Rain Tanks / Cisterns

Description: Rain tanks and cisterns are used to intercept, divert, store and release rain falling on rooftops for future use.

Variations:
- Aboveground Storage
- Underground Storage

Components:
- Roof surface
- Collection and conveyance system
- Pre-screening and first flush diverter
- Storage tank
- Distribution system
- Overflow, filter path or secondary runoff reduction practice

Advantages/Benefits:
- Water source for non-potable uses (toilet flushing, irrigation)

Disadvantages/Limitations:
- Systems must drain between storm events

Design considerations:
- Underground storage tanks must be above groundwater level
- Certain roof materials may leach metals or hydrocarbons, limiting potential uses for harvested rainwater
- Underground tanks should be set at least 10 feet from building foundations
- Cistern overflows should be designed to avoid soil saturation within 10 feet of building foundations
- Systems must be designed for consistent drawdown year-round
- Aboveground storage tanks should be UV resistant and opaque to inhibit algae growth
- Underground storage tanks must be designed to support anticipated loads
- Hookups to municipal backup water supplies must be equipped with backflow prevention devices

Additional Considerations:
- See Page 2

Selection Criteria:

Up to 90% Runoff Reduction Credit

Land Use Considerations:

X	**Residential**
X	**Commercial**
X	**Industrial**

Maintenance:
- Gutters and downspouts should be kept clean and free of debris and rust.
- Annual inspection

H	**Maintenance Burden** L = Low M = Moderate H = High

Roof Surface

- The rooftop should be made of smooth, non-porous material with efficient drainage either from a sloped roof or an efficient roof drain system.

Collection and Conveyance System

- Gutters and downspouts should be designed as they would for a building without a rainwater harvesting system.
- Gutters should be sized with slopes specified to contain the necessary amount of stormwater for treatment volume credit.
- Pipes (connecting downspouts to the cistern tank) should be at a minimum slope of 1.5% and sized/designed to convey the intended design storm.

Pre-Screening and First Flush Diverter

- Inflow must be pre-screened to remove leaves, sediment, and other debris.
- For large systems, the first flush (0.02 – 0.06 inches) of rooftop runoff should be diverted to a secondary treatment practice to prevent sediment from entering the system.
- Rooftop runoff should be filtered to remove sediment before it is stored.

Storage Tank

- Storage tanks are sized based on consideration of indoor and outdoor water demand, long-term rainfall and rooftop capture area.

Distribution System

- The rainwater harvesting system should be equipped with an appropriately-sized pump that produces sufficient pressure for all end-uses.
- Distribution lines should be installed with shutoff valves and cleanouts, and should be buried beneath the frost line or insulated to prevent freezing.

Overflow

- The system must be designed with an overflow mechanism to divert runoff when the storage tanks are full.
- Overflows should discharge to pervious areas set back from buildings and paved surfaces, or to secondary BMPs.

SECTION 1: DESCRIPTION

A cistern intercepts, diverts, stores and releases rainfall for future use. The term cistern is used in this specification, but it is also known as a rainwater harvesting system. Rainwater that falls on a rooftop is collected and conveyed into an above- or below-ground storage tank where it can be used for non-potable water uses and on-site stormwater disposal/infiltration. Non-potable uses may include flushing of toilets and urinals inside buildings, landscape irrigation, exterior washing (e.g. car washes, building facades, sidewalks, street sweepers, fire trucks, etc.), supply for chilled water cooling towers, replenishing and operation of laundry, if approved by Metro Water Services (MWS).

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

- Downspout Disconnection: GIP-07 (excluding rain tanks and cisterns). This may include release to a compost-amended filter path
- Sheet Flow to a Vegetated Filter Strip or Conserved Open Space: GIP-09
- Grass Channel: GIP-08
- Infiltration Trench: GIP-04
- Bioretention: GIP-01
- Urban Bioretention: GIP-02. Storage and release in a foundation planter.
- Water Quality Swale: GIP-05

Section 5.3 (Physical Feasibility & Design Applications) provides more detail on system configurations, including the use of secondary practices.

In addition, the actual runoff reduction rates for rainwater harvesting systems are "user defined," based on tank size, configuration, demand drawdown, and use of secondary practices.

SECTION 2: PERFORMANCE

The overall stormwater functions of the rainwater harvesting systems are described in **Table 11.1.**

Table 11.1: Runoff Volume Reduction Provided by Rainwater Harvesting

Stormwater Function	Performance
Runoff Volume Reduction (RR)	Variable up to 90% [1]

[1] Credit is variable. Credit up to 90% is possible if all water from storms with rainfall of 1 inch or less is used through demand, and the tank is sized such that no overflow from this size event occurs. The total credit may not exceed 90%.

SECTION 3: DESIGN

Rainwater harvesting system design does not have a design table. Runoff reduction credits are based on the total amount of annual internal water reuse, outdoor water reuse, and tank dewatering discharge calculated to be achieved by the tank system.

SECTION 4: TYPICAL DETAILS

Figures 11.1 through 11.3 of **Section 5.3** provide typical schematics of cistern and piping system configurations, based on the design objectives (year-round internal use, external seasonal irrigation, etc.).

Figures 11.4 through 11.6 of **Section 5.4** provide typical schematics of Cistern tank configurations, based on the desired Treatment Volume and stormwater management objectives (Treatment Volume only, channel protection, etc.).

SECTION 5: PHYSICAL FEASIBILITY & DESIGN APPLICATIONS

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 some recommendations that should be considered during the process of planning to incorporate rainwater harvesting systems into the site design. The following are key considerations.

5.1 Site Conditions

Available Space. Adequate space is needed to house the 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 or within buildings that are structurally designed to support the added weight, and adjacent to buildings. Designers can work with Architects and Landscape Architects to creatively site the tanks. Underground utilities or other obstructions should always be identified prior to final determination of the tank location.

Site Topography. Site topography and tank location should be considered as they relate to all of the inlet and outlet invert elevations in the rainwater harvesting system. The total elevation drop will be realized beginning from the downspout leaders to the final mechanism receiving gravity-fed discharge and/or overflow from the cistern.

These elevation drops will occur along the sloping lengths of the underground roof drains from roof drain leader downspouts at the building all the way to the cistern. A vertical drop occurs within the filter before the cistern. The cistern itself must be located sufficiently below grade and below the frost line, resulting in an additional elevation drop. When the cistern is used for additional volume detention for channel and/or flood protection, an orifice may be included with a low invert specified by the designer. An overflow will always be present within the system, with an associated invert. Both the orifice (if specified) and the overflow will drain the tank during large storms, routing this water through an outlet pipe, the length and slope of which will vary from one site to another.

All these components of the rainwater harvesting system have an elevation drop associated with them. The final invert of the outlet pipe must match the invert of the receiving mechanism (natural channel, storm drain system, etc.) that receives this overflow. These elevation drops and associated inverts should be considered early in the design, in order to ensure that the rainwater harvesting system is feasible for the particular site.

Site topography and tank location will also affect the amount of pumping needed. Locating storage tanks in low areas will make it easier to route roof drains from buildings to 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 roof drains with smaller slopes. However, this will also reduce the amount of pumping needed for distribution. In general, it is often best to locate the cistern close to the building, ensuring that minimum roof drain slopes and enclosure of roof drain pipes are sufficient.

Available Hydraulic Head. The required hydraulic head depends on the intended use of the water. For residential landscaping uses, the cistern should be sited up-gradient of the landscaping areas or on a raised stand. 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 demands through gravity-fed head. Cisterns can also use gravity- to accomplish indoor residential uses (e.g., laundry) that do not require high water pressure. In cases where cisterns are located on building roofs in order to operate under gravity-fed conditions, the structure must be designed to provide for the added weight of the rainwater harvesting system and stored water.

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 will 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"), conducting buoyancy calculations when the tank is empty, etc. The tank may need to be secured appropriately with fasteners or weighted to avoid uplift buoyancy. The tank must also be installed according to the tank manufacturer's specifications.

Soils. The bearing capacity of the soil upon which the cistern will be placed should be considered, as full cisterns can be very heavy. Storage tanks should only be placed on native soils or on fill in accordance with the manufacturer's guidelines, or in consultation with a geotechnical engineer. This is particularly important for above-ground cisterns, as significant settling could cause the cistern to lean or in some cases to potentially topple. A sufficient aggregate, or concrete base, may be appropriate depending on the soils. Cistern supplies may also need a pH adjustment, since rainwater may be corrosive towards metals in the system if the pH is less than 6.5.

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. Appropriate minimum setbacks from septic drainfields should be observed. Before digging, call Tennessee One-Call (811) to get underground utility lines marked.

Contributing Drainage Area. The contributing drainage area (CDA) to the cistern is the impervious area draining to the tank. In general, only rooftop surfaces should be included in the CDA. 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 rooftops to rainwater harvesting systems in closed roof drain systems or storm drain pipes, avoiding surface drainage, which could allow for increased contamination of the water.

Rooftop Material. The quality of the harvested rainwater will vary according to the roof material over which it flows. Water harvested from certain types of rooftops, 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. In general, harvesting rainwater from such roofs should be avoided, unless new information determines that these materials are sufficient for the intended use and are allowed by Metro. 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).

Water Quality of Rainwater. Designers should also note that the ***pH*** of rainfall in the eastern United States tends to be acidic (ranging from 4.5 to 5.0), which may result in leaching of metals from the roof surface, 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.

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. In some cases, however, industrial roof surfaces may also be designated as stormwater hotspots.

Setbacks from Buildings. Cistern overflow devices should be designed to avoid causing ponding or soil saturation within 10 feet of building foundations. Storage tanks should be designed to be watertight to prevent water damage when placed near building foundations. In general, it is recommended that underground tanks be set at least 10 feet from any building foundation.

Vehicle Loading. Whenever possible, underground rainwater harvesting systems should be placed in areas without vehicle traffic or be designed to support live loads from heavy trucks, a requirement that may significantly increase construction costs.

5.2 Stormwater Uses

The capture and reuse of rainwater can significantly reduce stormwater runoff volumes and pollutant loads. 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, etc). To enhance their runoff reduction and nutrient removal capability, rainwater harvesting systems can be combined with other rooftop disconnection practices, such as infiltration trenches (GIP-04) and bioretention or foundation planters (GIP-01 and GIP-02). In this specification, these allied practices are referred to as "secondary runoff reduction practices."

While the most common uses of captured rainwater are for non-potable purposes, such as those noted above, in some limited cases rainwater can be treated to potable standards. This is not permitted in Nashville at this time.

5.3 Design Objectives and System Configurations

Many rainwater harvesting system variations can be designed to meet user demand and stormwater objectives. This specification focuses on providing a design framework for addressing the Treatment Volume (T_v) objectives. From a rainwater harvesting standpoint, there are numerous potential configurations that could be implemented. However, in terms of the goal of addressing the design treatment volume, this specification adheres to the following concepts in order to properly meet the stormwater volume reduction goals:

- Credit is only available for dedicated year-round drawdown/demand for the water. While seasonal practices (such as irrigation) may be incorporated into the site design, they are not considered to contribute to the treatment volume credit (for stormwater purposes) unless a drawdown at an equal or greater rate is also realized during non-seasonal periods (e.g. treatment in a secondary runoff reduction practice during non-irrigation months).
- System design is encouraged to use rainwater as a resource to meet on-site demand or in conjunction with other runoff reduction practices (especially those that promote groundwater recharge).
- Pollutant load reduction is realized through reduction of the volume of runoff leaving the site.
- 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 continuous (year-round) use of rainwater through (1) internal use, and (2) irrigation and/or treatment in a secondary practice. Three basic system configurations are described below.

Configuration 1: Year-round indoor use with optional seasonal outdoor use (Figure 11.1). The first configuration is for year round indoor use along with optional seasonal outdoor use, such as irrigation. Because there is no on-site secondary runoff reduction practice incorporated into the design for non-seasonal (or non-irrigation) months, the system must be designed and treatment volume awarded for the interior use only. (However, it should be noted that the seasonal irrigation will provide an economic benefit in terms of water usage). Stormwater credit can be enhanced by adding a secondary runoff reduction practice (see Configuration 3 below).

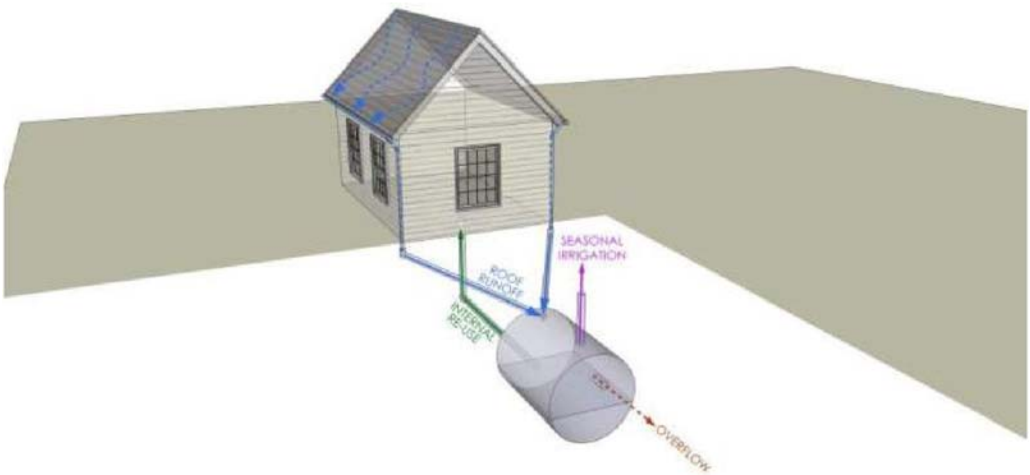

Figure 11.1. Configuration 1: Year-round indoor use with optional seasonal outdoor use (Source: VADCR, 2011)

Configuration 2: Seasonal outdoor use and approved year-round secondary runoff reduction practice (Figure 11.2). The second configuration uses stored rainwater to meet a seasonal or intermittent water use, such as irrigation. However, because these uses are only intermittent or seasonal, this configuration also relies on an approved secondary practice for stormwater credit. Compared to a stand-alone BMP (without the upgradient tank), the size and/or storage volume of the secondary practice can be reduced based on the storage in the tank. The tank's drawdown and release rate should be designed based on the infiltration properties, surface area, and capacity of the receiving secondary runoff reduction practice. The release rate therefore is typically much less than the flow rate that would result from routing a detention facility. The secondary practice should serve as a "backup" facility, especially during non-irrigation months. In this regard, the tank should provide some meaningful level of storage and reuse, accompanied by a small flow to the secondary practice. This is especially important if the size and/or storage volume of the secondary practice is reduced compared to using that practice in a "stand-alone" design (i.e., without an upgradient cistern). See **Section 5.4** Tank Design 3 for more information.

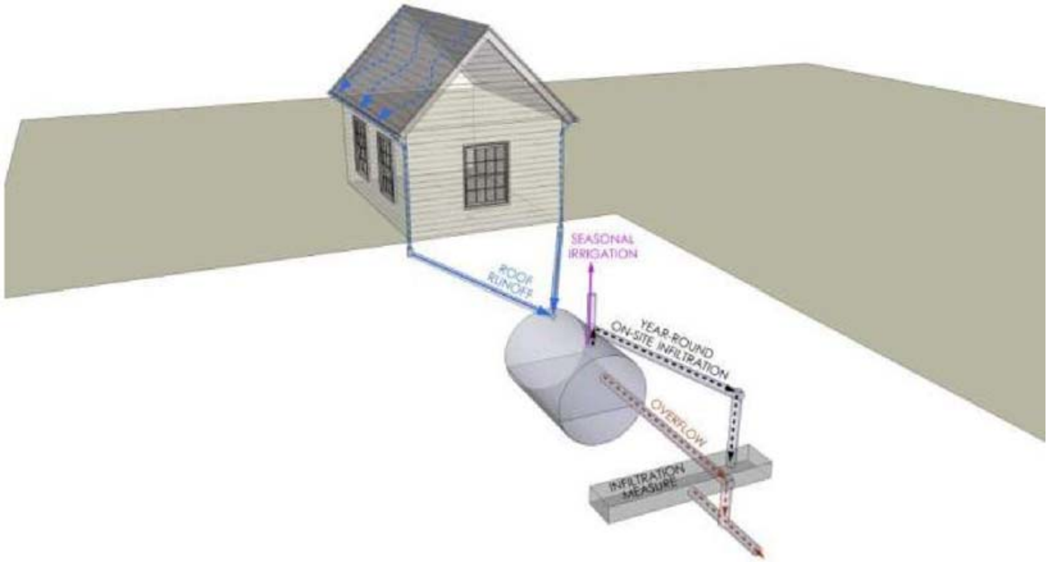

Figure 11.2. Configuration 2: Seasonal outdoor use and approved year-round secondary practice (Source: VADCR, 2011)

Configuration 3: Year-round indoor use, seasonal outdoor irrigation, and non-seasonal treatment in a secondary runoff reduction practice (Figure 11.3). The third configuration provides for a year-round internal non-potable water demand, and a seasonal outdoor, automated irrigation system demand. In addition, this configuration incorporates a secondary practice during non-irrigation (or non-seasonal) months in order to yield a greater stormwater credit. In this case, the drawdown due to seasonal irrigation must be compared to the drawdown due to water released to the secondary practice. The minimum of these two values is used for system modeling and stormwater credit purposes.

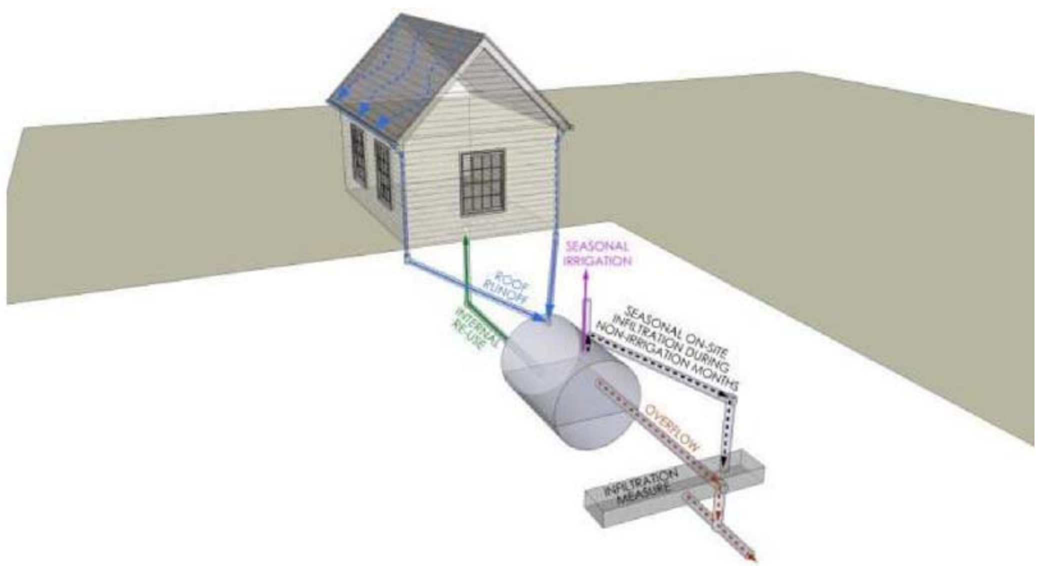

Figure 11.3. Configuration 3: Year-round indoor use, seasonal outdoor irrigation, and non-seasonal on-site treatment in secondary practice (Source: VADCR, 2011)

5.4 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 in **Section 5.3**.

Tank Design 1. The first tank set-up (**Figure 11.4**) maximizes the available storage volume associated with the Treatment Volume (T_v) to meet the desired level of treatment credit. 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 channel and flood protection volumes with this tank configuration, but the primary purpose is to address T_v.

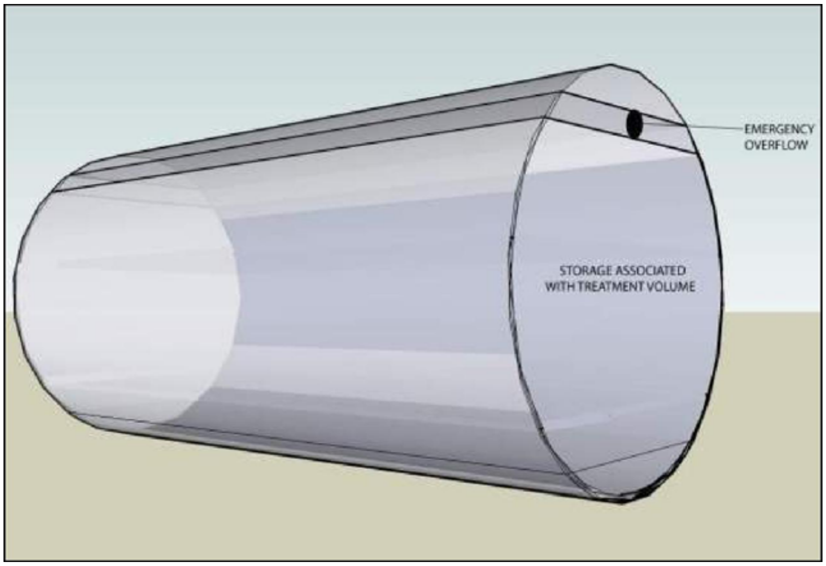

Figure 11.4. Tank Design 1: Storage Associated with Treatment Volume (Tv) only (Source: VADCR, 2011)

Tank Design 2. The second tank set-up (**Figure 11.5**) uses tank storage to meet the Treatment Volume (T_v) objectives as well as using an additional detention volume above the treatment volume space to also meet some, or all, of the channel and/or flood protection volume requirements. An orifice outlet is provided at the top of the design storage for the T_v storage level, and an emergency overflow is located at the top of the detention volume level. This specification only addresses the storage for the T_v. However, it may possible to model and size the Channel Protection and Flood Protection (detention) volumes.

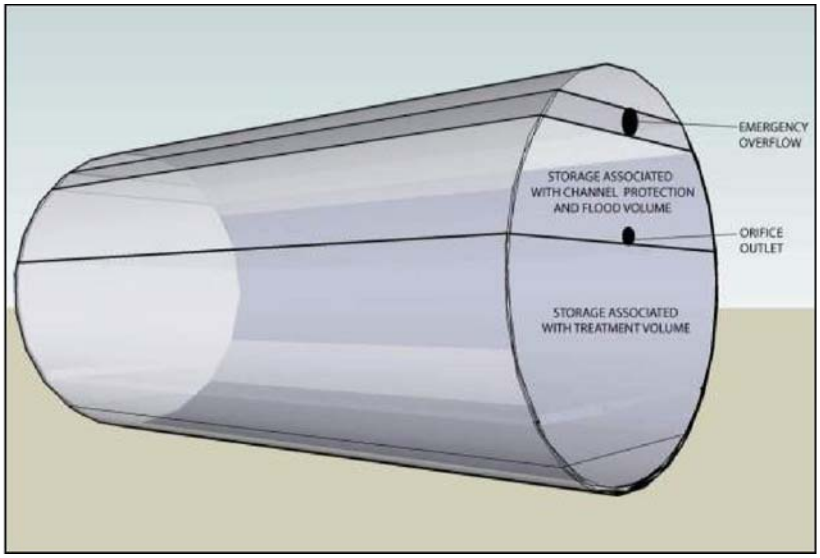

Figure 11.5. Tank Design 2: Storage Associated with Treatment, Channel Protection and Flood Volume (Source: VADCR, 2011)

Tank Design 3. The third tank set-up (**Figure 11.6**) 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, micro-scale infiltration, 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 the purposes of this tank design, the secondary practice must be considered a component of the rainwater harvesting system with regard to the runoff reduction percentage. In other words, the runoff reduction associated with the secondary practice must not be added (or double-counted) to the rainwater harvesting percentage. The reason for this is that the secondary practice is an integral part of a rainwater harvesting system with a constant drawdown. The exception to this would be if the secondary practice were also sized to capture and treat impervious area beyond the area treated by rainwater harvesting (for instance, the adjacent yard or a driveway). In this case, only these additional areas should be added to receive credit for the secondary practice.

While a small orifice is shown at the bottom of the tank in **Figure 11.6**, 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.

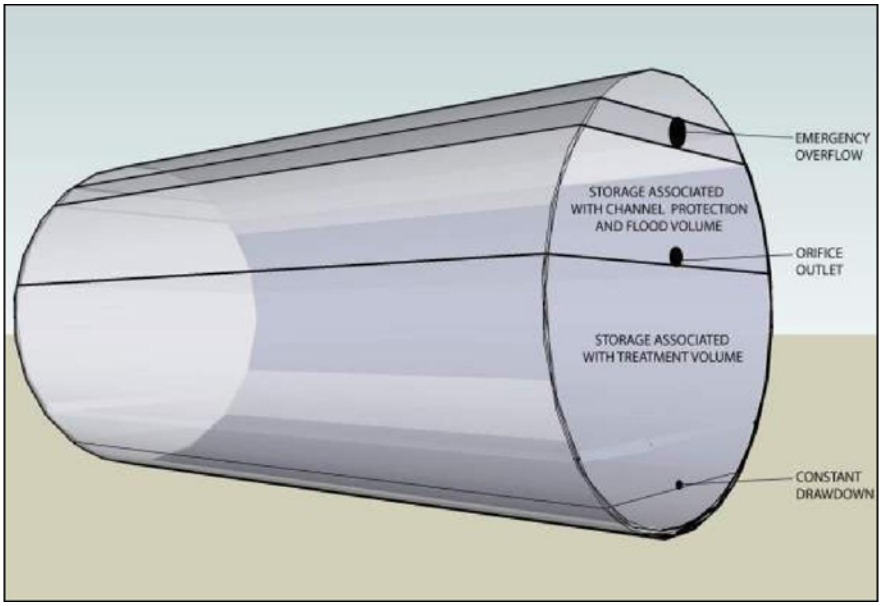

Figure 11.6. Tank Design 3: Constant drawdown, Storage Associated with Treatment, Channel Protection and Flood Volume (Source: VADCR, 2011)

5.5. On-Site Treatment in a Secondary Practice

Recent rainwater harvesting system design materials do not include guidance for on-site stormwater infiltration or "disposal". The basic approach is to provide a dedicated secondary runoff reduction practice on-site that will ensure water within the tank will gradually drawdown at a specified design rate between storm events. Secondary runoff reduction practices may include the following:

- Downspout Disconnection (GIP-07), excluding rain tanks and cisterns. This may include release to a compost-amended filter path.
- Sheet Flow (GIP-09)
- Grass Channel (GIP-08)
- Infiltration Trench (GIP-04)
- Bioretention (GIP-01)
- Urban Bioretention (GIP-02). Storage and release in foundation planter .
- Water Quality Swale (GIP-05)

The secondary practice approach is useful to help achieve the desired treatment volume when demand is not enough to sufficiently draw water levels in the tank down between storm events. Of course, if demand for the harvested rainwater is relatively high, then a secondary practice may not be needed or desired.

Use of a secondary practice may be particularly beneficial to employ in sites that use captured rainwater for irrigation during part of the year, but have no other use for the water during non-irrigation months. During non-irrigation months, credit cannot be realized unless on-site infiltration/treatment or another drawdown mechanism creates a year-round drawdown, since no stormwater benefit would be realized during non-seasonal periods.

The design of the secondary practice should account for soil types, ground surface areas, release rates, methods of conveyance (gravity fed or pumped), time periods of operation, and invert elevations to determine the disposal rate and sizing of the practice (both storage volume and surface area).

5.6 System Components

There are six primary components of a rainwater harvesting system (**Figure 11.7**):

- Roof surface
- Collection and conveyance system (e.g. gutter and downspouts)
- Pre-screening and first flush diverter
- Storage tank
- Distribution system
- Overflow, filter path or secondary runoff reduction practice

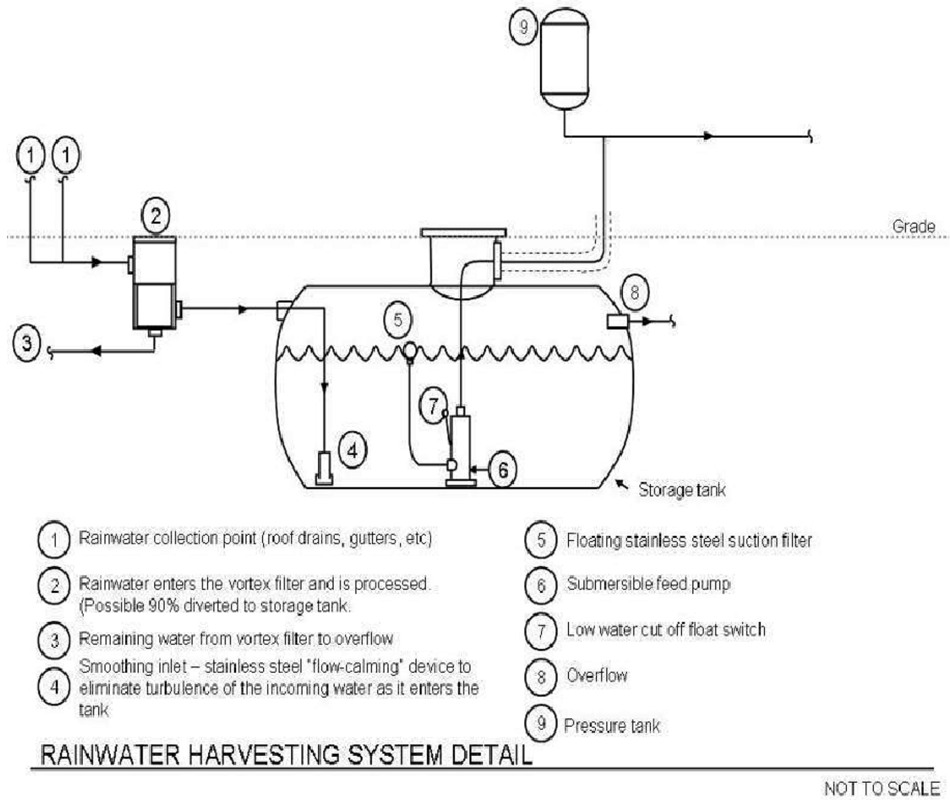

Figure 11.7. Sample Rainwater Harvesting System Detail (Source: VADCR, 2011)

Each of these system components is discussed below.

Rooftop Surface. The rooftop should be made of smooth, non-porous material with efficient drainage either from a sloped roof or an efficient roof drain system. Slow drainage of the roof leads to poor rinsing and a prolonged first flush, which can decrease water quality. If the harvested rainwater is selected for uses with significant human exposure (e.g. pool filling, watering vegetable gardens), care should be taken in the choice of roof materials. Some materials may leach toxic chemicals making the water unsafe for humans.

Collection and Conveyance System. The collection and conveyance system consists of the gutters, downspouts and pipes that channel stormwater runoff 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. Minimum slopes of gutters should be specified. At a minimum, gutters should be sized with slopes specified to contain the 1-inch storm at a rate of 1-inch/hour for treatment volume credit. If volume credit will also be sought for channel and flood protection, the gutters should be designed to convey the 2 and 10-year storm, using the appropriate 2 and 10 year storm intensities, specifying size and minimum slope. In all cases, gutters should be hung at a minimum of

0.5% for 2/3 of the length and at 1% for the remaining 1/3 of the length.

Pipes (connecting downspouts to the cistern tank) should be at a minimum slope of 1.5% and sized/designed 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.

Pre-Treatment: Screening, First Flush Diverters and Filter Efficiencies. 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 or maintenance-free. The purpose of pre-filtration is to significantly cut down on maintenance by preventing organic buildup in the tank, thereby decreasing microbial food sources.

For larger tank systems, the initial first flush must be diverted from the system before rainwater enters the storage tank. Designers should note that the term "first flush" in rainwater harvesting design does not have the same meaning as has been applied historically in the design of stormwater treatment practices. In this specification, the term "first flush diversion" is used to distinguish it from the traditional stormwater management term "first flush". The amount can range between the first 0.02 to 0.06 inches of rooftop runoff.

The diverted flows (first flush diversion and overflow from the filter) must be directed to an acceptable pervious flow path that will not cause erosion during a 2-year storm or to an appropriate BMP on the property, for infiltration. Preferably the diversion will be conveyed to the same secondary runoff reduction practice that is used to receive tank overflows.

Various first flush diverters are described below. In addition to the initial first flush diversion, filters have an associated efficiency curve that estimates the percentage of rooftop runoff that will be conveyed through the filter to the storage tank. If filters are not sized properly, a large portion of the rooftop runoff may be diverted and not conveyed to the tank at all. A design intensity of 1-inch/hour should be used for the purposes of sizing pre-tank conveyance and filter components. This design intensity captures a significant portion of the total rainfall during a large majority of rainfall events (NOAA 2004). If the system will be used for channel and flood protection, the 2- and 10-year storm intensities should be used for the design of the conveyance and pre-treatment portion of the system. For the 1-inch storm treatment volume, a minimum of 95% filter efficiency is required. This efficiency includes the first flush diversion. For the 2- and 10-year storms, a minimum filter efficiency of 90% should be met.

- ***First Flush Diverters.*** First flush diverters direct the initial pulse of stormwater runoff away from the storage tank. 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 (**Figure 11.8**). Simple first flush diverters require active management, by draining the first flush water volume to a pervious area following each rainstorm. First flush diverters may be the preferred pretreatment method if the water is to be used for indoor purposes. A vortex filter may serve as an effective pre-tank filtration device and first flush diverter.

- ***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 (**Figure 11.9**). Roof washers consist of a tank, usually between 25 and 50 gallons in size, with leaf strainers and a filter with openings as small as 30-microns (TWDB, 2005). The filter functions to remove very small particulate matter from harvested rainwater. All roof washers must be cleaned on a regular basis.

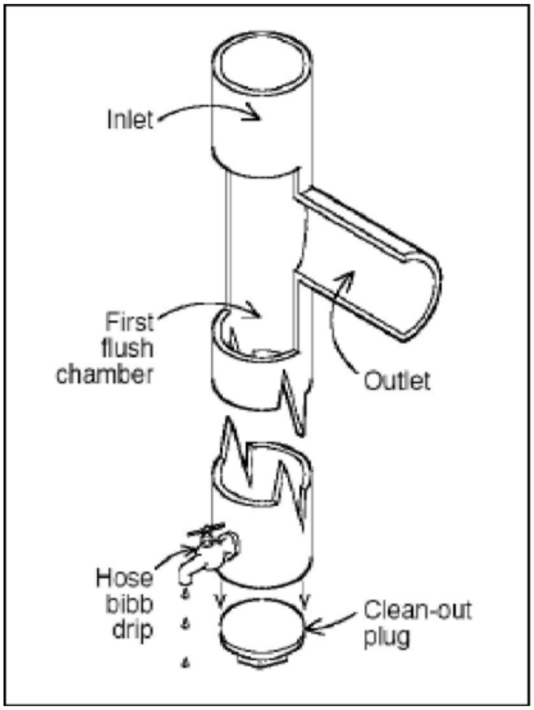

Figure 11.8 First Flush Diverter (Source: VADCR, 2011)

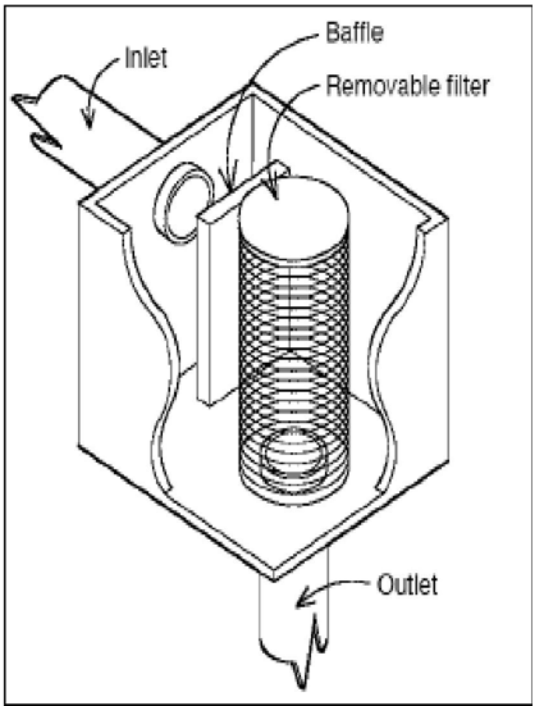

Figure 11.9 Roof Washer (Source: VADCR, 2011)

- ***Vortex Filters.*** For large scale applications, vortex filters can provide filtering of rooftop rainwater from larger rooftop areas. Two images of the vortex filter are displayed below. The first image (**Figure 11.10**) provides a plan view photograph showing the interior of the filter with the top off. The second image (**Figure 11.11**) displays the filter just installed in the field prior to the backfill.

Figure 11.10. Interior of Vortex
(Source: VADCR, 2011)Filter

Figure 11.11. Installation of Vortex Filter prior to backfill (Source: VADCR, 2011)

Storage Tanks. The storage tank is the most important and typically the most expensive component of a rainwater harvesting system. Cistern capacities range from 250 to over 30,000 gallons. Multiple tanks can be placed adjacent to each other and connected with pipes to balance water levels and increase overall storage on-site as 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 treatment volume objectives, as described in **Section 6** of this specification.

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

- Aboveground storage tanks should be UV and impact resistant.
- Underground storage tanks must be designed to support the overlying sediment and any other anticipated loads (e.g., vehicles, pedestrian traffic, etc.).
- Underground rainwater harvesting systems should have a standard size manhole or equivalent opening to allow access for cleaning, inspection, and maintenance purposes. This access point should be secured/locked to prevent unwanted access.
- 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 11.2** below compares the advantages and disadvantages of different storage tank materials.
- Storage tanks should be opaque or otherwise protected from direct sunlight to inhibit algae growth and should be screened to discourage mosquito breeding and reproduction.
- 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 hookup to a municipal backup water supply should have a backflow prevention device to keep municipal water separate from stored rainwater. Check with Metro Codes and MWS for any regulations pertaining to this.

Table 11.2. 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 be painted or tinted 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 50 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 (2007, 2009)

The images below in **Figures 11.12 to 11.14** display three examples of various materials and shapes of cisterns discussed in **Table 11.2** above.

Figure 11.12. Example of Multiple Fiberglass Cisterns in Series (Source: VADCR, 2011)

Figure 11.13. Example of two Polyethylene Cisterns (Source: VADCR, 2011)

Figure 11.14. Example of Modular Units
(Source: VADCR, 2011)

Distribution Systems. Most distribution systems require a pump to convey harvested rainwater from the storage tank to its final destination, whether inside the building, an automated irrigation system, or gradually discharged to a secondary runoff reduction practice. The rainwater harvesting system should be equipped with an appropriately-sized pump that produces sufficient pressure for all end-uses. Separate plumbing labeled as non-potable may be required.

The typical pump and pressure tank arrangement consists of a multi-stage centrifugal pump, which draws water out of the storage tank and sends it into the pressure tank, where it is stored for distribution. When water is drawn out of the pressure tank, the pump activates to supply additional water to the distribution system. The backflow preventer is required to separate harvested rainwater from the main potable water distribution lines.

Distribution lines from the rainwater harvesting system should be buried beneath the frost line. Lines from the rainwater harvesting system to the building should have shut-off valves that are accessible when snow cover is present. A drain plug or cleanout sump, also draining to a pervious area, should be installed to allow the system to be completely emptied, if needed. Above-ground outdoor pipes should be insulated or heat-wrapped to prevent freezing and ensure uninterrupted operation during winter.

Overflow, Filter Path and Secondary Runoff Reduction Practice. 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. 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. The overflow pipe should be screened to prevent access to the tank by rodents and birds.

The filter path is a pervious or grass corridor that extends from the overflow to the next runoff reduction practice, the street, an adequate existing or proposed channel, or the storm drain system. The filter path must be graded with a slope that results in sheet flow conditions. If compacted or impermeable soils are present along the filter path, compost amendments may be needed (**see GIP-09, Appendix 9-A**). It is also recommended that the filter path be used for first flush diversions.

In many cases, rainwater harvesting system overflows are directed to a secondary runoff reduction practice to boost overall runoff reduction rates. These options are addressed in **Section 5.5**.

SECTION 6: DESIGN CRITERIA

6.1 Sizing of Rainwater Harvesting Systems

The rainwater harvesting cistern sizing criteria presented in this section was developed using best estimates of indoor and outdoor water demand, long-term rainfall data, and rooftop capture area data.

6.2 Incremental Design Volumes within Cistern

Rainwater tank sizing is determined by accounting for varying precipitation levels, captured rooftop 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 treatment volume (permanent storage), storage needed for channel protection and flood 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 11.15** for a graphical representation of these various incremental design volumes.

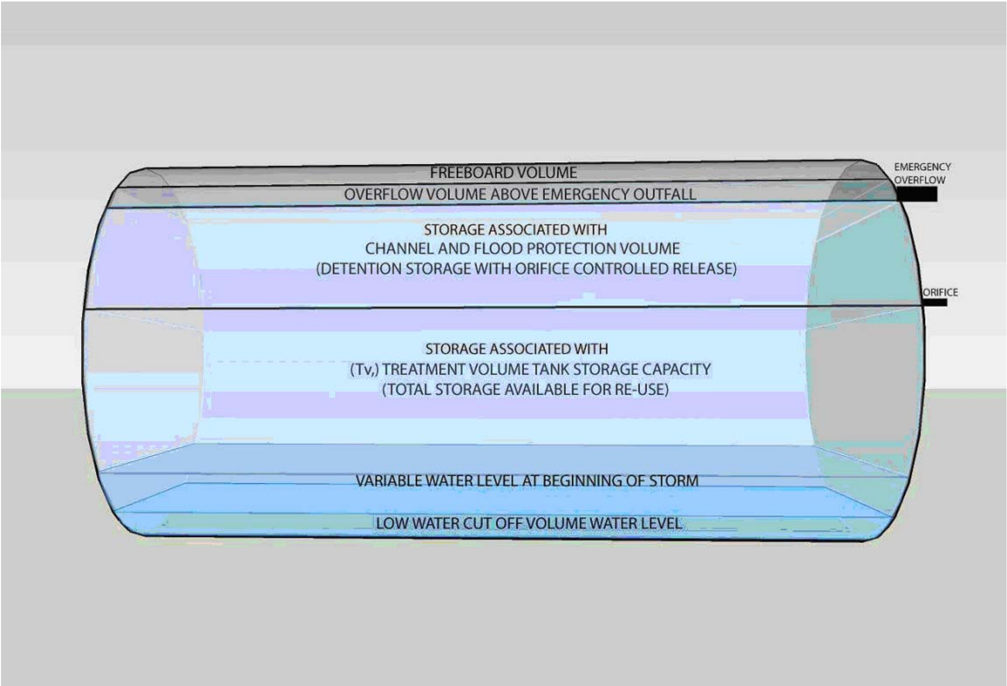

Figure 11.15. Incremental Design Volumes associated with tank sizing (Source: VADCR, 2011)

The "Storage Associated with the Treatment Volume" is the storage within the tank that is modeled and available for reuse. While the Treatment Volume will remain the same for a specific rooftop capture area, the "Storage Associated with the Treatment Volume" may vary depending on demand and runoff reduction credit 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.

6.3 Cistern Design Guidance

Go to Metro Water Services website for future guidance and Cistern Design Tools (CDT):

www.nashville.gov/stormwater/LIDManual.asp

6.4 Rainwater Harvesting Material Specifications

The basic material specifications for rainwater harvesting systems are presented in **Table 11.3**. 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 11.3. Design Specifications for Rainwater harvesting systems

Item	Specification
Gutters and Downspout	Materials commonly used for gutters and downspouts include 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. • The length of gutters and downspouts is determined by the size and layout of the catchment and the location of the storage tanks. • Be sure to include needed bends and tees.
Pre-Treatment	At least one of the following (all rainwater to pass through pre-treatment): • First flush diverter • Vortex filter • Roof washer • Leaf and mosquito screen (1 mm mesh size)
Storage Tanks	• Materials used to construct storage tanks should be structurally sound. • Tanks should be constructed in areas of the site where native soils can support the load associated with stored water. • Storage tanks should be water tight and sealed using a water-safe, non-toxic substance. • Tanks should be opaque to prevent the growth of algae. • Re-used tanks should be fit for potable water or food-grade products. • Underground rainwater harvesting systems should have a minimum of 18 to 24 inches of soil cover and be located below the frost line. • The size of the rainwater harvesting system(s) is determined during the design calculations.

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

SECTION 7: SPECIAL CASE DESIGN ADAPTATIONS

7.1 Steep Terrain

Rainwater harvesting systems can be useful in areas of steep terrain where other stormwater treatments are inappropriate, provided the systems are designed in a way that protects slope stability. Cisterns should be located in level areas where soils have been sufficiently compacted to bear the load of a full storage tank.

Harvested rainwater should not be discharged over steep slopes; rather, the rainwater should be used for indoor non-potable applications or outdoor irrigation.

SECTION 8: CONSTRUCTION

8.1 Construction Sequence

It is advisable to have a single contractor install the rainwater harvesting system, outdoor irrigation system and secondary runoff reduction practices. The contractor should be familiar with rainwater harvesting system sizing, installation, and placement. A licensed plumber is required to install the rainwater harvesting system components to the plumbing system.

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 roof drains 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 with vegetation.

8.2 Construction Inspection

The following items shall 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 runoff reduction practice(s) is installed as shown on plans

SECTION 9: AS-BUILT REQUIREMENTS

After the cistern has been installed, the developer must have an as-built certification of the cistern conducted by a registered professional engineer. The as-built certification verifies that the BMP was installed as designed and approved. The following components are vital components of a properly working cistern and must be addressed in the as-built certification:

Incorporation of Rainwater Harvesting System into the site Grading and Drainage Plan, as follows*:*

1. Include a roof plan of the building that will be used to capture rainwater, showing slope direction and roof material.
2. Include a roof plan of the building that will be used to capture rainwater, showing slope direction and roof material.
3. Display downspout leaders from the rooftops being used to capture rainwater.

4. Display the storm drain pipe layout (pipes between building downspouts and the tank) in plan view, specifying materials, diameters, slopes and lengths, to be included on typical grading and utilities or storm sewer plan sheets.

5. Include a detail or note specifying the minimum size, shape configuration and slope of the gutter(s) that convey rainwater

Rainwater Harvesting System Construction Document sheet, to show the following:

1. The Cistern or Storage Unit material and dimensions in a scalable detail (use a cut sheet detail from Manufacturer, if appropriate).

2. Include the specific Filter Performance specification and filter efficiency curves. Runoff estimates from the rooftop area captured for 1-inch storm should be estimated and compared to filter efficiencies for the 1-inch storm. It is assumed that the first flush diversion is included in filter efficiency curves. A minimum of 95% filter efficiency should be met for the Treatment Volume credit. If this value is altered (increased), the value should be reported. Filter curve cut sheets are normally available from the manufacturer. Show the specified materials and diameters of inflow and outflow pipes.

3. Show the inverts of the orifice outlet, the emergency overflows, and, if applicable, the receiving secondary runoff reduction practice or on-site infiltration facility.

4. Include a cross section of the storage unit displaying the inverts associated with the various incremental volumes (if requested by the reviewer).

SECTION 10: MAINTENANCE

10.1 Maintenance Document

The requirements for the Maintenance Document are in Appendix C of Volume 1 of the Manual. They include the execution and recording of an Inspection and Maintenance Agreement or a Declaration of Restrictions and Covenants, and the development of a Long Term Maintenance Plan (LTMP) by the design engineer. The LTMP contains a description of the stormwater system components and information on the required inspection and maintenance activities. The property owner must submit annual inspection and maintenance reports to MWS.

10.2 Maintenance Inspections

All rainwater harvesting systems components shall be inspected by the property owner twice per year (preferably Spring and the Fall). A comprehensive inspection by a professional engineer or landscape architect shall occur every five years. Maintenance checklists are located in Volume 1 Appendix C of this Manual.

10.3 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 11.4** describes routine maintenance tasks to keep rainwater harvesting systems in working condition.

Table 11.4. 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 runoff reduction practices	O: Once a year
Inspect tank for sediment buildup	I: Every third year
Clear overhanging vegetation and trees over roof surface	I: 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: Every third year

Key: O = Owner I = qualified third party inspector

SECTION 11: COMMUNITY & ENVIRONMENTAL CONCERNS

Although rainwater harvesting is an ancient practice, it is enjoying a revival due to the inherent quality of rainwater and the many beneficial uses that it can provide (TWDB, 2005). Some common concerns associated with rainwater harvesting that must be addressed during design include:

Winter Operation. Rainwater harvesting systems can be used throughout the year if they are located underground or indoors to prevent problems associated with freezing, ice formation and subsequent system damage. Alternately, an outdoor system can be used seasonally, or year round if special measures and design considerations are incorporated.

Plumbing Codes. Designer and plan reviewers shall consult building codes to determine if they explicitly allow the use of harvested rainwater for toilet and urinal flushing. In the cases where a Metro backup supply is used, rainwater harvesting systems are required to have backflow preventers or air gaps to keep harvested water separate from the main water supply. Pipes and spigots using rainwater must be clearly labeled as non-potable.

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.

Child Safety. Above-grade residential rainwater harvesting systems cannot have unsecured openings large enough for children to enter the tank. For underground cisterns, manhole access should be secured to prevent unwanted access.

SECTION 12: REFERENCES

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