Cisterns

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

Advantages/Benefits:

- Water source for non-potable uses (toilet flushing, irrigation)

Disadvantages/Limitations:

- Systems must drain between storm events
- Underground storage tanks must be designed to support anticipated loads
- Certain roof materials may leach metals or hydrocarbons, limiting potential uses for harvested rainwater

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

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

There are six primary components of a rainwater harvesting system:

- 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

SECTION 2: PERFORMANCE

The overall stormwater functions of the rainwater harvesting systems are described in **Table 10.1.**

Table 10.1: Runoff Volume Reduction Provided by Rainwater Harvesting	
Stormwater Function	**Performance**
Runoff Volume Reduction (RR)	Variable up to 90%[1]
Treatment Volume (Tv) Multiplier[2]	1.0

[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%.
[2]Incorporated into LID Site Design Tool calculations

SECTION 3: SCHEMATICS

See Appendix 10-A for schematics for use in cistern design.

SECTION 4: 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:

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.

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.

Elevation Considerations. 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. Site topography and tank location will also affect the amount of pumping needed. 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.

Subsurface Constraints. The cistern itself must be located sufficiently below grade and below the frost line, resulting in an additional elevation drop. Cisterns should be separated from the water table to prevent risk of floatation. 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.

Utilities. Public underground utilities and associated easements shall not be located within the cistern footprint. Local utility design guidance shall be consulted in order to determine clearances required between stormwater infrastructure and other dry and wet utility lines.

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.

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.

Floodplains. Flood waters shall be prohibited from entering the cistern overflow system.

Applications. Cisterns are typically used in medium to high density commercial, institutional and residential sites to capture and reuse rainwater. 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).

SECTION 5: DESIGN CRITERIA

5.1 Sizing of Cisterns

5.1.1 Stormwater Quality

To determine runoff volume reduction, MWS utilizes the Rainwater Harvester 2.0. The model, user manual and local data can be found at http://www.nashville.gov/stormwater.

5.2 Pre-treatment

Pre-treatment methods should be implemented per manufacturers specifications. Pre-treatment is required to keep sediment, leaves, contaminants and other debris from the system. Leaf screens and gutter guards are recommended to capture floatables before entering the system. Rooftop runoff should be filtered to remove sediment before it is stored.

5.3 Conveyance and Overflow

An overflow structure should always be incorporated into on-line designs to safely convey larger storms through the cistern. 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 SCMs.

5.4 Design Guidance

Design guidance for rainwater harvesting systems are presented in **Table 10.2** Designers should consult with experienced cistern installers on the choice of recommended manufacturers of prefabricated tanks and other system components.

Table 10.2. Design Guidance for Rainwater harvesting systems	
Item	**Specification**
Gutters and Downspout	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.
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 watertight 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.
Distribution Systems	- Pump that produces sufficient pressure for all end-uses. - Separate plumbing labeled as non-potable may be required. - Backflow preventer is required to separate harvested rainwater from the main potable water distribution lines.

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

5.5 Cistern Materials

Rainwater harvesting systems may be ordered from a manufacturer or can be constructed on site from a variety of materials. The material options for cisterns are presented in **Table 10.3**. Designers should consult manufacturer's technical specifications for specific criteria and guidance.

Table 10.3. 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	Longevity may be less than other materials; higher risk of puncturing of water tight

Table 10.3. Advantages and Disadvantages of Various Cistern Materials		
Tank Material	**Advantages**	**Disadvantages**
	to fit site; relatively inexpensive	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)

SECTION 6: SPECIAL CASE DESIGN ADAPTATIONS

6.1 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.

SECTION 7: CONSTRUCTION

7.1 Construction

Construction Stage Erosion and Sediment Controls. Stormwater Management Manual Volume 4 or TDEC EPSC Handbook should be utilized for proper EPSC controls during construction.

Excavation. The proposed site should be checked for existing utilities prior to any excavation. The excavated area should be prepared in accordance with the manufacturer's installation specifications.

7.2 Cistern Installation

The contractor should be familiar with cistern installation. 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.

Step 1. Choose the tank location on the site.

Step 2. Route all downspouts or roof drains to pre-screening devices and first flush diverters.

Step 3. Properly install the tank.

Step 4. Install the pump (if needed) and piping to end-uses (indoor, outdoor irrigation, or tank dewatering release.

Step 5. Route all pipes to the tank.

Step 6. Stormwater should not be diverted to the rainwater harvesting system until the overflow filter path has been stabilized with vegetation.

Step 7. Conduct the final construction inspection (see Section 8). Then log the GPS coordinates for each cistern and submit them to MWS.

SECTION 8: AS-BUILT REQUIREMENTS

After the cistern has been constructed, the owner/developer must have an as-built certification of the cistern conducted by a registered Professional Engineer. The as-built certification verifies that the GIP was installed per the approved plan. The following items shall be provided in addition to the as-built requirements found in SWMM Volume 1.

1. The Engineer shall include a copy of the GIP summary table found in Appendix 10-B.
2. Supporting documents such as invoices and photos shall be included in the submittal package.

SECTION 9: MAINTENANCE

9.1 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.

9.2 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.

9.3 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 10.4** describes routine maintenance tasks to keep rainwater harvesting systems in working condition.

Table 10.4. 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 10: 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 11: REFERENCES

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Virginia Department of Conservation and Recreation (VADCR). 2011. Stormwater Design Specification No. 6: Rainwater Harvesting, Version 1.9.5, March 1, 2011.. Available at: http://vwrrc.vt.edu/swc/NonProprietaryBMPs.html.

APPENDIX 10-A
SCHEMATICS

Figure 10.1 through 10.3 provide typical schematics of cistern and piping system configurations

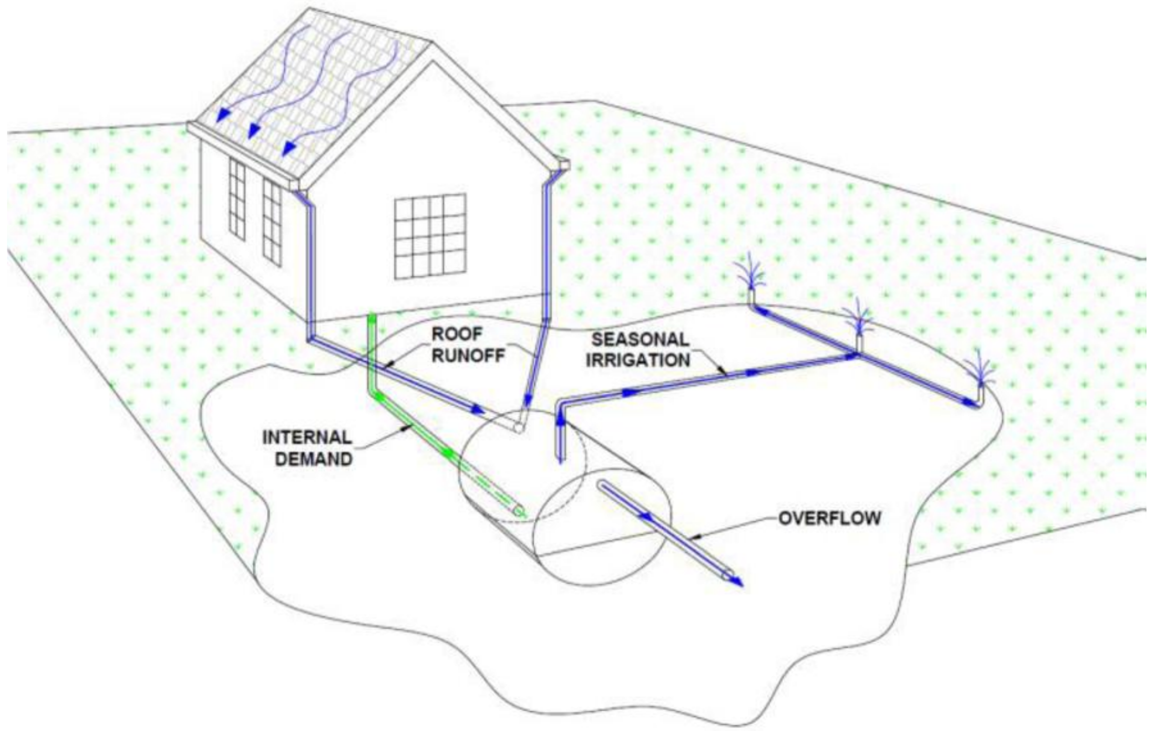

Figure 10.1. Configuration 1: Year-round indoor use with optional seasonal outdoor use (Source: VA, 2013)

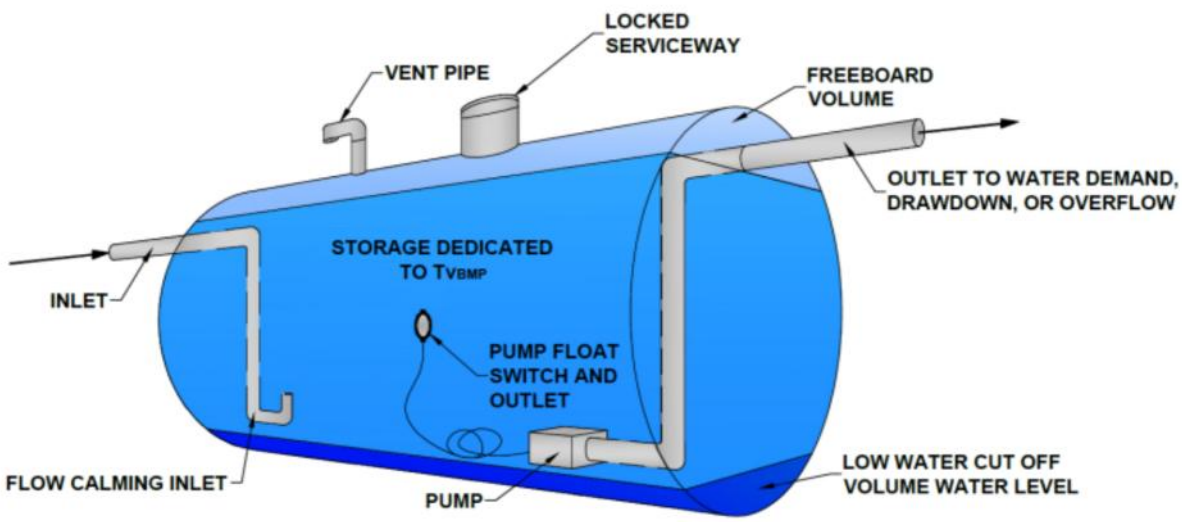

Figure 10.2. Tank Design 1: Storage Associated with Treatment Volume (Tv) only (Source: VA, 2013)

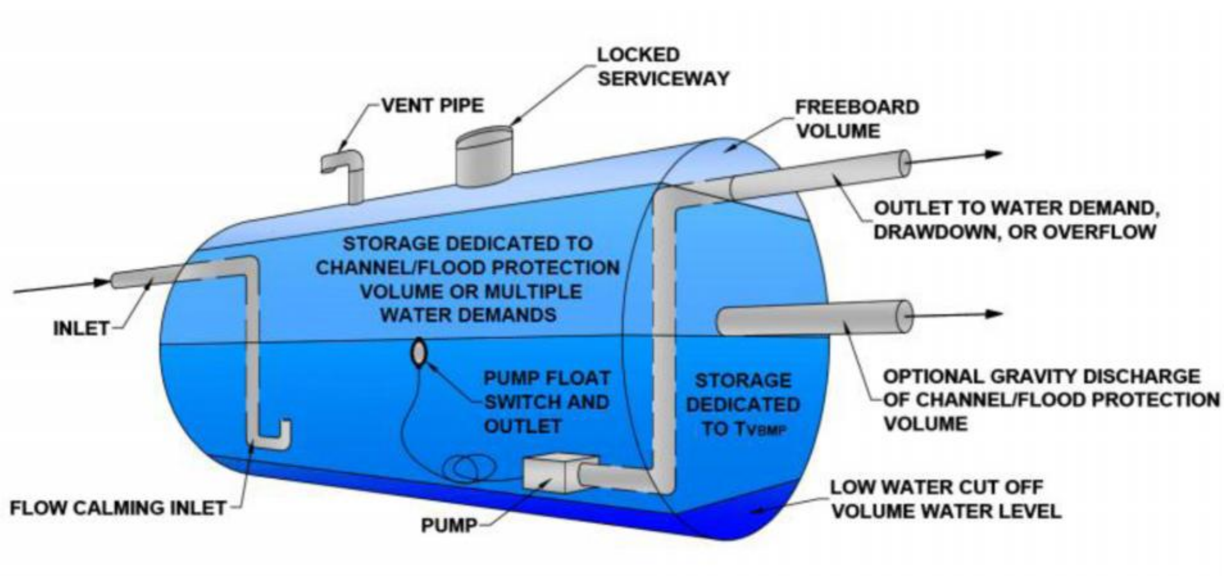

Figure 10.3. Tank Design 2: Storage Associated with Treatment, Channel Protection and Flood Volume (Source: VA, 2013)

APPENDIX 10-B
AS-BUILT REQUIREMENTS

A printer friendly version of this table can be found on the MWS Development Services website or by request.

Cistern Number:

	Design	As-built
Treatment Volume (Tv), CF		
Low Flow Orifice/ Weir*		
Overflow Invert		
* N/A if not required		
ALL Elevation shall be NAVD88		

APPENDIX 10-C
MISCELLANEOUS PHOTOS

The images below in **Figures 10.4 and 10.5** display three examples of various materials and shapes of cisterns discussed in **Table 10.3**.

Figure 10.4. Example of Multiple Fiberglass Cisterns in Series (Source: VADCR, 2011)

Figure 10.5. Example of two Polyethylene Cisterns (Source: VADCR, 2011)