C-7. Rainwater Harvesting

Design Objective

Rainwater harvesting (RWH) includes many components that work together to collect, store, and use rainwater. Usually RWH captures runoff from roofs; however, collecting runoff from other surfaces, such as parking lots, sidewalks and landscaped areas is allowed. RWH can be very effective at providing stormwater, mainly through runoff reduction. They can be used as stand-alone SCMs or can simply reduce the need for BMPs elsewhere on the site. An added benefit of RWH may be conservation of potable water.

Design Volume

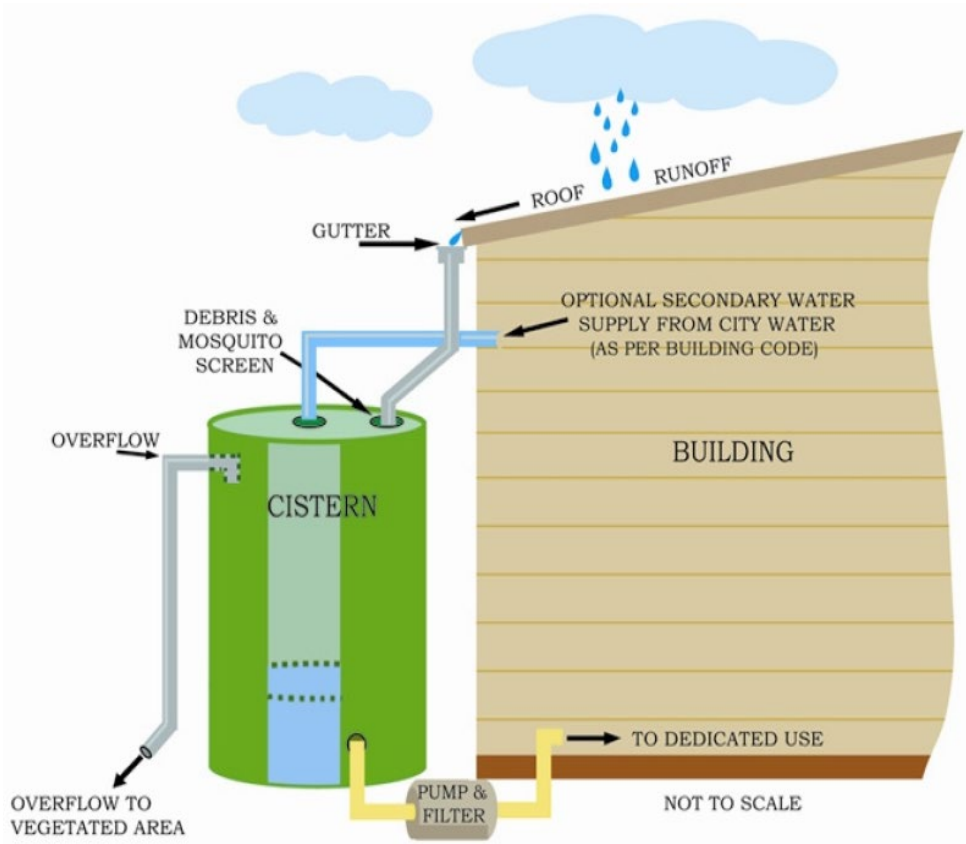
To be considered as a Primary Treatment SCM, a RWH shall be sized to capture a minimum of 85% of the total runoff as demonstrated through water balance calculations.

Important Links

Rule 15A NCAC 2H .1057. MDC for Rainwater Harvesting Systems

SCM Credit Document, C7. Credit for Rainwater Harvesting Systems

Figure 1. Example RWH System (NCSU-BAE)



Guidance on the MDC

RHW MDC 1. MAJOR COMPONENTS OF A RAINWATER HARVESTING SYSTEM
Rainwater harvesting systems shall include the following components:
(a) a collection system;
(b) a pre-treatment device to minimize gross and coarse solids collection in the tank;
(c) a cistern or other storage device;
(d) an overflow; and
(e) a distribution system.

Figure 1 above depicts the five required components of a RWH system. These components are further described in the tables and figures below.

Table 1: RWH Required Components

RWH Component	Recommendation
Collection System	For roofs, runoff is usually collected via gutters then conveyed to the cistern by downspouts. For other surfaces, often runoff will be piped to the cistern.
Pre-Treatment Device	Pre-treatment prevents sediment, leaves and debris from entering the cistern. It includes screens, basket screens and filters, and first flush diverters. Other options include settling tanks, oil-grit separators, hydrodynamic separators, sand filters, or proprietary devices. See Figure ? below for some examples.
Cistern	The cistern should be sited in a location where the catchment area can drain by gravity. Above-ground cisterns are commercially available in sizes ranging from 50-gallon rain barrels to tanks with capacities well over 10,000 gallons. Below ground cisterns are typically selected for systems over 50,000 gallons.
Overflow	The overflow discharges rainfall that exceeds than the cistern storage volume.
Distribution system	Water will drain via gravity or be pumped to the point of use.

Figure 2. Fine filter used upstream of an underground cistern (left), gutter screen (center), downspout screen (right) (NCSU BAE left and center and UNC-CH right).

Table 2: Guidance on Cistern Material

Type of Cistern	Recommendations About Materials
Above Ground	Material should block light to avoid algae growth within the cistern. Good options include plastics and metal tanks with internal bladders. Sometimes wooden or stone facades are used for aesthetic reasons. Though most tanks are cylindrical, narrow width options are available.
Below Ground	The specified cistern materials and construction methods shall be capable of providing a level of water-tightness that reflects the allowable leakage rate. In-situ testing for water-tightness is recommended. Good options include plastics and fiberglass. Other materials may be used if they are lined with a water-tight membrane. Non-proprietary systems include gravel and cast-in-place concrete. Proprietary systems include pipes (plastic, concrete, and metal), vaults, and modular proprietary products that provide more void space than gravel.

Figure 3. Metal cistern under construction (left), underground concrete vault wrapped in an impermeable liner (center) and a series of plastic cisterns (right) (UNC-CH left and NCSU BAE center and right)

Optional additional components of an RWH include:
Water level indicator – This is especially useful for actively managed systems.
Make-up water supply – An automated secondary water supply may be provided to supplement the rainwater captured.
Post-storage (point-of-use) treatment - Post-storage treatment is sometimes included, depending upon the quality of water in the storage tank and the quality needed for the designated non-potable water uses.
Usage meter – Meters on the distribution system may be required by local jurisdictions. They may also be desired by owners of larger-scale systems who wish to monitor their water use.

RWH MDC 2. FATE OF CAPTURED WATER
Captured stormwater shall be used or discharged as follows: (a) use to meet a water demand. The usage, type, volume, frequency, and seasonality of water demand shall be established and justified; (b) discharge via a passive drawdown device to a vegetated infiltration area or another SCM; or (c) a combination of use and passive discharge.

RWHs often serve one or more non-potable water demands, so an early design step is to identify these uses. Water designated "**non-potable**" has not been treated to or tested for the standards applied to potable (drinking) water. Non-potable water is unsuitable for drinking, hand washing, bathing, dishwashing, and pool/spa filling.

Table 3 highlights possible uses for harvested rainwater. The designer must understand the pros and cons of the proposed use before speaking with the owner. The designer and owner must also be aware that the use of RWH systems for stormwater credit requires that these uses must continue. If the non-potable water demand ceases because of a change to the site, the local government and/or NCDEQ will require that an alternative non-potable water use may be found or that another SCM be installed on site to replace the RWH system.

In many RWH systems the required water captured in the cistern will exceed the non-potable water demands at the site, so passive drawdown will be required. In any RWH system used solely for seasonal irrigation, a passive drawdown will be needed.

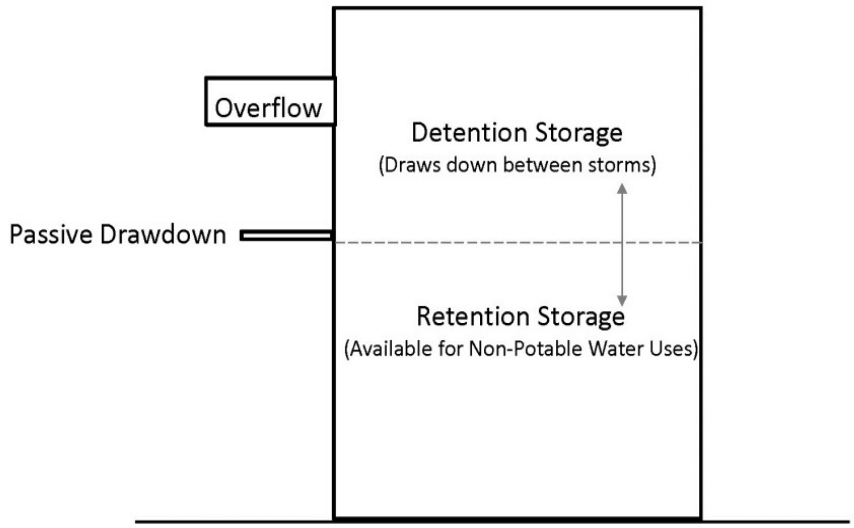
The storage in the cistern will be divided into two zones:

- retention volume, which remains available for non-potable water uses
- detention volume, which discharges via the passive drawdown orifice over 2-5 days

Table 3: Potential Demands for Cistern Water

Demand Type	Pros and Cons
Hand Watering	**Pros:** The water does not require additional treatment before use, there is a simple distribution system (gravity or small pump), and a back-up to the cistern is not necessary because the owner can hand water from a separate spigot when needed. **Cons:** This use depends on site owner/user to initiate use of the water and much of storage will be dedicated to detention and will rarely be available for irrigation.
Automated Irrigation	**Pros:** Can significantly reduce the use of potable water. The pump system is similar to systems used for irrigation ponds, on-site water and wastewater systems, and building plumbing systems. Therefore, maintenance personnel will have typically have applicable experience with installation and maintenance. **Cons:** There will be added cost to operate and maintain a pump instead of relying on the system pressure from a domestic water system.
Toilet Flushing	**Pros:** Consistent, automated, year-round use on commercial and institutional sites. Visible, sustainable building feature. Appeals to owners/developers interested in green building. **Cons:** Harvested water requires additional treatment per the NC Plumbing Code. More complex distribution system that irrigation application due to treatment requirements. Requires a separate set of plumbing for toilet and urinal flushing, which is a cost factor. Increased risk of cross-connection requires physical and educational controls.
Vehicle Washing	**Pros:** Hand washing of vehicles a common use. Use in automated systems also possible. No additional treatment is typically needed. **Cons:** Vehicle washing must be done on year-round on a regular basis.
Cooling Tower Make-up	**Pros:** This use is present on many commercial, institutional, and industrial sites. Where present, this use typically represents the largest water demand at the site. **Cons:** Cooling towers require additional treatment for all water sources, including potable water (rainwater will require significantly more treatment). Treating harvested rainwater will increase the cost versus treating potable water. However, the payback time may be short due to the high volume of consumption.
Street Sweeper Tank Filling	**Pros:** There is potential for a large savings of potable water and a consistent, year round need for the water. **Cons:** May require filtration to a specific particle size to prevent clogging spray nozzles.
Laundry	**Pros:** Laundry can provide a consistent, year-round use. **Cons:** Additional treatment may be required, depending on the use, catchment area, and any special water quality requirements for the specific application.
Animal Systems	**Pros:** Flushing animal waste tanks/systems, washing kennels and pens, etc. can provide a consistent, year-round use. **Cons:** Additional treatment may be required, depending on the use, catchment area, and any special water quality requirements for the specific application.

Figure 4. Passive Release and Storage Zones. (UNC-CH and NCSU BAE)



The passive drawdown should discharge over 2-5 days to a downstream vegetated receiving area meeting the requirement of this chapter or to another SCM. To determine if a passive drawdown is required, calculate the average 5-day, year-round non-potable demand. For seasonal uses such as irrigation, this will be zero. If the only non-potable water demand is seasonal irrigation, then a passive drawdown is needed. If the Water Quality Runoff Volume is greater than the average 5-day, year-round demand (V_{5day}), then a passive drawdown is needed. The *NCSU Water Harvesting Model* can be used to optimize the height and diameter of the passive drawdown mechanism.

Because the orifice for passive drawdown is often very small, the passive release mechanism should be equipped with some type of filter, located on the inside of the tank, to prevent clogging. An example low-flow orifice system is presented in a technical memo by NC State University Biological & Agricultural Engineering.

Figure 5. Anti-Clogging Passive Drawdown Mechanism (NCSU BAE)

RWH MDC 3. SIZING
A rainwater harvesting system shall be considered as a primary SCM if the system is sized and water demand, passive discharge or a combination of the two is provided for 85% of the total annual runoff volume as demonstrated through water balance calculations.

To receive stormwater credit, the cistern shall be sized to capture a minimum of 85% of the total annual runoff as demonstrated through water balance calculations. Note that this is 85% of runoff from all storms, not from a water quality storm. This 85% volume capture is approximately equivalent to the typical volume of water treated annually by other SCMs when designed to capture the water quality volume and detaining the water volume for slightly more than 2 days (Smolek et al. 2012).

The water balance may be calculated using the Rainwater Harvest 3.0 model (available on the NCSU Stormwater Engineering Group web site under the "Resources" tab) or another continuous-simulation hydrologic model that calculates the water balance on a daily or more frequent time-step using a minimum of 5 representative years of actual rainfall records. The model shall account for withdrawals from the cistern for usage and for the active or passive drawdown as well as additions to the cistern by rainfall and runoff and by a make-up water source (if applicable).

The following information is needed to begin the water balance calculations:

- Catchment area (drainage area).
- Capture factor for the drainage area or other variable(s) used to calculate runoff from rainfall.
- Rainfall records for a nearby city with a minimum of 5 representative years of data at a daily or more frequent time-step.
- Non-potable water demand(s) – either consistent daily values or with values that vary by day of the week or by month (seasonal variation).
- Make-up water supply – if make-up water supply is discharged into the cistern, know the trigger points for started and ending the flow.
- Supplemental water supply flow rate (e.g. Condensate from air handling units, discharge from foundation drains).
- Detention volume.
- Passive drawdown release rate.

The cistern size will be optimized through iterative calculations. The NCSU Rainwater Harvester Model will calculate a cistern size based on the above inputs. If using a model that doesn't perform this calculation, the iterative calculations can be started using a capacity in gallons equal to the square feet of catchment area. The key output from the water balance is the total annual runoff volume captured in the cistern, which must be 85% or higher. In the NCSU Water Harvesting Model this output is called the "**Total Volume Captured**."

RWH MDC 4. WATER BALANCE CALCULATIONS
The water balance shall be calculated using the NCSU Rainwater Harvester model or another continuous-simulation hydrologic model that calculates the water balance on a daily or more frequent time-step using a minimum of five representative years of actual rainfall records. The model shall account for withdrawals from the cistern for use, active or passive drawdown, and additions to the cistern by rainfall, runoff and a make-up water source if applicable.

Calculating the non-potable water demand to be met with harvested rainwater is a key component of the stormwater design. In RWH design, demand estimates should not be over or under estimated. If the designer significantly over-estimates the non-potable water demand, the cistern will frequently be full and will provide less treatment than intended. Municipalities may require submittal of documentation that the system is functioning per design. If the designer significantly under-estimates the demand, then the cistern may frequently be empty and the owner will not see the planned water savings planned.

Figure 6. Harvested rainwater used in irrigation and vehicle washing. (NCSU-BAE)

Typical irrigation design is based on the minimum irrigation needed to maintain health and quality in the vegetation. The alternate approach maximizes the amount of irrigation by calculating the maximum amount of water that can be applied while maintaining health and quality in the vegetation and preventing runoff of the irrigated water. This is done by considering the soils, slopes, vegetation, evapotranspiration rates, irrigation rates, and other factors. Designers may be familiar with this concept from non-discharge wastewater systems that employ irrigation for disposal.

The designer shall include documentation of the demand calculations and the assumptions and data sources behind these calculations in the design submittal. The demand estimates should be calculated using the best available information for the site. Possible data sources are listed in Table 4.

Table 4: Possible Data Sources for Different Cistern Demands

Cistern Demand	Possible Data Sources
Metered water consumption	For existing sites being retrofitted with a RWH system, actual historic meter data can be used.
Irrigation design calculations	For sites where an irrigation design is prepared, this can be incorporated into the demand calculations. o Detailed irrigation designs consider soil type, plant species and water need, and local ET rates. o Other designs may be less site-specific, but still provide helpful estimates, such as the inches per week by month. o Designers may choose to maximize irrigation as described in the box below. This approach will further reduce the need for other BMPs on-site, but will result in more complicated design and operation.
Specialty design calculations	For cooling tower make-up, animal systems, or other specialty uses where water use is integral to the site's function, water demand calculations will be part of the overall design.
Field Observations	For some practices, field observations may be required to determine the design demand. For example, a vehicle washing station may require field observation of the time spent washing each vehicle.
Toilet Flushing Estimates	For sites designing RWH systems for toilet flushing, the calculations can be trickier than other uses. o Good starting points include the plumbing design fixture counts, gallons per flush, building occupancy information, and potable water demand information. o However, it is important to note that these other design calculations typically over-estimate the demand for toilet and urinal flushing. In particular, this is because estimation methods are often based on historic data for buildings without low-flow fixtures. Therefore, this demand should be calculated in multiple ways before selecting a design demand. o In addition to the volume, it is important to consider whether there is seasonality to the demand. For example, a school would have drastically lower demand during certain months while an office building may see fairly even demand through the year.

RWH MDC 5. DISTRIBUTION SYSTEM
The distribution system shall be tested for functionality prior to the completion of the rainwater harvesting system. The design shall include a protocol for testing the functionality of the distribution system upon completion of the initial system and upon additions to the existing system.

RWH MDC 6. SIGNAGE REQUIREMENTS
All harvested rainwater outlets such as spigots and hose bibs, and appurtenances shall be labeled as “Non-Potable Water” to warn the public and others that the water is not intended for drinking. Passive drawdown devices, when employed, shall be marked with identifying signage or labels that are visible to owners and maintenance personnel.

Signage is required to indicate that the cistern water is not potable as well as to indicate that the “dripping” from a passive drawdown system is a part of the design and not a defect.

Figure 7. Signage Example (NCSU BAE)

All harvested rainwater outlets (e.g. spigots, hose bibs), storage facilities, and appurtenances shall be labeled as “Non-Potable Water” or “Non-Potable Water Do Not Drink” to warn the public and others that the water is not intended for drinking.

These required locations may include:
- Cistern
- Hose bibs
- Quick-coupling locations for the irrigation system
- Irrigation controller
- Toilet flushing locations

Passive drawdown devices, when employed, shall be marked with signage or labels that are visible to owners and maintenance personnel. This is to prevent the passive discharge drawdown from being plugged or capped.

RWH Recommendation 1. Inform Owner About Use, Operation and Maintenance
Before pursuing a RWH design beyond the conceptual stage, the designer shall meet with the owner to explain the non-potable water use requirement and the operation and maintenance requirements of the proposed system.

RWH systems require more hands-on operation and more frequent maintenance than other stormwater controls. The cost of these requirements should be offset by savings during the construction phase and/or during operation. This preliminary discussion should involve a subset of the following people, as applicable to the site:

Table 5: Possible Data Sources for Different Cistern Demands

People to Include	Recommendations
Homeowner	For homes where the resident-owner is involved in management of the RWH.
Owner and their representatives	For commercial, institutional, and industrial sites, the affected groups may include: o Property manager or building engineer o In-house maintenance staff responsible for the operation and maintenance of plumbing, grounds and landscape, irrigation systems, on-site water and wastewater treatment systems, control systems, etc. o Contracted maintenance staff (e.g. landscaping contractor)
Developer	At sites where the post-construction owners are not involved in the design, development team will be responsible for conveying information about restrictive covenants, recorded maintenance agreements, and similar information to buyers, including separate homebuilders in a subdivision.
Design team	The design professionals may include: o Architect o Civil engineer o Plumbing, mechanical, electrical (PME) engineer(s) o Landscape architect o Irrigation designer

Before meeting, the designer should review the design, construction, and operation & maintenance portion of this chapter and prepare a list of questions for the team. Key objectives in the discussion include:

- Selecting one or more uses for the harvested rainwater.
- Explaining the level of operation and maintenance involvement needed and determining if the owner will be capable of this effort.
- Clarifying the goals for the RWH system. This may range from exclusively stormwater management to primarily water conservation. This information is needed to optimize the sizing of the system.
- Soliciting information related to selecting quantifying the non-potable water demand.

RWH RECOMMENDATION 2. RAIN SENSORS
Before pursuing a RWH design beyond the conceptual stage, the designer shall meet with the owner to explain the non-potable water use requirement and the operation and maintenance requirements of the proposed system.

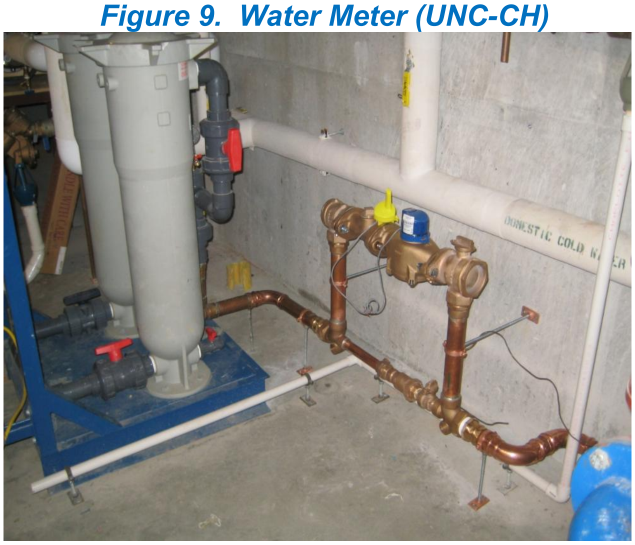
Figure 8. Irrigation Controller (NCSU BAE)

Rain sensors should be installed for all automated irrigation systems to ensure that turf and landscaped areas are not over-watered.

All spigots, hose bibs or other outlets for the harvested rainwater should be of a type, or secured in a manner, that permits operation only by authorized personnel, such as a locked below grade vault or a spigot that can only be operated by a tool.

RWH RECOMMENDATION 3. USAGE METERING
Metering the use from the cistern can provide a metric of the system's cost-effectiveness.

Figure 9. Water Meter (UNC-CH)



Many owners choose to meter harvested water as a metric of sustainability or cost savings. For indoor uses that discharge to the sanitary sewer, such as toilet flushing, the public water supplier may require metering. Because most public water suppliers base sewer billing on water consumption, these agencies are concerned about lost revenue due to rainwater harvesting. The agency may require their meter to be installed on the harvested rainwater distribution pipe entering the building to be used as the basis for sewer billing. For small sites, the agency may allow estimated payments without a meter. A water meter from the local public water/sewer provider is installed where harvested rainwater the building to be used for toilet flushing.

RWH RECOMMENDATION 4. REVIEWS BY ADDITIONAL PARTIES
Remember that RWH may require reviews by agencies that typically do not review stormwater designs.

RWH projects may require reviews by agencies that typically do not review stormwater designs. The primary conditions that would trigger these reviews are:

- Indoor Use, which triggers the Building Code
- Uses that discharge to the Sanitary Sewer (e.g. Toilet Flushing, Laundry), which may trigger review by the Local Water Supplier
- Potable Water Make-up, which triggers cross-connection control requirements

Table 6. Non-Stormwater Agencies That May Review RWH Systems

Regulation	Implementing Agency	Explanation
NC Plumbing Code	Local government or state construction office (state projects)	The NC Plumbing Code applies only if the harvested rainwater is brought inside a building. The code is uniform throughout the state and is implemented by local jurisdictions and the State via plan reviews, building inspections and the issuance of a certificates and/or permits.
NC Administrative Code	NC Division of Environmental Health, Public Water Supply Section AND public water suppliers (local government, water and sewer authority, or private company)	RWH systems are specifically addressed in Section 608 and Appendix C-1; although it is possible for other portions of the Code to apply to these systems.
Local Water Supply	Public water suppliers (may be the local government, a water and sewer authority, or a private company) AND/OR local health departments	The NCAC requires the implementation of backflow prevention measures to protect potable public water supplies from contamination via RWH systems.

Construction

Construction oversight by a design professional familiar with RWH system installation can help ensure that the investment results in adequate long-term performance.

Construction Step 1: Install Cistern Footing/Complete Excavation

Because cisterns are extremely heavy when full of water, the cistern base should be level to avoid the loss of storage space and/or the cistern falling over. The occupied by the cistern should be cleared of any vegetation or debris and a level depression excavated. The depth of the depression should be at least 12-18 inches deep to avoid freezing of any pipes entering or exiting the bottom of the cistern. However, the cistern should not be buried more than 2 feet deep, to prevent the pressure of soil on the sides of the tank from causing collapse. The area of excavation should be approximately 2 feet greater in diameter than the cistern to allow for optimum positioning and room for plumbing.

For cisterns 1,500 gallons and smaller, an aggregate base 6-8 inches deep should be placed in the depression and leveled. Typically crusher run or #57 stone is used but others types are also acceptable. For cisterns greater than 1,500 gallons, a concrete pad 4-6 inches thick should be poured into the depression and leveled for the base (Figure 25-15). In cases where the excavation of a depression is not feasible (e.g., paved surfaces or foundations), the cistern may be placed on ground surface; however, it is important that there still be a gravel or concrete base of the appropriate thickness to support the cistern. Also, any exposed piping that remains full of water between times of use should be well insulated to prevent freezing.

A concrete footing should be provided for cisterns greater than 1,500 gallons. Reinforcement of the concrete pad is not needed unless the cistern is larger than 10,000 gallons.

All cistern installations must follow manufacturer's recommendations and Appendix C-1 of the NC Plumbing Code. Please consult the NC Building Code Sections 1803.5.7 and 1804.1 to ensure that the requirements for footing depth, design and placement is correct and will not compromise any adjacent structures. ***Make sure to call 811 and locate all utilities prior to siting the cistern.***

Check the footing to make sure that it is level and at the correct elevation before placing the cistern structure and waterproofing.

Figure 10. Preparing a cistern footing of aggregate (left) and a concrete footing for a cistern exceeding 1,500 gallons (right) (NCSU BAE)

Construction Step 2: Place Cistern in its Location and Waterproof

Any entry into confined space such as a cistern must in accordance with local, state, federal workplace safety requirements under OSHA. If possible, install the passive drawdown, pump, and other components internal to the cistern before placement to avoid the need to enter the system later.

Figure 11. Assemble interior components prior to installing the cistern to avoid a confined space entry (NCSU BAE)

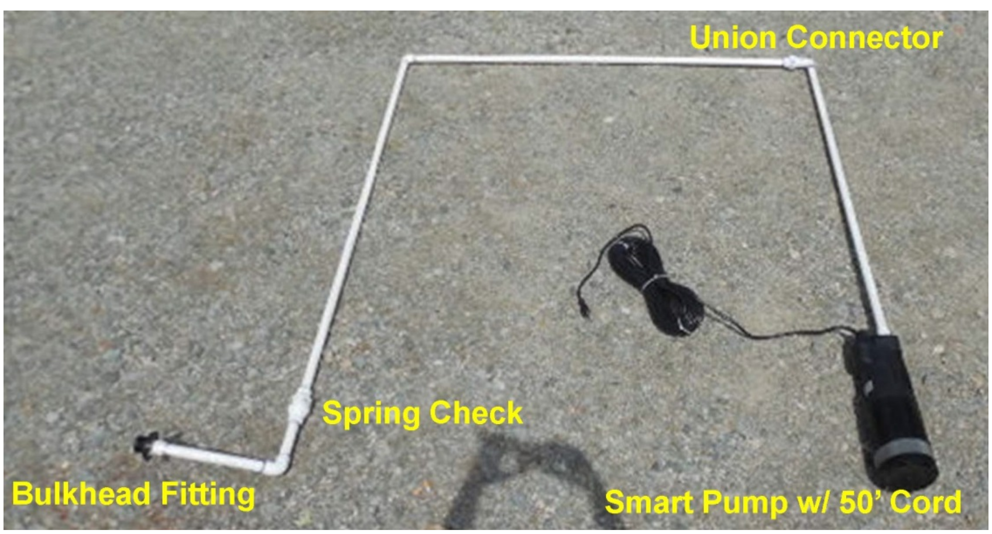


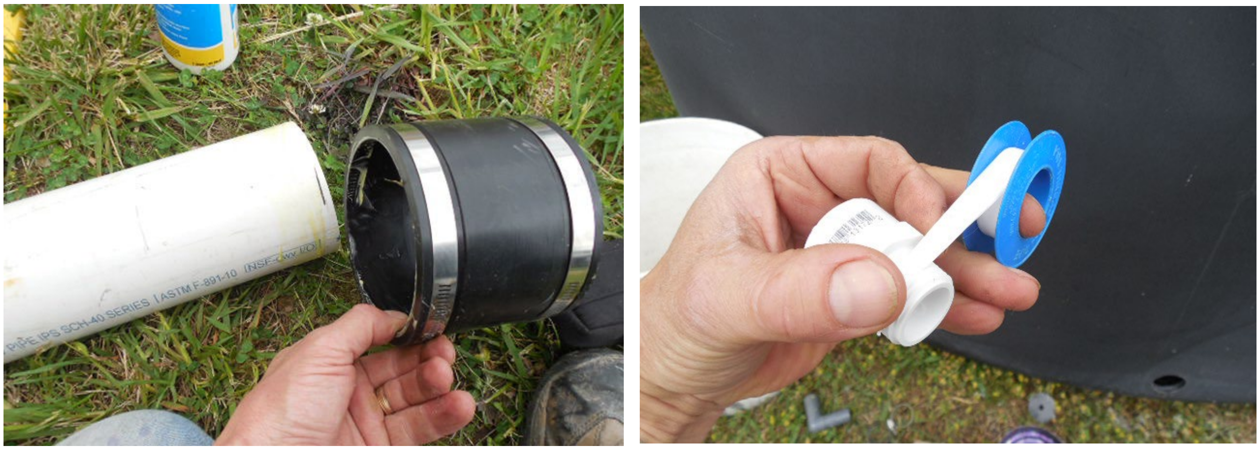
Figure 12. Installation of a membrane on a 15,000 gallon underground cistern at the Fayetteville Technical Community College NCSU BAE)

After placement of the cistern, the designer should check the elevations of the drainage components (passive drawdown, pump, fittings, connectors and check valves) to ensure that they are correct. If not, the designer should initiate field changes to ensure the correct volumes are provided.

The next steps are as follows:

- Install collection system components (if this is a new rather than a retrofit site.)
- Ensure that pipe sizing not changed – e.g. downspout sizing can impact the performance
- Clean the collection system prior to connecting to the cistern.
- Ensure that all connections are water-tight.
- Install the distribution system.
- Flush the distribution system piping before attaching to an irrigation system or other components that may be damaged by sediment or debris in the line.

Figure 13. Ensure the connections are water-tight. (NCSU BAE)



Construction Step 3: Fill the Cistern

Gutters should already be installed when a cistern is to be implemented. Place the downspout debris filter so that it can be easily seen and maintained while still allowing for positive drainage to the tank. There should be approximately 2-3 inches of clearance between the downspout opening and the debris filter to allow for easy removal of debris and leaves. The downspout can be cut with a hack saw, or by another method that will produce a smooth, straight edge.

The debris filter should be mounted on the wall and a pipe should be attached to the bottom of the filter to convey water from the filter to the tank (be sure the pipe is at least as big as the existing gutter downspout.) A rubber gasket should be used where the pipe enters the cistern to prevent leaking and ensure a tight fit (Figure 14). These gaskets come in multiple sizes and can be purchased from most cistern vendors.

First flush diverters are used in some cases. They may be needed on systems that do not employ complex debris filters (i.e. vortex filters), or on systems that have a lot of overhanging or nearby vegetation (especially pine trees). Pollen is the primary reason to have them, as this will not be removed by a typical debris filter.

The overflow pipe should be inserted into the tank at a height at or below that of the inflow pipe. A rubber gasket should be used to create a water-tight seal where the overflow pipe enters the tank. The overflow pipe should be positioned such that water is directed away from the tank and any building foundations. Ideally, the overflow water should be piped or diverted to a BMP such as a rain garden. It is not necessary for the overflow piping to be leak-proof (i.e. HDPE pipe may be used in lieu of PVC); however, it is necessary to use PVC pipe when first exiting the tank due to its size (relative to the gasket) and rigidity.

Figure 14. (a) Pipe leading from debris filter to the tank;
(b) Rubber gasket used to create leak-free seal when pipe enters the tank. (NCSU-BAE)

The last step in the construction process is to plumb any spigots or other distribution apparatus. The extract point may be gravity-fed or controlled by a pump. Pumps should be installed per manufacturer's recommendation. Any exposed piping (i.e. connecting an external pump to the cistern, or connecting a spigot to the pump) must be either buried at least a foot or otherwise insulated to prevent freezing or bursting. It is recommended to include a drain valve at the bottom of the tank to facilitate draining of the cistern for maintenance or winterizing.

RWH systems shall be water tight and the distribution system shall be functioning prior to being considered complete. For underground cisterns, test the cistern for water-tightness per the specifications. As stated in the design steps, the designer must specify the testing procedure for underground cisterns. Also, check with the manufacturer for recommended testing about specific products. If an automated make-up water supply is included, check the programming for the start and stop of the make-up water supply to ensure that it is per design.

Construction Step 4: Install Downstream BMP or vegetated receiving area (if applicable)

For construction requirements for downstream BMPs, refer to those chapters. For vegetated infiltration area construction, refer to the DIS chapter.

Construction Step 5: As-Built Inspection

After installation, an appropriately licensed NC design professional shall perform a final as-built inspection and certification that includes:

- Preparing the as-built plans…
- Inspect the cistern and components for cleanliness
- Check the sizing of the downstream BMP or vegetated infiltration area.
- Check site stabilization
- Confirm that water-tightness testing successfully performed
- Confirm that distribution system testing successfully performed
- Confirm that an air gap is provided if a make-up water supply is provided.

Any deficiencies found during the as-built inspection shall be promptly addressed and corrected.

The RWH system design must include maintenance access for each component. This will vary by site and installation type, but key issues in the design are listed in Table 25-9 below.

Table 7. Providing Maintenance Access for Cisterns

Type of Cistern	Access Recommendation
All cisterns	• Include a drawdown valve so that the cistern can be drained for maintenance • Cisterns must include a maintenance access that allow cleaning • If submerged pumps are used, there must be a mechanism to safely pull the pumps for maintenance. • Collection systems should include cleanouts or manholes at bends in the pipe to allow for cleaning. 2.
Above ground cisterns	• If possible, downspout filters or other pre-treatment should be accessible for maintenance without the use of a ladder. • Include an access point that allows visual access to the cistern interior. • For safety reasons, access hatches should be locked or require special tools for opening, or otherwise be inaccessible to the general public. • Depending on the height of the cistern, other provision may be needed for maintenance, such as tie-off points for workers. 3.
Below ground cisterns	• Include manways that allow for the set-up of a tripod for confined space entry. This requires level space surrounding the opening and vertical clearance. • A minimum of one access point per cistern tank and per treatment devices should be located where they can be driven to by a pump truck. The location must also have sufficient vertical clearance for the pump truck. • Underground cisterns should be a sufficient distance from building foundations and other infrastructure to allow excavation to the cistern structure in case repairs are needed.

Maintenance

Maintenance is crucial to RWH system performance. Most notably, the gutters and the debris screen should be checked for leaves and other debris after every major storm event, particularly when a tree canopy is near a roof top. Failure to do so will result in water backing up into gutters and onto roofs due to clogging piping and filters. In-line pipe filters, pump intake filters, and spigot filters should be checked annually to ensure they don’t become clogged.

It is critical for first flush diverters to be maintained frequently to work correctly. The drain port must be checked frequently, especially during high pollen times. If the port isn't cleaned out, water will bypass the filter completely (rendering it useless) or, in the winter, the water will freeze and burst the pipe on the filter.

Hose and pipe connections should be checked for leaks, especially after freezing temperatures. The cistern should be checked for stability prior to high-wind events (such as hurricanes or severe thunderstorms). If the cistern is consistently low on stormwater, it may become light and require some sort of anchoring system to keep it in pace. The owner of the cistern may want to fill it part way with potable water to prevent wind from tipping the cistern. A list of maintenance activities and their associated frequency is shown in Table 25-11.

If water within the cistern is not used for an extended period of time, it may become stagnant and develop a strong odor. To correct this problem, one should drain the stagnant water out of the cistern and add 2 fluid ounces (1/4 cup) of bleach to the tank for every 1,000 gallons of storage. **Be sure to allow the tank to fill up prior to using water**; otherwise the bleach will not be diluted enough to safely use the water. Debris filters are often not fine enough to prevent pollen from entering the tank. While this is generally not problematic, some people find pollen can also create an unpleasant odor. To correct this, add bleach as described above.

The designer and owner must also be aware that the use of RWH systems for stormwater credit requires that these uses must continue. If the non-potable water demand ceases because of a change to the site, the local government and/or NCDENR will require that an alternative non-potable water use may be found or that a properly designed BMP treatment system be installed on site to replace the RWH system.

Figure 15. Pumps need to be pulled periodically for cleaning and preventive maintenance (left). Overhanging vegetation increases the needed frequency of maintenance (right) (NCSU BAE)

Figure 16. Example of animal damage to cistern and patching of hole. (NCSU BAE)

The O&M manual should include manufacturer-specific operation and parts manual for the following components, as applicable:
Pre-treatment (downspout filter, first-flush diverter, etc.)

- Cistern
- Pump
- Valves
- Control System
- Level indicators
- Spigots
- Point-of-Use Treatment (filtration and disinfection)

Important maintenance procedures:

- The roof area will be maintained to reduce the debris and sediment load to the system. Excess debris can clog the system and lead to bypass of the design storm, and reduced reuse volume.
- To ensure proper operation as designed, a licensed Professional Engineer, Landscape Architect, or other qualified professional will inspect the system annually.
- The system components will be repaired or replaced whenever they fail to function properly.
- If the outlet is metered, use must be recorded at a minimum of monthly. These records shall be kept on site.

The system will be inspected by the owner/operator **at least monthly and within 24 hours after each rain event.** Records of operation and maintenance will be kept in a known set location and will be available upon request.

Inspection activities shall be performed as follows. Any problems that are found shall be repaired immediately.

Table 8:
Sample Operation and Maintenance Provisions for Water Harvesting Systems

BMP Element	Potential Problems	Remedy
The entire system	A component of the system is damaged or leaking.	Make any necessary repairs or replace if damage is too large for repair.
	Water is flowing out of the overflow pipe during a design rainfall or smaller event when there has not been another rainfall event during the past five days.	1. Check system for clogging and damage. Repair as needed so the design volume is stored properly without discharged during a design storm. 2. Check that the pump is operating properly and that the water is actually being used at the volume designed. 3. If it is still not operating properly, then consult an expert.
The captured roof area	Excess debris or sediment is present on the rooftop.	Remove the debris or sediment as soon as possible.
The gutter system	Gutters are clogged, or water is backing up out of the gutter system.	Unclog and remove debris. May need to install gutter screens to prevent future clogging.
	Rooftop runoff is not making it into the gutter system.	Correct the positioning or installation of gutters. Replace if necessary to capture the roof runoff.
The cistern	Sediment accumulation of 5% or more of the design volume.	Remove sediment.
	Algae growth is present inside the cistern.	1. Do not allow sunlight to penetrate the cistern. 2. Treat the water to remove/prevent algae.
	Mosquitoes in the cistern.	1. Check screens for damage and repair/replace. 2. Treat with 'mosquito dunks' if necessary.
The screens and filters	Debris and/or sediment has accumulated. Screens and filters are clogged.	1. Search for the source of the debris/sediment and remedy the problem if possible. 2. Clean/clear debris/sediment from screen or filter. Replace if it cannot be cleaned.

The pump	Pump is not operating properly.	1. Check to see if the system is clogged and flush if necessary. 2. If it is still not operating, then consult an expert.
The overflow pipe	Erosion is evident at the overflow discharge point.	Stabilize immediately.
	The overflow pipe is clogged.	Unclog or replace if it cannot be unclogged.
	The outflow pipe is damaged.	Repair or replace the pipe.
The secondary water supply	Not operating properly.	Consult an expert.

Additional Resources

American Rainwater Catchment Systems Association (ARCSA) is a national organization of rainwater harvesting professionals. The organization is focused on the water supply benefits rather than the stormwater benefits of rainwater harvesting.

Rainwater Harvesting: Guide for Homeowners (NCSU)

EPA Municipal Handbook: Rainwater Harvesting Policies

N.C. Plumbing Code Appendix C-1

Georgia Rainwater Harvesting Guidelines

Texas Manual on Rainwater Harvesting

References

Ahmed, W., T. Gardner and S. Toze. 2011. Microbiological quality of roof-harvested rainwater and health risks: A review. *J Env. Q.* 40(1): 13-21.

Basinger, M., F. Montalto and U. Lall. 2010. A rainwater harvesting system reliability model based on nonparametric stochastic rainfall generator. *J. Hydrol.* 392(3-4): 105-118.

Brodie, I. M. 2008. Hydrological analysis of single and dual storage systems for stormwater harvesting. *Wat. Sci. Tech.* 58(5): 1039-1046.

DeBusk, K.M., W.F. Hunt, and J.D. Wright. 2014. Characterization of Rainwater Harvesting Performance in Humid Regions of the United States. *Journal of the American Water Resources Association*. (in press – February issuevcc n ccn nvc vvvnm)

Fewkes, A. and P. Warm. 2000. Method of modelling the performance of rainwater collection systems in the United Kingdom. *Build. Serv. Eng. Res. T.* 21(4): 257-265.

Guo, Y. and B. W. Baetz. 2007. Sizing of rainwater storage units for green building applications. *J. Hydrol. Eng.* 12(2): 197-205.

Hermann, T. and U. Schmida. 1999. Rainwater utilisation in Germany: Efficiency, dimensioning, hydraulic and environmental aspects. *Urban Water J.* 1307-316.

Jones, M. P. and Hunt, W. F. *Rainwater Harvesting: Guidance for Homeowners*. N.C. Cooperative Extension publication AG-588-11. Raleigh: N.C. State University

Jones, M. P. and Hunt, W. F. (2006). *Choosing a Pump for Rainwater Harvesting*. N.C. Cooperative Extension publication AG-588-08. Raleigh: N.C. State University

Kim, K. and C. Yoo. 2009. Hydrological modeling and evaluation of rainwater harvesting facilities: Case study on several rainwater harvesting facilities in Korea. *J. Hydrol. Eng.* 14(6): 545-561.

Kus, B., J. Kandasamy, S. Vigneswaran and H. K. Shon. 2010. Analysis of first flush to improve the water quality in rainwater tanks. *Wat. Sci. Tech.* 61(2): 421-428.

NCSU BAE Stormwater Engineering Group http://www.bae.ncsu.edu/stormwater

NC Department of Agriculture and Consumer Services. 2013. *Community Conservation Assistance Program Design Manual. Chapter 7: Rainwater Harvesting*. 47-63.

Rainwater Harvesting at North Carolina State University http://www.bae.ncsu.edu/topic/waterharvesting/

Reidy, P. C. 2010. Integrating rainwater harvesting for innovative stormwater control. *In conf proc. World Environmental and Water Resources Congress,* American Society of Civil Engineers.

The Texas Manual on Rainwater Harvesting (2005, 3rd Ed.), Texas Water Development Board. Austin, Texas

Zhang, D., R. M. Gersberg, C. Wilhelm and M. Voigt. 2009. Decentralized water management: Rainwater harvesting and greywater reuse in an urban area of Beijing, China. *Urban Water J.* 6(5): 375-385.