flush Diverter (Photo: Marty Morganello)*

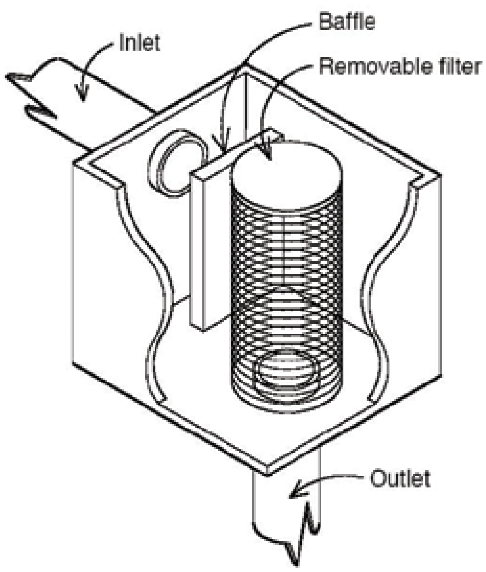


*Figure 4.6-4. Roof Washer (TWRB, 2005).*

a tank, usually between 25 and 50 gallons in size, with leaf strainers and a filter with openings as small as 30-microns. The filter functions to remove very small particulate matter from harvested rainwater. All roof washers must be cleaned on a regular basis.

- ✧ **Vortex Filters:** For large scale applications, vortex filters can provide filtering of rainwater from larger CDAs. Vortex filters do not collect debris, but rather allow it to wash through the filter in order to minimize maintenance. The debris is washed out of the filter with a portion of the rainwater, thereby reducing slightly the amount of rainwater collected to the storage tank.

### *Rainwater Harvesting Design Criteria*

**System Components:** Seven primary components of a rainwater harvesting system include:

- ✧ Contributing Drainage Area (CDA)
- ✧ Collection and conveyance system (e.g. gutter and downspouts)
- ✧ Pre-screening and first flush diverter (Pretreatment)
- ✧ Storage tank
- ✧ Water quality treatment
- ✧ Distribution system
- ✧ Overflow, filter path or secondary stormwater retention practice

The system components are discussed below:

**CDA Surface:** When considering CDA surfaces, note smooth, non-porous materials will drain more efficiently. Slow drainage of the CDA leads to poor rinsing and a prolonged first flush, which can decrease water quality. If the harvested rainwater will be directed towards uses with significant human exposure (e.g. pool filling, public sprinkler fountain, etc.), care should be taken in the choice of CDA materials, and treatment to potable standards may be required. Some materials may leach toxic chemicals making the water unsafe for humans.

**Collection and Conveyance System:** See *Rainwater Harvesting Feasibility Criteria*.

**Pretreatment:** See *Rainwater Harvesting Pretreatment Criteria*.

**Storage Tank:** The storage tank is the most important and typically the most expensive component of a rainwater harvesting system. Cistern capacities typically range from 250 to over 30,000 gallons, but can be as large as 100,000 gallons or more for larger projects. Multiple tanks can be placed adjacent to each other and connected with pipes to balance water levels and to tailor the volume storage needed. Typical rainwater harvesting system capacities for residential use range from 1,500 to 5,000 gallons. Storage tank volumes are calculated to meet the water demand and stormwater storage volume objectives, as described in more detail below.

While many of the graphics and photos in this specification depict cisterns with a cylindrical shape, 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 step vertically to match the topography of a site.

*Above ground storage tanks* should be of an opaque material, approved for above-ground use in direct sunlight or be shielded from direct sunlight. Tanks should be installed in an accessible location to allow for inspection and cleaning. The access opening must be installed in such a way as to prevent surface- or groundwater from entering through any fittings, and must be secured/locked to prevent unwanted entry.

*Underground storage tanks* must be structurally designed to withstand anticipated earth or other loads. Underground tanks should be provided with manholes with openings located at least 4 inches above the surrounding grade. The access opening must be installed in such a way as to prevent surface- or groundwater from entering through any fittings, and must be secured/locked to prevent unwanted entry.

Additional factors that should be considered when designing a rainwater harvesting system and selecting a storage tank:

- All rainwater harvesting systems should be sealed using a water-safe, non-toxic substance.
- Rainwater harvesting systems may be ordered from a manufacturer or can be constructed on site from a variety of materials. Table 4.6-1 compares the advantages and disadvantages of different storage tank materials.
- Dead storage below the outlet to the distribution system and an air gap at the top of the tank should be added to the total volume. 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.
- Any connection to a municipal backup water supply should have a backflow prevention device to keep municipal water separate from stored rainwater; this may include incorporating an air gap to separate the two supplies.

**Distribution Systems:** Some rainwater harvesting systems require a pump to convey the water to its final distribution point. Whether it is a submersible pump or an external pump with or without a pressurized storage tank, it should be sized appropriately to the application. Some pump designs may require a back up water supply to ensure proper operation of the pump during low water level periods.

**Water Quality Treatment:** Depending upon the collection surface, method of dispersal and proposed use for the harvested rainwater, a water quality treatment device may be necessary.

**Overflow:** See Rainwater Harvesting Conveyance Criteria section.

**Table 4.6-1. Advantages and disadvantages of various cistern materials**

| Tank Material | Advantages | Disadvantages |
|---|---|---|
| Fiberglass | Commercially available, alterable and moveable; durable with little maintenance; light weight; integral fittings (no leaks); broad application | Must be installed on smooth, solid, level footing; pressure proof for below-ground installation; expensive in smaller sizes |
| Polyethylene | Commercially available, alterable, moveable, affordable; available in wide range of sizes; can install above or below ground; little maintenance; broad application | Can be UV-degradable; must a dark, opaque color for above-ground installations; pressure-proof for below- ground installation |
| Modular Storage | Can modify to topography; can alter footprint and create various shapes to fit site; relatively inexpensive | Longevity may be less than other materials; higher risk of puncturing of water tight membrane during construction |
| Plastic Barrels | Commercially available; inexpensive | Low storage capacity (20 to 100 gallons); limited application |
| Galvanized Steel | Commercially available, alterable, and moveable; available in a range of sizes; film develops inside to prevent corrosion | Possible external corrosion and rust; must be lined for potable use; can only install above ground; soil pH may limit underground applications |
| Steel Drums | Commercially available, alterable, and moveable | Small storage capacity; prone to corrosion, and rust can lead to leaching of metals; verify prior to reuse for toxics; water pH and soil pH may also limit applications |
| FerroConcrete | Durable and immoveable; suitable for above or below ground installations; neutralizes acid rain | Potential to crack and leak; expensive |
| Cast in Place Concrete | Durable, immoveable, versatile; suitable for above or below ground installations; neutralizes acid rain | Potential to crack and leak; permanent; will need to provide adequate platform and design for placement in clay soils |
| Stone or concrete Block | Durable and immoveable; keeps water cool in summer months | Difficult to maintain; expensive to build |
| *Source: Cabell Brand Center, 2007; Cabell Brand Center, 2009* | | |

**Rainwater Harvesting Material Specifications:** The basic material specifications for rainwater harvesting systems are presented in Table 4.6-2. Designers should consult with experienced rainwater harvesting system and irrigation installers on the choice of recommended manufacturers of prefabricated tanks and other system components.

**Table 4.6-2. Design specifications for rainwater harvesting systems**

| Item | Specification |
|---|---|
| Gutters and Downspout | ♦ Materials commonly used for gutters and downspouts include polyvinyl-chloride (PVC) pipe, vinyl, aluminum and galvanized steel. Lead should not be used as gutter and downspout solder, since rainwater can dissolve the lead and contaminate the water supply.<br>♦ The length of gutters and downspouts is determined by the size and layout of the catchment and the location of the storage tanks.<br>♦ Be sure to include needed bends and tees. |
| Pre-Treatment | At least one of the following (all rainwater to pass through pretreatment):<br>♦ First flush diverter<br>♦ Vortex filter<br>♦ Roof washer<br>♦ Leaf and mosquito screen (1 mm mesh size) |
| Storage Tanks | ♦ Materials used to construct storage tanks should be structurally sound.<br>♦ Tanks should be constructed in areas of the site where native soils can support the load associated with stored water.<br>♦ Storage tanks should be water tight and sealed using a water-safe, non-toxic substance.<br>♦ Tanks should be opaque to prevent the growth of algae.<br>♦ Reused tanks should be fit for potable water or food-grade products.<br>♦ The size of the rainwater harvesting system(s) is determined through design calculations. |

*Note: This table does not address indoor systems or pumps.*

**Design Objectives and System Configuration:** Many rainwater harvesting system variations can be designed to meet user demand and stormwater objectives. This specification focuses on providing a design framework for achieving the water quality volume objectives for compliance with state regulations. From a rainwater harvesting standpoint, there are numerous potential configurations that could be implemented. However, in terms of addressing the design storm, this specification adheres to the following concepts in order to meet the stormwater retention goals properly:

- System design is encouraged to use rainwater as a resource to meet on-site demand or in conjunction with other stormwater retention practices.
- Peak flow reduction is realized through reduced volume and temporary storage of runoff.

Therefore, the rainwater harvesting system design configurations presented in this specification are targeted for use of rainwater through either internal use or seasonal irrigation. While internal use results in a steady year-round demand for the harvested rain water, seasonal irrigation will vary with the time of year, and the retention value is reduced accordingly.

**Design Objectives and Tank Design Set-Ups:** Pre-fabricated rainwater harvesting cisterns typically range in size from 250 to over 30,000 gallons. There are three basic tank design configurations used to meet the various rainwater harvesting system configurations that are described below.

**Tank Design 1.** The first tank set-up (Figure 4.6-5) maximizes the available storage volume associated with the water quality volume to meet the desired level of stormwater retention. This layout also maximizes the storage that can be used to meet a demand. An emergency overflow exists near the top of the tank as the only gravity release outlet device (not including the pump, manway or inlets). It should be noted that it is possible to address 10-year storm volumes with this tank configuration, but the primary purpose is to address the smaller water quality design storm.

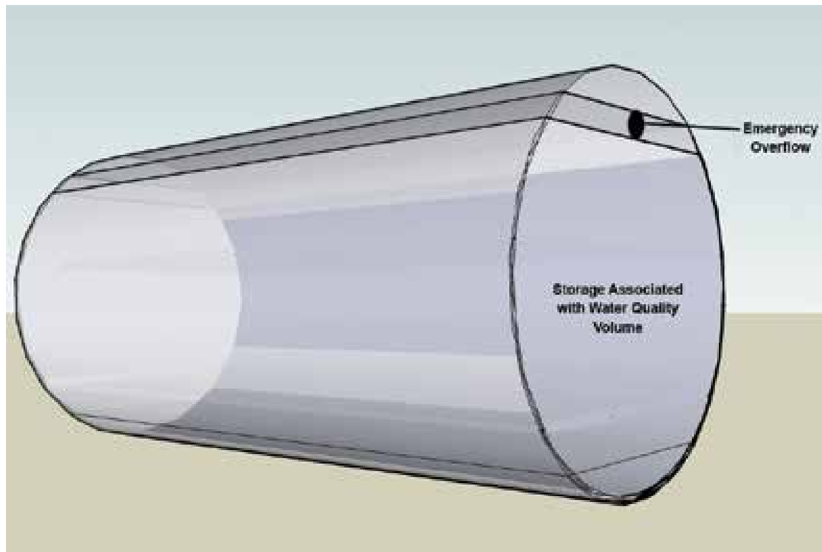


*Figure 4.6-5. Tank Design 1: Storage Associated with the Design Storm Volume Only (Source: Alex Foraste)*

**Tank Design 2.** The second tank set-up (Figure 4.6-6) uses tank storage to meet the storage objectives as well as using an additional detention volume to meet some or all of the 10-year storm volume requirements. An orifice outlet is provided at the top of the design storage for the water quality volume level, and an emergency overflow is located at the top of the detention volume level.

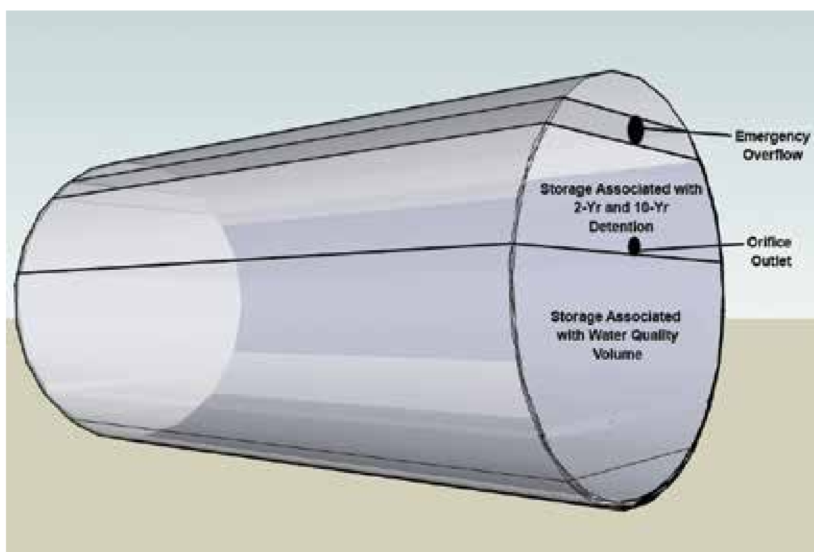


*Figure 4.6-6. Tank Design 2: Storage Associated with SWTV, 2-year and 10-year Storms. (Source: Alex Foraste)*

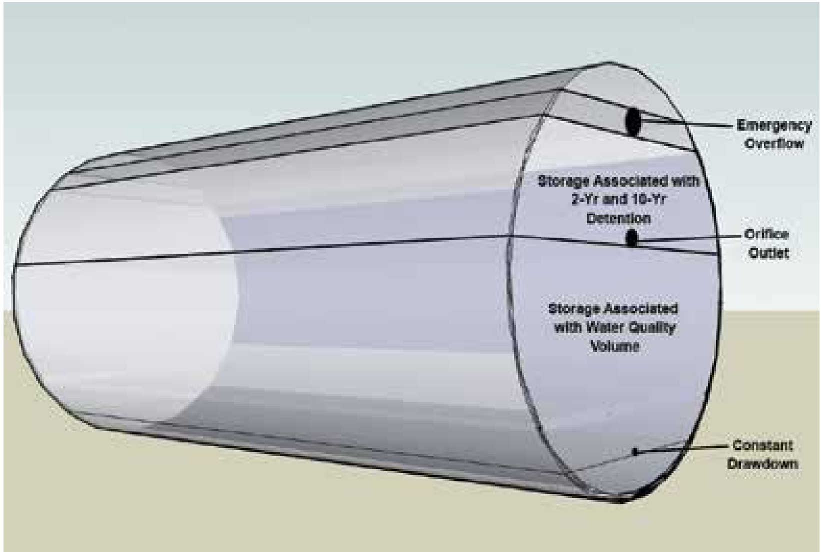


*Figure 4.6-7. Tank Design 3: Constant drawdown, Storage Associated with WQTV, 2-year and 10-year Storms. (Source: Alex Foraste)*

**Tank Design 3.** The third tank set-up (Figure 4.6-7) creates a constant drawdown within the system. The small orifice at the bottom of the tank needs to be routed to an appropriately designed secondary practice (e.g., rain garden, urban bioretention, etc.) that will allow the rainwater to be treated and allow for groundwater recharge over time. The release should not be discharged to a receiving channel or storm drain without treatment, and maximum specified drawdown rates from this constant drawdown should be adhered to, since the primary function of the system is not intended to be detention.

For Tank Design 3 volume calculations, the constant drawdown volume should be considered as a part of the secondary practice (e.g. the tank volume acts as additional ponding volume for a bioretention area), rather than a rainwater harvesting practice that requires use of the Rainwater Harvesting Spreadsheet (RHS).

While a small orifice is shown at the bottom of the tank in Figure 4.6-7, the orifice could be replaced with a pump that would serve the same purpose, conveying a limited amount of water to a secondary practice on a routine basis.

**Sizing of Rainwater Harvesting Systems:** The rainwater harvesting cistern sizing criteria presented in this section were developed using a spreadsheet model that used best estimates of indoor and outdoor water demand, long-term rainfall data, and CDA capture area data (Forasté and Lawson, 2009). It is primarily intended to provide guidance in sizing cisterns and to quantify the storage volume achieved for input into the compliance calculator spreadsheet for stormwater management compliance purposes. A secondary objective of the spreadsheet is to increase the beneficial uses of the stored stormwater, treating it as a valuable natural resource. More information on the RHS can be found below.

**Incremental Design Volumes within Cistern:** Rainwater tank sizing is determined by accounting for varying precipitation levels; captured CDA runoff; first flush diversion (through filters) and filter efficiency; low water cut-off volume; dynamic water levels at the beginning of various storms; storage needed for the design storm (permanent storage); storage needed for 2-year or 10-year volume (temporary detention storage); seasonal and year-round demand use and objectives; overflow volume; and freeboard volumes above high water levels during very large storms. See Figure 4.6-8 for a graphical representation of these various incremental design volumes.

This specification does not provide design guidance for sizing larger storms (e.g., 10-yr) but rather provides guidance on sizing for the water quality volume (WQV).

The "Storage Associated with the Design Storm" is the storage within the tank that is modeled and available for reuse. While the water quality volume (WQV) will remain the same for a specific CDA, the "Storage Associated with the Design Storm" may vary depending on demand and storage volume retention objectives. It includes the variable water level at the beginning of a storm and the low water cut-off volume that is necessary to satisfy pumping requirements, if needed.

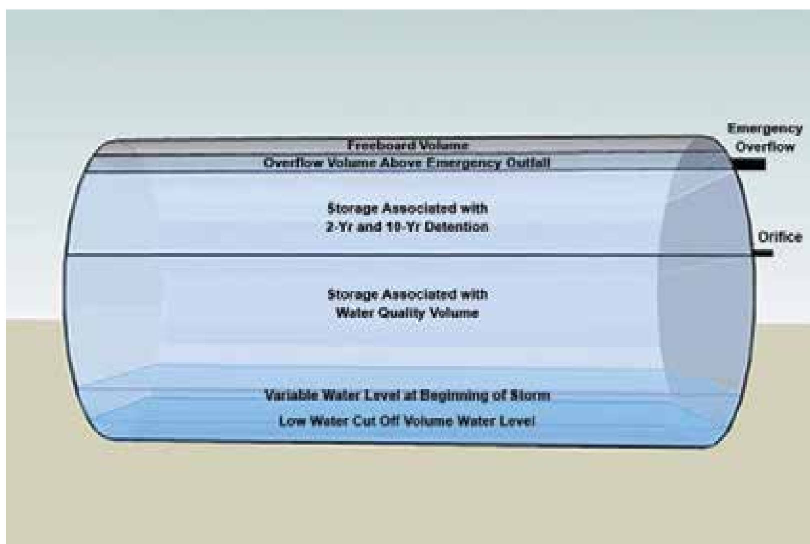


*Figure 4.6-8. Incremental Design Volumes Associated with Tank Sizing. (Source: Alex Foraste)*

### *Rainwater Harvesting Spreadsheet*

This specification is linked with the Rainwater Harvesting Spreadsheet (RHS). The spreadsheet uses daily rainfall data from December 3, 1982 to December 31, 2012 at Charleston International Airport to model performance parameters of the cistern under varying CDAs, demands on the system and tank size.

The spreadsheet begins with determining the runoff from the CDA. The CDA is assumed to be impervious, so a runoff coefficient of 0.95 is used. The runoff produced by any storm event enters the cistern and is added to the water level that existed in the cistern the previous day, while all of the selected water demands are subtracted on a daily basis. If any overflow is realized, the volume is quantified and recorded. If the tank runs dry (reaches the cut-off volume level), then the volume in the tank is fixed at the low level, and a dry-frequency day is recorded. The full or partial demand met in both cases is quantified and recorded. A summary of the water balance for the system is provided below.

**Water Contribution:**

- ✧ **Precipitation.** The volume of water contributing to the rainwater harvesting system is a function of the rainfall and drainage area captured, as defined by the designer.
- ✧ **Municipal Backup (optional).** In some cases, the designer may choose to install a municipal backup water supply to supplement tank levels. Some pump designs may require a back up water supply to ensure proper operation of the pump during low water level periods. Note that municipal backups also may be connected post-tank (i.e. a connection is made to the non-potable water line that is used for pumping water from the tank for reuse), thereby not contributing any additional volume to the tank. Municipal backup designs that supply water directly to the tank are not accounted for in the RHS.

**Water Losses:**

- ✧ **Drainage Area Runoff Coefficient.** The CDA is assumed to convey 95% of the rainfall that lands on its surface (i.e. Rv = 0.95).
- ✧ **First Flush Diversion.** The first flush that is directed to filters is diverted from the system in order to prevent clogging it with debris. This value is assumed to be contained within the filter efficiency rate.
- ✧ **Filter Efficiency.** It is assumed that, after the first flush diversion and loss of water due to filter inefficiencies, the remainder of the runoff will be successfully captured. Typical minimum filter efficiencies are included in the RHS, although they can be altered if appropriate. The RHS applies these filter efficiencies, or interpolated values, to the daily rainfall record to determine the volume of runoff that reaches the tank. For the purposes of selecting an appropriately sized filter, a rainfall intensity of 1 inch per hour should be used for the water quality volume. The appropriate rainfall intensity values for the 2-year and 10-year storms shall be used when designing for larger storm events.
- ✧ **Drawdown (Storage Volume).** This is the stored water within the cistern that is used for activities such as irrigation, toilet and urinal flushing, cooling towers, constant

drawdown, etc. It is the volume of runoff that is removed from the cistern on a daily basis. This water loss is what creates available cistern space for subsequent storm events, and translates into retention water quality credit volume.

- ✧ **Overflow.** This is the volume of water that may be lost during large storm events or successive precipitation events.

**Results for Water Quality Volume:** The amount of CDA runoff volume that the tank can capture and use or draw down is quantified and recorded. These results are presented on the "Results-Water Quality Volume" tab. This information is used to calculate the storage volume achieved, which is used as an input to the compliance calculator spreadsheet.

- ✧ **Maximum Credited Volume.** The maximum credited volume is calculated for multiple sizes of cisterns. A trade-off curve plots these results, which allows for a comparison of the credited volume achieved versus cistern size. While larger tanks yield higher water quality credit, they are more costly. The curve assists the user to choose the appropriate tank size, based on the design objectives and site needs, as well as to understand the rate of diminishing returns. Above a certain tank size, the credited volume does not increase, because the 1 inch of runoff has been completely captured.
- ✧ **Overflow Volume.** The overflow volume resulting from storm events producing 1 inch of runoff is also reported in this tab. A chart of the credited volume and overflow volume versus the cistern size is provided. An example is shown in Figure 4.6-9.

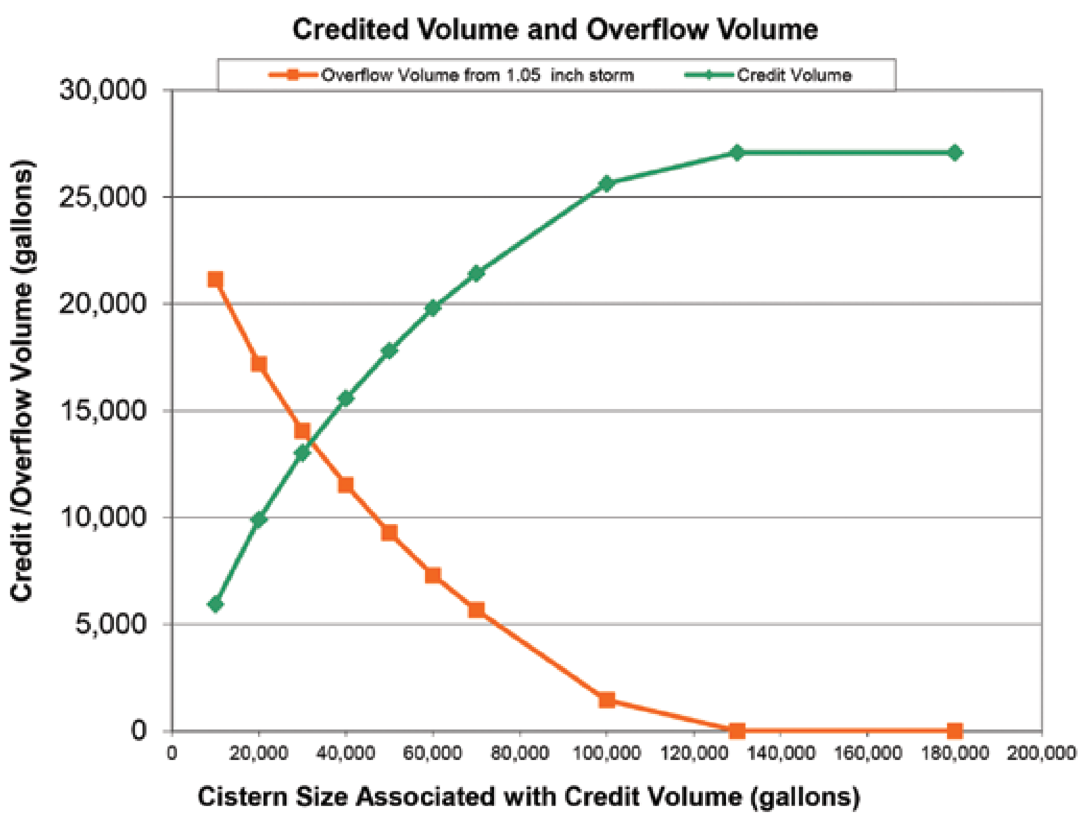


*Figure 4.6-9. Credited Volume and Overflow Volume vs. Cistern Size (Example).*

These plotted results establish a trade-off relationship between these two performance metrics. In the above example, a 100,000 gallon cistern optimizes the credit volume achieved and the overflow volume (near the inflection point of both curves).

**Results – General:** The performance results of the rainwater harvesting system for all days during the entire period modeled, including the full spectrum of precipitation events, is included in the "Results-General" tab. This tab is not associated with determining the water quality credit achieved, but rather it may be a useful tool in assisting the user to realize the performance of the various rainwater harvesting system sizes with the design parameters and demands specified.

- **Percent Demand Met.** This is where the demand met for various sizes of cisterns and CDA/demand scenarios is reported. A graph displaying the percentage of demand met for various cistern sizes is provided in this tab. This graph is intended to assist the user in understanding the relationship between cistern sizes and optimal/diminishing returns. An example is provided in Figure 4.6-10.

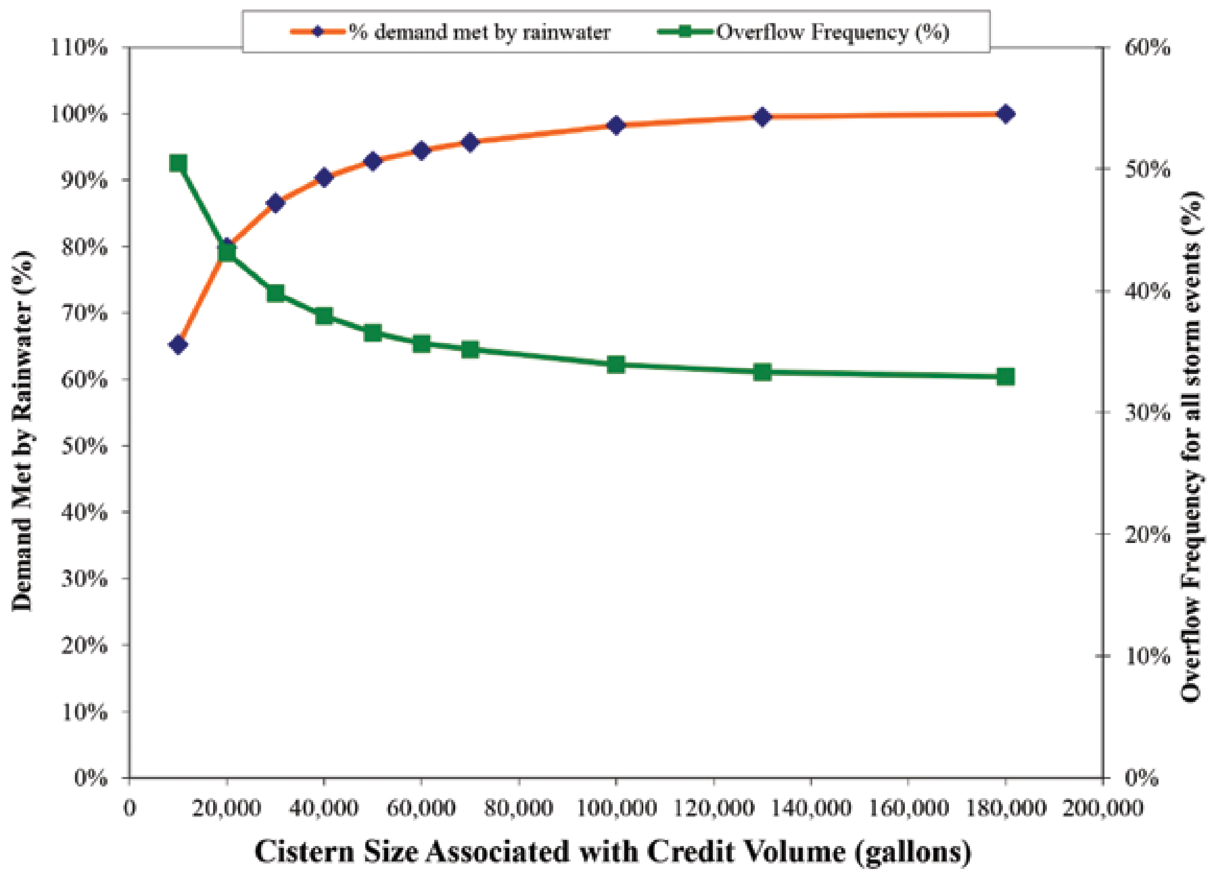


*Figure 4.6-10. Demand Met and Overflow Frequency vs. Cistern Size (Example).*

At some point, larger cisterns no longer provide significant increases in percentages of demand met. Conversely, the curve informs the user when a small increase in cistern size can yield a significant increase in the percentage of time demand that is met.

- ✧ **Dry Frequency.** Another useful measure is the dry frequency. If the cistern is dry a substantial portion of the time, this measure can inform the user that he/she may want to decrease the size of the cistern, decrease the demand on the system or explore capturing more CDA to provide a larger supply, if feasible. It can also provide useful insight for the designer to determine whether he/she should incorporate a municipal backup supply to ensure sufficient water supply through the system at all times.
- ✧ **Overflow Frequency.** This is a metric of both overflow frequency and average volume per year for the full spectrum of rainfall events. This will inform the user regarding the design parameters and magnitude of demand and associated performance of the system. If the system overflows at a high frequency, then the designer may want to increase the size of the cistern, decrease the CDA captured, or consider other mechanisms that could increase drawdown (e.g. increase the area to be irrigated, incorporate or increase on-site infiltration, etc.).
- ✧ **Inter-relationships and Curves of Diminishing Returns.** Plotting various performance metrics against one another can be very informative and reveal relationships that are not evident otherwise. One such inter-relationship is the percentage of demand met versus cistern size compared to the percentage of overflow frequency versus tank size, depicted on the same graph. A range of cistern sizes tends to emerge, informing the designer where a small increase or decrease in cistern size can have a significant impact on dry frequency and overflow frequency. Conversely, outside this range, changes in cistern sizes would yield small changes to dry frequency and overflow frequency, yet yield a large trade-off compared to the cost of the rainwater harvesting system.

***Results from Rainwater Harvesting Spreadsheet to be transferred to Compliance Calculator Spreadsheet. In the LID Compliance Calculator spreadsheet, rainwater harvesting practices receive a runoff reduction credit and a storage credit based upon the average volume available in the cistern.***

Two results from this RHS should be transferred to the LID Compliance Calculator spreadsheet, as follows:

1. **Contributing Drainage Area (CDA):** Enter the CDA that was used in the RHS into the Impervious Cover Draining to BMP.
2. **Maximum Credited Volume:** Once the cistern size has been selected, enter the maximum credited volume (cubic feet) from column K in the RHS as the Storage Volume in the LID Compliance Calculator spreadsheet. This credited storage volume, *Sv*, is given 100% credit toward water quality volume requirements.

**Completing the Sizing Design of the Cistern:**

The total size of the cistern tank is the sum of the following four volume components:

1. **Low Water Cutoff Volume** (Included). A dead storage area must be included so that the pump will not run the tank dry. This volume is included within the Cistern Design Spreadsheet volume modeled.

2. **Cistern Storage Associated with Design Volume** (Included). This is the volume that was designed for using the Cistern Design Spreadsheet.
3. **Adding Channel Protection and Flood Volumes** (Optional). Additional detention volume may be added above and beyond the Cistern Storage associated with the design storm volumes for the 10-year event. Typical routing software programs may be used to design for this additional volume.
4. **Adding Overflow and Freeboard Volumes** (Required). An additional volume above the emergency overflow must be provided in order for the tank to allow very large storms to pass. Above this, overflow water level will be an associated freeboard volume. This volume must account for a minimum of 5% of the overall tank size; however, sufficient freeboard should be verified for large storms. These volumes need to be added to the overall size of the cistern tank.

### *Rainwater Harvesting Landscaping Criteria*

If the harvested water is to be used for irrigation, the design plan elements should include the proposed delineation of planting areas to be irrigated, the planting plan, and quantification of the expected water demand. The default water demand for irrigation is 1.0 inch per week over the area to be irrigated. Justification should be provided if larger volumes are to be used.

### *Rainwater Harvesting Construction Sequence*

**Rainwater Harvesting Installation.** It is advisable to have a single contractor to install the rainwater harvesting system, outdoor irrigation system, and secondary water quality practices. The contractor should be familiar with rainwater harvesting system sizing, installation, and placement. The American Rainwater Catchment Systems Association (ARCSA) provides professional accreditation for those with expertise in this field. Any back flow prevention devices or connections to municipal water supply must be made by a licensed plumbing contractor.

A standard construction sequence for proper rainwater harvesting system installation is provided below. This can be modified to reflect different rainwater harvesting system applications or expected site conditions.

- Choose the tank location on the site.
- Route all downspouts or pipes to pre-screening devices and first flush diverters.
- Properly install the tank.
- Install the pump (if needed) and piping to end-uses (indoor, outdoor irrigation, or tank dewatering release).
- Route all pipes to the tank.
- Stormwater should not be diverted to the rainwater harvesting system until the overflow filter path has been stabilized.

**Construction Inspection.** The following items should be inspected prior to final sign-off and acceptance of a rainwater harvesting system:

- Rooftop area matches plans
- Diversion system is properly sized and installed

- ✧ Pretreatment system is installed
- ✧ Mosquito screens are installed on all openings
- ✧ Overflow device is directed as shown on plans
- ✧ Rainwater harvesting system foundation is constructed as shown on plans
- ✧ Catchment area and overflow area are stabilized
- ✧ Secondary stormwater treatment practice(s) is installed as shown on plans

### *Rainwater Harvesting Maintenance Criteria*

**Maintenance Inspections**

It is highly recommended that periodic inspections and maintenance be conducted for each system.

**Rainwater Harvesting System Maintenance Schedule:**

Maintenance requirements for rainwater harvesting systems vary according to use. Systems that are used to provide supplemental irrigation water have relatively low maintenance requirements, while systems designed for indoor uses have much higher maintenance requirements. Table 4.6-3 describes routine maintenance tasks to keep rainwater harvesting systems in working condition.

**Table 4.6-3. Suggested maintenance tasks for rainwater harvesting systems.**

| Activity | Frequency |
|---|---|
| Keep gutters and downspouts free of leaves and other debris | O: Twice a year |
| Inspect and clean pre-screening devices and first flush diverters | O: Four times a year |
| Inspect and clean storage tank lids, paying special attention to vents and screens on inflow and outflow spigots. Check mosquito screens and patch holes or gaps immediately | O: Once a year |
| Inspect condition of overflow pipes, overflow filter path, and/or secondary stormwater treatment practices | O: Once a year |
| Inspect water quality devices | I: According to Manufacturer |
| Inspect tank for sediment buildup | I: Every third year |
| Clear overhanging vegetation and trees over roof surface | O: Every third year |
| Check integrity of backflow preventer | I: Every third year |
| Inspect structural integrity of tank, pump, pipe, and electrical system | I: Every third year |
| Replace damaged or defective system components | I: As needed. |
| *Key: O = Owner    I = Qualified third party inspector* | |

**Mosquitoes.** In some situations, poorly designed rainwater harvesting systems can create habitat suitable for mosquito breeding and reproduction. Designers should provide screens on above- and below-ground tanks to prevent mosquitoes and other insects from entering the tanks. If screening is not sufficient in deterring mosquitoes, dunks or pellets containing larvicide can be added to cisterns when water is intended for landscaping use.

An example maintenance checklist for rainwater harvesting is included in *Appendix F*.

### Rainwater Harvesting References and Additional Resources


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