IOWA STORMWATER MANAGEMENT MANUAL

6.03 RAINWATER HARVESTING

Department of Natural Resources

CONTENTS

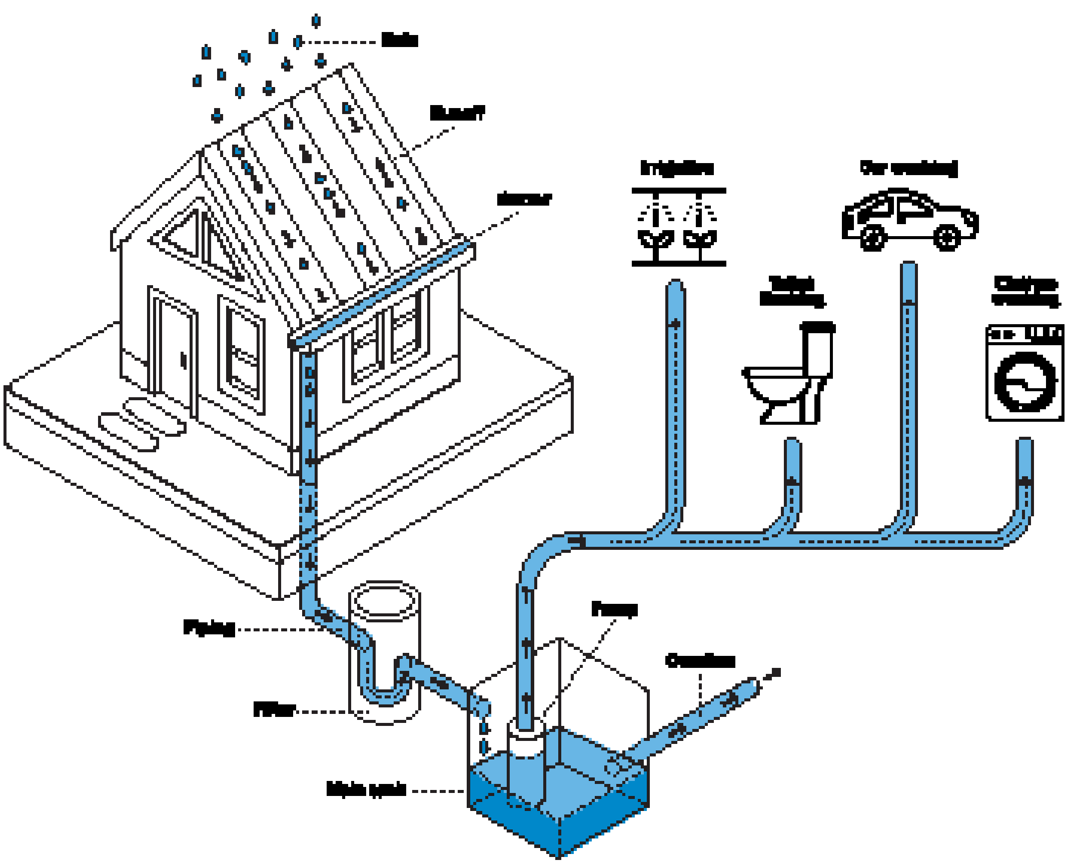
Refer to the glossary for words in **bold black text.**
Some items of emphasis are in **bold blue text.**

6.03.1 DESIGN

A. SUMMARY AND SCOPE

Rainwater harvesting systems are primarily used to collect water for non-potable applications, to reduce the demand on **potable water** sources. This section will primarily focus on irrigation applications for rainwater harvesting systems, but will briefly review other applications. Systems generally consist of four main components: a **collection system** (from sources such as roof tops, parking lots, **A/C condensate**, and drainage tiles); **a storage system** (a tank, cistern, pond, etc.); a **treatment and/or filter system**; and **distribution system** (to convey water to the given application). Water typically is prefiltered prior to entering a storage device. Pump stations are used to provide pressurized water, filtration or other treatment, and water source management for the entire system.

These systems incorporate multiple disciplines both in the design phase and construction phase. It is not uncommon for civil, plumbing, electrical, landscape, and structural engineering to be involved in coordination of such projects. The success of these systems hinges on having a single point of responsibility to coordinate all disciplines. It is also best to obtain as many of the components as possible from a single source supplier to limit errors and omissions in scope.



NOTE

Iowa currently has limited regulations related to public health and rainwater systems, but it is advisable to check with the state health department before designing such systems.

B. APPLICATION

The primary applications discussed in this section will be the following:

- Landscape irrigation
- Small farm and food crop irrigation (including greenhouse infrastructure)

Additional plumbing applications will also be covered briefly throughout this section. Examples include toilet flushing, vehicle washing, and cooling tower water.

Designers should evaluate the water quality of the captured water in each system and compare to water quality requirements for each application as well as any possible public health risks. A designer/builder must be aware that anything that the captured water comes in contact with can negatively affect water quality. ESSENTIAL

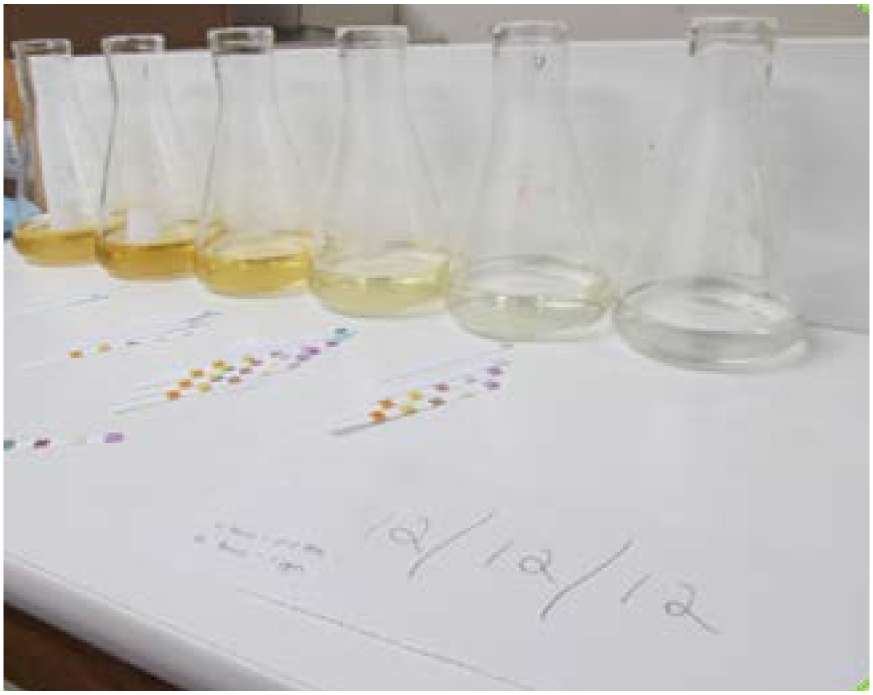
These systems have been installed throughout the United States. While each installation has its own unique design, there are several reference materials that can assist engineers, contractors, and owners in designing rainwater harvesting systems. These standards are meant to be used in conjunction with national building, electrical, and plumbing codes.

ANSI / ICC 805: Rainwater Harvesting Systems: https://codes.iccsafe.org/content/CSAB8052022P1

FSMA Final Rule on Produce Safety | FDA:
https://www.fda.gov/food/food-safety-modernization-act-fsma/fsma-final-rule-produce-safety

National Young Farmers Coalition
https://youngfarmers.org

USDA-NRCS National Engineering Handbook – Part 623 Irrigation, Chapter 7 Microirrigation:
https://directives.nrcs.usda.gov//sites/default/files2/1720457402/Chapter%207%20-%20Microirrigation.pdf



Water quality variability: water collected from green roof before and after treatment.
Image courtesy of Watertronics.

C. SITE FEASIBILITY

Rainwater harvesting systems can be integrated into most sites; however, there are certain restrictions related to climate, site topography, space, and other site constraints to consider.

- **Climate** – The climate of the site should be evaluated, paying particular attention to unique weather constraints during periods with intended usage.
  - In Iowa, above-ground tanks may need to be bypassed and/or drained during winter.
  - Drainage pipes need to be inspected for proper operation when freeze-thaw action occurs.
  - If water usage is required year-round (i.e., an indoor green house) a below-ground tank may be a better choice to avoid freezing.
  - Warm weather can affect water quality in above ground tanks, as increased water temperatures and exposure to sunlight can cause algal blooms within the tank.
  - Above-ground tanks can provide access for rodents and other pests to potentially intrude into the rainwater system. Proper rodent screening should be used on any possible point of entry.
  - Above ground tanks need to be engineered for expected wind and snow loads, and must be properly anchored.
- **Site Topography** – Drainage from collection surface is gravity fed via drainage pipes to the storage system. Pipe slope, distance from collection surface, and destination of any excess water must be evaluated. Roof drainage piping and storm drainage piping are governed by national and local plumbing codes for type, size, and quantity.
- **Space and other site constraints** – Pump systems require power and larger systems often require 3-phase power. It's important to compare the power available on the project site with your potential power needs of the system. Physical size of tanks must fit within the given area without obstructing access, blocking windows, or possibly transmitting load to an adjacent structure.
- When utilizing below ground tanks, **ground water elevations must be evaluated** and a buoyancy calculation must be performed to ensure **storage tank** will not rise out of the ground. ESSENTIAL
- Other risks such as wind loading, flood risk, etc. should be considered when designing above ground storage systems. ESSENTIAL
- Check for local design and plumbing codes for separation or setback requirements when storage systems, pipes or other elements are going to be located near utilities or structures. ESSENTIAL

NOTE

An example that may pose a difficult design or install would be the use of an above-ground tank on a building where all the roof drain pipes exit below ground near the building exterior. When using above-ground tanks, it is best to have the water drain into the tank near the top, or above the max water level of the tank.

NOTE

Transmitting load refers to the weight of a heavy object (like a tank) being transferred through the ground. Usually there is an angle of influence (about 45 degrees) where the weight of the object pushes against building footings, structures, etc. A structural engineer should evaluate this during design.

NOTE

Buoyancy is where subsurface storage systems may want to "float" when soils become saturated, because they weigh less than the volume of water they displace. Manufacturers often provide these calculations, or they can be completed by a structural engineer.

D. DESIGN ELEMENTS AND COMPONENTS

COLLECTION SURFACE

Roof areas are the most commonly used collection surface (often made of rubber, shingles, metal or glass).

There are other collection surfaces which may be used, but require additional filtration or treatment. These include but are not limited to:

- Green roofs
- Landscaped surfaces (mulch, wood chips)
- Rain gardens
- Parking lots (concrete & asphalt)
- **Stormwater** ponds

The following elements are typically included in the design of rainwater harvesting systems:

1. Collection surface - What surface will rainwater be collected from? Are there other sources of water that are to be collected (such as condensation from air conditioner units)?
2. Quantity - How much water can be collected? This is often a function of the size of the collection surface that rainwater will be collected from. How much water is needed, based on the expected uses (irrigation, small crop production, interior building water uses, etc.)?
3. Pre-filtration - **Filters** are typically required to remove debris and some other contaminates before they can enter pumps and other equipment. When parking lots, landscape areas or other surfaces are used as a collection surface, hydrodynamic separators or other water quality practices may be needed to remove sediments or other debris.
4. Storage devices - Below and above ground tanks are most commonly used for storage, but about anything that can store water temporarily can be used. If ponds are used for storage, additional pre-filtration may be required before water passes through pumps or other system elements.
5. Pumps and treatment - In many cases, stored water will need to be pumped into a distribution system. Different levels of treatment are required based on the expected use of the water and how it may come into contact with people.

These elements are covered in the following part of this section which contain the following tables that note how different collection surfaces should be used for different water uses. Such uses are grouped into different end use tiers, which require different levels of treatment.

The ANSI/ICC 805 standard provides a quality matrix of roof collection surfaces and which end use can be satisfied from each surface.

Table 6.03-1-1. End Use Tier Applications Based on Collection Surfaces

End User Tier Applications Based on Collection Surfaces		
SUBSYSTEMS DESIGN AND INSTALLATION		
Collection surfaces per water and use tier for the prescriptive approach		
Collection surface		**End use tier**
Roofing material	Asbestos cement	#
	Asphalt	1, 2, 3, 4
	Asphalt felt and bituminous and tar membranes	1, 2, 3
	Ceramic	1, 2, 3, 4
	Clay	1, 2, 3, 4
	Concrete	1, 2, 3, 4
	Copper	1, 2, 3
	Fiberglass	1, 2, 3, 4
	Glass	1, 2, 3, 4
	Polyethylene membrane	1, 2, 3, 4
	Polymer and acrylic	1, 2, 3
	Rubber/Butyl/EPDM membrane	1, 2, 3
	Steel, coated	1, 2, 3, 4
	Steel, stainless	1, 2, 3, 4
	Tin	1, 2, 3, 4
	Wood, untreated	1, 2, 3
	Wood, treated	1, 2, 3
	PVC	1, 2, 3, 4
	TPD	1, 2, 3, 4
Public pedestrian accessible roofs		1, 2, 3
Vegetated roofs		1, 2*, 3
Pedestrian and parking surfaces (e.g., sidewalks, courtyard, driveways, parking areas, pervious surfaces)		1, 2*, 3
Landscaped runoff		1, 2*, 3
Street, freeway, shoulder areas		#
Subsurface collection^		1, 2, 3
Surface waters and stormwater detention ponds		#

* HVAC evaporative cooling applications not included.
^ Subsurface water shall not be collected from sites which contain contaminated soils.
# Not in the scope of this Standard.

Source: ANSI/ICC 805, Table 7.1 (refer to that standard for more information).

NOTE

On the following pages, different levels of treatment are required based on the type of collection surface. Roofs are grouped into one category.

Other collection surfaces are grouped into "stormwater runoff" categories. These areas may be higher sources of pollutants such as bacteria, pet waste, sediment, fertilizers, pesticides, debris, etc. For these reasons, higher levels of treatment and disinfection are typically required.

NOTE

Surface water and stormwater ponds used as a collection surface are not covered by the ANSI/ICC 805 standard.

Golf courses and other locations often use ponds as sources for irrigation water. When used as a source for this purpose for landscape irrigation, consider timing of irrigation use to limit potential public exposure.

NOTE

Restricted access or exposure means areas that are closed to the public or personnel when water is being applied, or timing application when the risk of exposure is limited (overnight application, for example).

NOTE

For food crop production, the end use tier will depend on the method of irrigation and the expected level of access or potential exposure.

NOTE

Water collected from organic surfaces, such as green roofs, landscape or natural vegetative surfaces may best be used with drip irrigation applications to limit public exposure to the irrigated water.

Table 6.03-1-2. Potential Applications and End Use Tiers

End Use Tier	Category	Potential for human contact	Examples for uses
1	Non-potable	Low	Trap primers Spray irrigation (restricted access or exposure) Surface and subsurface irrigation (drip, bubbler) Fire protection Ice rinks
2	Non-potable	Medium	Toilet and urinal flushing Clothes washing Rooftop thermal cooling HVAC evaporative cooling (e.g. cooling tower, evaporative condenser, spray cooler, direct and indirect evaporative cooling)
3	Non-potable	High	Hose bibs Pressure washing Decorative fountains Vehicle washing Spray irrigation (non-restricted access or exposure)
4	Potable	High	Human consumption Oral care Food preparation Dishwashing Bathing, showering and hand washing Pool / hot tubs / spas / splash pads Misting stations Swamp coolers

Source: ANSI/ICC 805, Tables 8.3 and 8.4 (refer to that standard for more information).

Table 6.03-1-3. Minimum Performance Criteria
Roof Runoff Water Treatment for Multi-Residential and Non-Residential Applications

Log Reduction (% reduction)				
End Use Tier	Viruses	Bacteria	Protozoa	pH
1	0	0	0	--
2	0*	2 (99%)	2 (99%)	--
3	0*	3 (99.9%)	3 (99.9%)	--
4	0*	6 (99.9999%)	4 (99.99%)	7 to 10.5

* For HVAC evaporative cooling, treatment shall consider all equipment manufacturer water quality requirements and be designed according to ANSI / ASHRAE 188.

Source: ANSI/ICC 805, Tables 8.3 and 8.4 (refer to that standard for more information).

Table 6.03-1-4. Minimum Prescriptive Requirements
Roof Runoff Water Treatment for Multi-Residential and Non-Residential Applications

Options for Post-Storage Treatment Before End Use					
	UV		Chemical-based Disinfectants		
End Use Tier	Filtration	Disinfection	Filtration	Disinfection	Microfiltration or Ultrafiltration
1	None Required				
2	5 µm	16 mJ/cm²	1 µm absolute	CT for 2 Log reduction for bacteria and at least 0.5 mg/L chlorine residual	0.5 µm with at least 0.5 mg/L chlorine residual
3	5 µm	30 mJ/cm² with at least 0.5 mg/L chlorine residual	1 µm absolute	CT for 3 Log reduction for bacteria and at least 0.5 mg/L chlorine residual	0.5 µm with at least 0.5 mg/L chlorine residual
4	5 µm	40 mJ/cm² (2)	1 µm absolute	CT for 6 Log reduction for bacteria and at least 0.5 mg/L chlorine residual	0.2 µm third-party certified with at least 0.5 mg/L chlorine residual

1 – For HVAC evaporative cooling, treatment shall consider all equipment manufacturer water quality requirements and be designed according to ANSI / ASHRAE 188

2 – 40 mJ/cm² and third-party certified to Class A of NSF/ANSI 55 or validated to US EPA UVDGM or DVGW W294 with at least 0.5 mg/L chlorine residual

Source: ANSI/ICC 805, Table 8.3 (refer to that standard for more information).

NOTE

These tables reference uses for multi-family and non-residential applications.

Collection and stormwater use by private landowners for single-family applications and non-commercial uses are not typically regulated. It is up to the owner on what level of risk they want to take for their own personal use.

NOTE

As noted on the previous pages, different levels of treatment are required based on the type of collection surface. Roofs are grouped into one category. Other collection surfaces such as parking lots, landscaped areas, etc. are grouped into "stormwater runoff" categories.

NOTE

As noted on the previous pages, for food crop production, the end use tier will depend on the method of irrigation and the expected level of access or potential exposure.

Application methods are based on the Food Safety Standard Act. Requirements vary based on the type of crop (some are eaten raw, while others are typically cooked).

Table 6.03-1-5. Minimum Performance Criteria
Stormwater Runoff Treatment Requirements for Multi-Residential and Non-Residential Applications

Log Reduction (% reduction)				
End Use Tier	Viruses	Bacteria	Protozoa	pH
1	0	0	0	--
2	4 (99.99%)	4 (99.99%)	3 (99.9%)	--
3	4 (99.99%)	4 (99.99%)	3 (99.9%)	--
4	**	**	**	**

* For HVAC evaporative cooling, treatment shall consider all equipment manufacturer water quality requirements and be designed according to ANSI / ASHRAE 188. Also see ANSI / ICC 805 for additional information.

** Not included in the ANSI / ICC 805 standard.

Source: ANSI/ICC 805, Table 8.4 (refer to that standard for more information).

Table 6.03-1-6. Minimum Prescriptive Requirements
Stormwater Runoff Treatment Requirements for Multi-Residential and Non-Residential Applications

Options for Post-Storage Treatment Before End Use					
	UV		Chemical-based Disinfectants		
End Use Tier	Filtration	Disinfection	Filtration	Disinfection	Microfiltration or Ultrafiltration
1	None Required				
2	5 µm	40 mJ/cm^2	1 µm absolute	CT for 4 Log reduction for bacteria and at least 0.5 mg/L chlorine residual	0.5 µm with at least 0.5 mg/L chlorine residual
3	5 µm	40 mJ/cm^2	1 µm absolute	CT for 4 Log reduction for bacteria and at least 0.5 mg/L chlorine residual	0.5 µm with at least 0.5 mg/L chlorine residual
4	(3)	(3)	(3)	(3)	(3)

1 – For HVAC evaporative cooling, treatment shall consider all equipment manufacturer water quality requirements and be designed according to ANSI / ASHRAE 188

2 – 40 mJ/cm^2 and third-party certified to Class A of NSF/ANSI 55 or validated to US EPA UVDGM or DVGW W294 with at least 0.5 mg/L chlorine residual

3 – Not included in the ANSI / ICC 805 standard

Source: ANSI/ICC 805, Table 8.4 (refer to that standard for more information).

Table 6.03-1-7. Tentative Water Quality Criteria for Classifying Waters Used with Micro Irrigation (adapted from Hanson et al. 1994; Hassan 1998)

Water Testing			
Type of Factor	Minor	Moderate	Severe
Physical			
Suspended solids[a]	50	50-100	>100
Chemical pH	7.0	7.0-8.0	>8.0
Dissolved solids[a]	500	500-2,000	>2,000
Manganese[a]	0.1	0.1-1.5	>1.5
Total iron[a]	0.2	0.2-1.5	>1.5
Hydrogen sulfide[a]	0.2	0.2-2.0	>2.0
Carbonate+bicarbonate[a]	50.0	50-100	>100
Biological			
Bacterial population[b]	10,000	10,000-50.000	>50,000

a – Maximum measured concentration from a representative number of water samples using standard analytical procedures for analysis in ppm (mg/L)

b – Maximum number of bacteria per milliliters can be obtained from a portable field sampler using standard analytical procedures for analysis

Source: USDA NCRS, Part 623 Irrigation National Engineering Handbook, Table 7.2 (refer to that standard for more information).

NOTE

This document does not address Per- and polyfluoroalkyl substances (PFAS) which are an emerging pollutant of concern.

NOTE

Table 6.03-1-7 notes how different water quality measurements can be used to evaluate the suitability of water for use in micro-irrigation applications. The minor, major and severe categories are different levels of concern for use. Refer to NRCS's National Engineering Handbook, Part 623, Chapter 7 for more information.

NOTE

Sizing of rainwater harvesting systems is not based on a single storm event. Detailed calculations for monthly and daily water capture and use are needed to properly size the collection, storage and distribution system.

Calculations of these types will be repeated for multiple storm events over an analysis period. See Part 6.03-2 of this section for more information.

DETERMINING HOW MUCH WATER CAN BE COLLECTED

To estimate gallons of water potentially collected from a given surface, begin by calculating the total area of hard surface that is being collected. One inch of rainfall collected from 1,000 square-foot of hard surface would provide 620 gallons of water. An efficiency factor should also be applied to project the number of gallons that the user can expect to collect from a given rain event.

Recommended efficiency factor (EFF%):

- Hard surface = 90%
- Green roof / soil / vegetative surface = 35-50% (depending on density and vegetation)

Calculation Example

A rain event of 1.75 inches occurs over a 13,000 square foot hard surface roof. How many gallons will this produce?

13,000 square feet x 1.75 inches x (1/12 inch per foot) x 7.481 (gallons per cubic foot) x 90% efficiency factor = 12,764 gallons projected to be collected.

Roof drain (left) and scupper (right) on membrane roof. Image courtesy of Google images.

NOTE

Roof drains, gutters and downspouts are some ways where rainwater can be collected from roofs.

Asphalt shingle collection surface. Image courtesy of Google images.

PRE-FILTER

The best place to filter the water in a rainwater harvesting system is at the source. The sooner the water is filtered, the less time, money, and effort is required to filter the water later in the system. Pre-filters are gravity type devices that are installed between the collection surface and the storage device.

Pre-filters remove total suspended solids (TSS) and keep items such as leaves, dirt, and debris out of the storage tank. **The decomposition of organic matter in the storage structure is the single worst contributor to poor water quality of the water to be used.** It can cause the collected water to have an undesirable color, odor, and even contain harmful pathogens. Pre-filters prevent these items from entering the storage tank. Most pre-filters filter the water to a 350–1000 micrometer (micron) level.

Pre-filters cannot remove total dissolved solids (TDS), as they are dissolved in the water and will not settle out. Examples of dissolved solids include salt in saltwater or **tannins** in water collected from a **green roof**. In these cases **reverse osmosis** must be used.

When collecting water from parking lot surfaces, it is important to utilize a hydrodynamic separator, as these types of pre-filters also utilize a way to separate hydrocarbons from the water in addition to removing TSS from the water. TARGET

Pre-filters work on an efficiency principle. The more water passing through them, the less efficient they are at removal. They contain one (1) inlet and two (2) outlets. In the image below, water from the roof enters the filter from the upper left pipe. Water flows across the screen and gravity pulls it through it. Clean, filtered, water is sent to the storage tank through the lower left pipe. The pipe on the right is the excess outlet that takes the excess dirty water to the storm drain or final overflow destination. Since these pre-filters can be installed within a roof drainage system, they must always allow water to leave the rooftop. If this screen were to become completely clogged water would

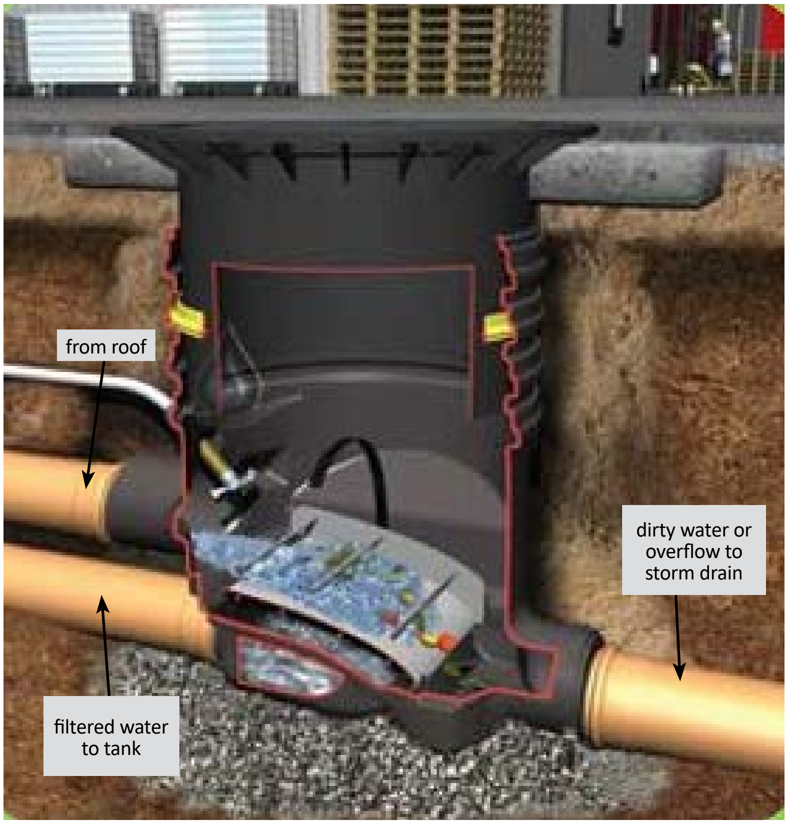


Image courtesy of GRAF.

pass over the plugged screen and out the right-side pipe, allowing the water to bypass the pre-filter.

Contrast the arrangement shown and described on the previous page with a typical in-line style filter (see image below). If the screen in this image becomes clogged, the water will back up and pool on the roof top. This type of backup could cause water to leak through the roof or even cause structural damage to the roof due to the added water load. Pipe joints may also fail due to the pressure buildup upstream of a clogged filter.

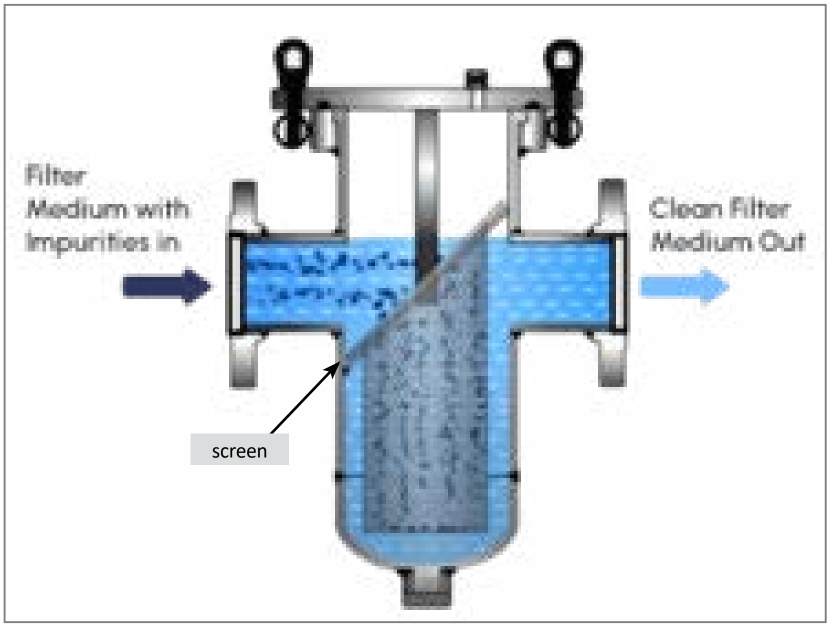


Image courtesy of Hanke Filters.

PRE-FILTER SIZING

Pre-filters are sized based on flow rate. The equation for this will use rainfall intensity (rate), not rainfall amount (volumetric). It is important to clearly know the difference. The rainfall intensity over the roof area produces the flow rate in a given pipe to the pre-filter, not the total rainfall volume.

Example: calculate flow rate from a roof top

The peak rate of flow for small watershed areas may be found using the rational method:

Q (flow, cfs) = C x I x A

Given:

Runoff Coefficient (C) = 1.00 (all rainwater expected to be collected)
Rainfall Intensity (I) = 5.59 inches / hour*
Roof Area (A) = 13,000 SF (0.30 acres)

*See ISWMM Rainfall and Runoff Analysis Section – (value for this example is based on Central Iowa, Region 5 – 2-year storm, Tc = 5 minutes. For design, base values on site specific conditions.)

Q = 1.00 x 5.59 in/hr x 0.30 acres = 1.67 cfs

Converting to gallons per minute (gpm):

1 cfs = 1 cubic foot x (7.481 gallons / cubic foot) x (60 seconds per minute) = 448.9 gallons per minute

1.67 cfs x 448.9 (gpm / cfs) = 750 gallons per minute

Filter manufacturers will publish performance curves for the filter. It is important to select a rainfall rate that represents a common occurrence for the site. Normally, a 2- to 5-year rainfall return rate is selected. It is not recommended to size a **tank pre-filter** based on a 100-year rainfall rate, as this would require a more expensive filter whose capacity would be used very infrequently. ESSENTIAL

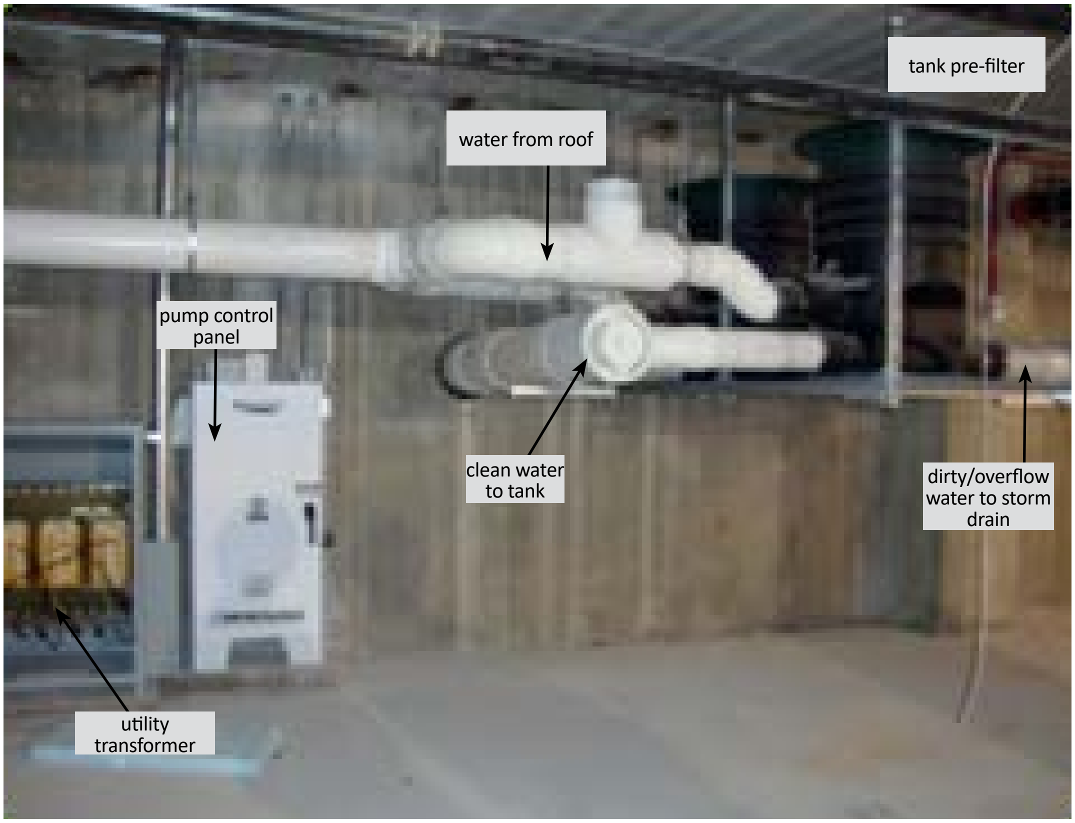
NOTE

For this calculation, the designer needs to identify what storm event is expected to pass through the pre-filter, and what will be expected to bypass the collection system. This may vary from project to project.

NOTE

For this example, a 5-minute Tc was assumed because of the short travel path on a rooftop area.

Other Pre-Filter Examples



Images courtsey of Watertronics and Graf.

HYDRODYNAMIC SEPARATORS

When collecting from a parking lot, a hydrodynamic separator system (HDS) should be used (see below image). There are various HDS units constructed by a variety of manufacturers, with different pollutant removal rates. The type of unit selected will depend on the intended use for the collected runoff which will dictate the need to address certain pollutants. For parking areas, sediments and hydrocarbons are frequently the greatest concern. HDS are sized using a treatment flow rate. They can filter all of the water up to a certain flow rate. Once this flow rate is exceeded, flows will bypass the filtration elements of the system. It is important to note that if the treatment flow rate is exceeded, unfiltered water will end up in the storage vessel. For this reason, a flow diversion structure is often needed upstream of the HDS unit, to limit the amount of flow that can pass through the HDS during large events. See ISWMM Section 5.05 (Hydrodynamic Separators) for more information on the sizing and selection of HDS systems.

Image courtesy of Contech.

NOTE

In these applications, the HDS unit is being used as pre-filter.

STORAGE DEVICES

Storing the water after pre-filtration can be done in any vessel that will hold water. Commonly these are above ground tanks, below ground tanks, tanks cast into building foundations, or even ponds. There are many tank types and styles available, and each type of storage device has its pros and cons. This section will review common products used in rainwater harvesting applications and should not be considered a complete list of products that are available. When proprietary storage devices are used, always follow the manufacturer's guidance for design and installation.

Multiple types of storage devices can be used on a given project. They could be hydraulically connected to allow water to fill each device, allowing water to be pumped from a single **pump**.

If multiple collection surfaces are present (roofs and parking lots/landscape areas, for example), it might be advisable to have separate storage devices to have them in proximity to the collection source or to provide for different levels of disinfection or treatment, based on the collection source. In such a case, separate pumps and treatment systems would be needed. IDEAL

NOTE

When selecting an underground storage tank, designers should refer to manufacturer's specifications related to expected bury depth, for both freeze protection and cover limitations.

Some tank materials have a limited bury depth due to their ability to support the weight of soils and other materials located above.

BELOW GROUND TANKS

Advantages

- Offer freeze protection in Iowa climate (bury depth provides insulation)
- Integrates easier into drainage systems as water usually exits buildings near ground surface
- Does not take up valuable land / footprint
- Can be installed below paved plazas and parking lots when rated for expected traffic loads
- Many options in sizes and materials

Disadvantages

- Expensive to install
- Buoyancy (anti-floatation) calculations required (evaluate uplift pressures on the tank, when empty)
- Difficult to service/clean
- Below ground tanks have limited bury depths and load ratings

FRP below ground storage tanks with anchoring. Image courtesy of Watertronics.

TYPES AND MATERIALS OF BELOW GROUND TANKS

Fiberglass Reinforced Plastic (FRP)

These tanks are molded at a factory and shipped to site complete with all penetrations and openings. They are available in sizes ranging from approximately 2,000 gallons – 40,000 gallons in a single tank. There are larger sizes available, but freight costs are extremely high. Multiple tanks can be connected to each other with a balance pipe to form larger vessels.

Concrete

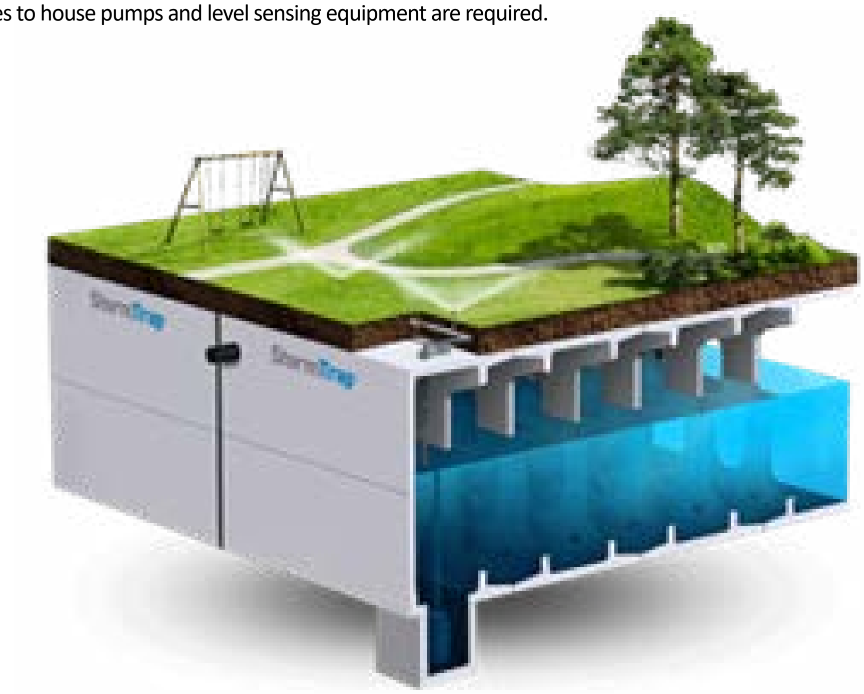
Concrete tanks can be poured in place on site or pre-cast and delivered in multiple sections to a site. Poured in place tanks have size and footprint flexibility. If tanks are pre-cast and assembled on site, a liner may also be used to seal the joints between sections. Sizes with concrete tanks are virtually limitless.

High Density Polyethylene (HDPE)

HDPE tanks are typically shipped to sites fully assembled. Penetrations into tanks are usually made with threaded bulkhead fittings and are done on site by an installing contractor. Penetration sizes can be limited by the size of threaded bulkheads available. Some HDPE fabricators can fabricate and weld larger pipe connections onto HDPE tanks. HDPE tanks also have limited bury depths due to the nature/strength of HDPE vs. other materials. Single tank sizes can range from 300 gallons – 10,000 gallons.

Plastic with PVC Liner

These tanks use a plastic cube structure to create a storage space. A liner is wrapped around the structure creating a void to hold the water. Size and shape can be determined by designer/installer. These structures are often used in high groundwater applications as the depth of tank can be controlled by tank layout/design. Integration of pump systems can be limited due to the nature of the blocks not providing open space to install equipment. Often times additional structures to house pumps and level sensing equipment are required.



Concrete below ground tank. Image courtesy of Stormtrap.

NOTE

Soils contaminated with hydrocarbons may limit use of FRP, HDPE and PVC materials.

Refer to Iowa DNR Leaking Underground Storage Tank (LUST) database for information about known contaminations.

Design plans should include notes to inform the Owner's Representative if contaminated soils are unexpectedly encountered during construction. In such a case, tank materials may need to be changed if FRP, HDPE or PVC materials had been specified.

ESSENTIAL

FRP tank. Image courtesy of Norwesco.

Below ground HDPE tank. Image courtesy of Norwesco.

Liner style below ground tank (plastic with PVC liner).
Image courtesy of Atlantis.

ABOVE GROUND TANKS

Advantages

- Service and access is easier than below ground
- Less expensive installation and materials (in most cases)
- No buoyancy or anti-floatation concerns
- Comes in a variety of size and materials
- Allows for pumping items to be installed next to tank for easier service and access
- Can visually educate or "show off" the system
- Easier to drain

Disadvantages

- Sunlight must be limited into tank (to prevent algae bloom)
- Water temps can become high during warm summer months in Iowa
- Uses valuable land/footprint
- Insect/rodent intrusion management is required
- May or may not integrate with visual architecture of building
- Requires drainage piping to be intercepted at higher elevation
- Forces pre-filter to also be installed above grade
- Special engineering required for wind and seismic loads (depending on location)
- Possible Insurance difficulties related to access and/or potential flooding
- Tank may need to be drained or winterized. Usually this is completed as part of end of season maintenance and dewatering of irrigation system.

TYPES AND MATERIALS OF ABOVE GROUND TANKS

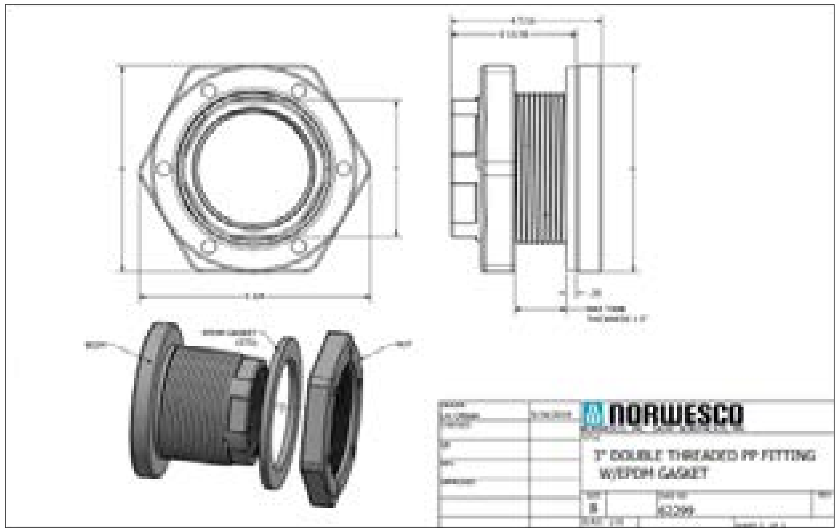
High Density Polyethylene (HDPE)

These tanks are very cost effective and available in many locations around the country. Penetrations are made via threaded bulkheads. Tank sizes range from 150 gallon – 15,000 gallon. If installed outdoors it is important to purchase a tank color that limits light into tank, such as black or dark green to limit algal growth. ESSENTIAL

HDPE above ground storage tanks. Image courtesy of Norwesco.

NOTE

See photo of bolted steel tanks on page 21.



Threaded bulkhead fitting used for penetration in HDPE tanks.

Corrugated Metal

Corrugated metal tanks utilize a steel corrugated exterior with a PVC liner suspended from the upper perimeter to hold water. These tanks have no bottom and rely on the concrete pad they sit on to allow the liner to form the bottom of the tank. For reference, these are very similar to how a swimming pool liner is installed. These tanks are 100% site-assembled and may require special tools and/or crane. Penetrations are also made on site with proprietary

Corrugated metal tanks. Image courtesy of Watertronics.

flange penetrations from the tank manufacturer. Often, warranty of these tanks is contingent upon purchaser/owner utilizing the manufacturer's assembly team to complete the install. Tank sizes range from 700 gallons to over 500,000 gallons.

Bolted Steel

These tanks are modular panel constructed by bolting panels together on site to erect the tank. Normally reserved for large capacity storage, these tanks range from 4,000 gallon – 2.5 million gallons. Steel panels block light from entering the tank. Penetrations are made in desired panels by the manufacturer.

Bolted steel tanks. Image courtesy of Superior Tank.

PUMPING AND TREATMENT

A pump is often required to send flow into the distribution system. A **pump station** can also provide the owner or operator with the ability to monitor system performance. Pumps require power to operate. The pump station provides pressurized non-potable water to the distribution system utilizing submersible or above-grade pumps. It also controls some or all peripheral equipment such as filters, level sensor, pressure sensor, treatment devices, etc. If designed to do so, the pump station can also be the device that measures how much water has been harvested and used within the system.

Images courtesy of Watertronics.

TYPES OF PUMPS

Horizontal Centrifugal

Image courtesy of Goulds.

Water well submersible turbine, installed vertically or horizontally

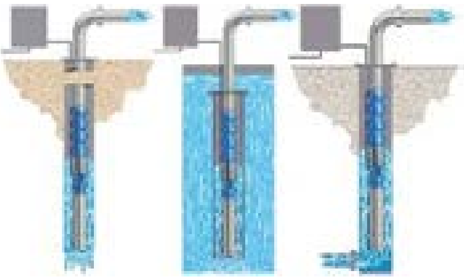


Image courtesy of Goulds.

Submersible pump in Flow Inducer tube

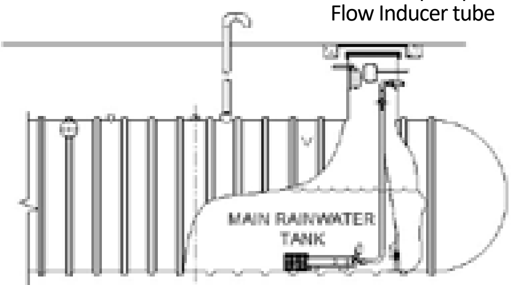


Image courtesy of Watertronics.

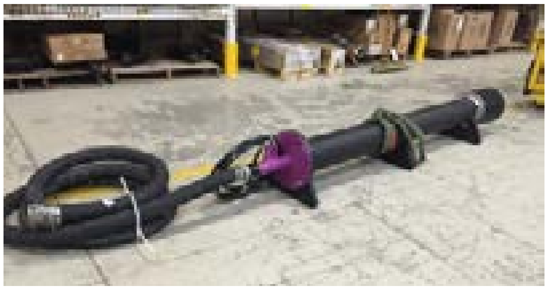


Image courtesy of Watertronics.

PUMPING APPLICATIONS

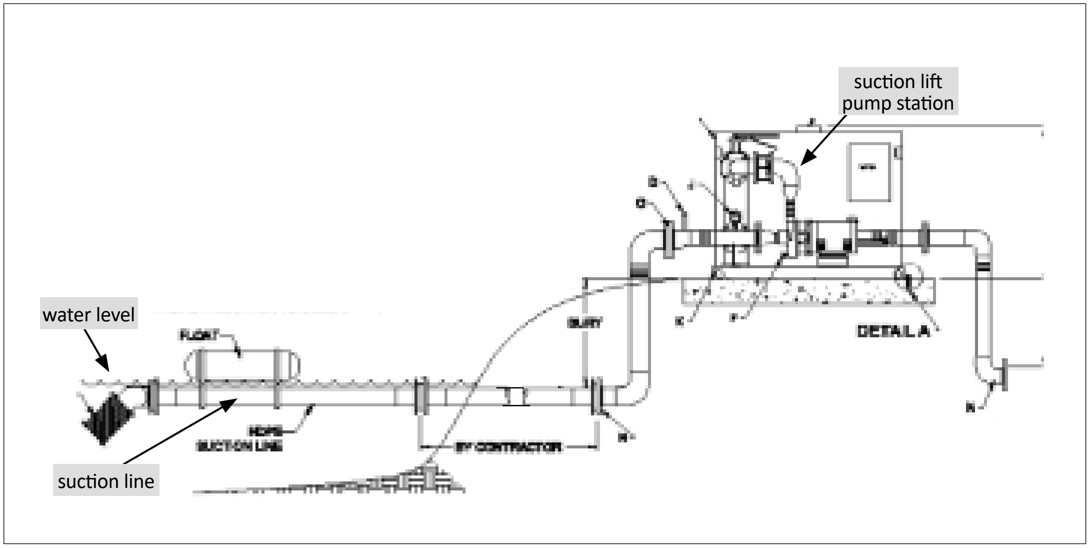
There are three common categories of pumping stations used in rainwater harvesting systems.

- **Suction Lift**
- **Flooded Suction**
- **Submersible**

The below images illustrate the application for each.

Suction Lift

These systems are used where water levels are located below the pump. As seen in the diagram below, the pump station is lifting the water out of the pond via a floating suction line. There are limits to this pump station design; it cannot lift water an infinite vertical distance. The physics of the pump come into play as well as atmospheric pressure. Generally, if the water surface is more than 10 feet vertically lower from the pump station, a suction lift pump will not work. Suction line design and priming methods are other requirements to evaluate when utilizing this pumping application. CAUTION



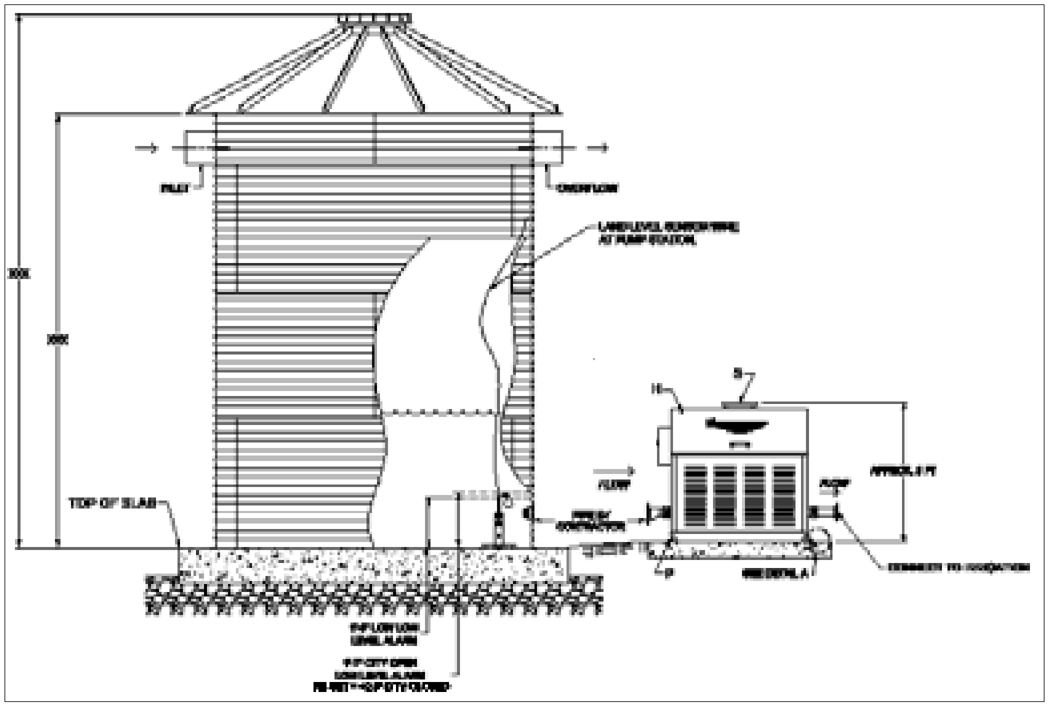
Suction lift application. Image courtesy of Watertronics.

NOTE

A master valve is recommended downstream of the pump station, to prevent emptying of the tank due to a pipe break.

Flooded Suction

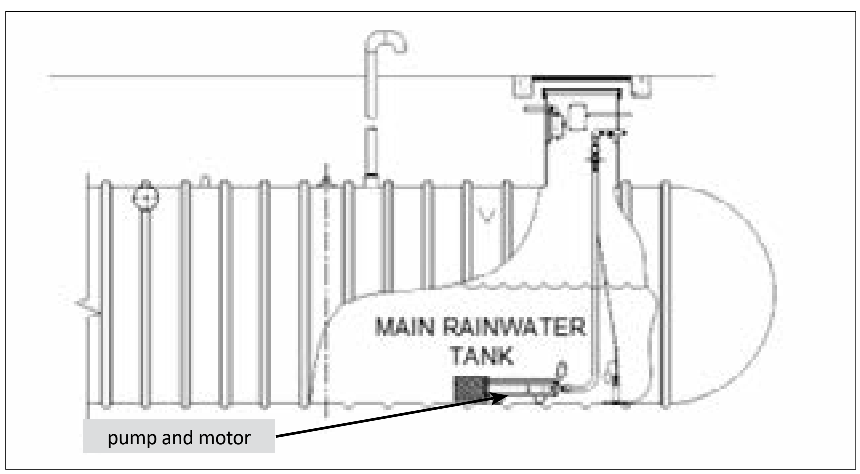
This system has the water level above the pump intake. This style of pump is most commonly used in above ground tank applications as it allows the pump station to sit next to the storage tank for ease of service instead of having to access a pump within the tank.



Flooded suction application. Image courtesy of Watertronics.

Submersible

Submersible pumps are installed in the body of water. Commonly used in below ground tanks where suction lift cannot be applied, or when priming issues with suction lift are not desired.



Submersible pump installed in below grade tank. Image courtesy of Watertronics.

PUMP SIZING

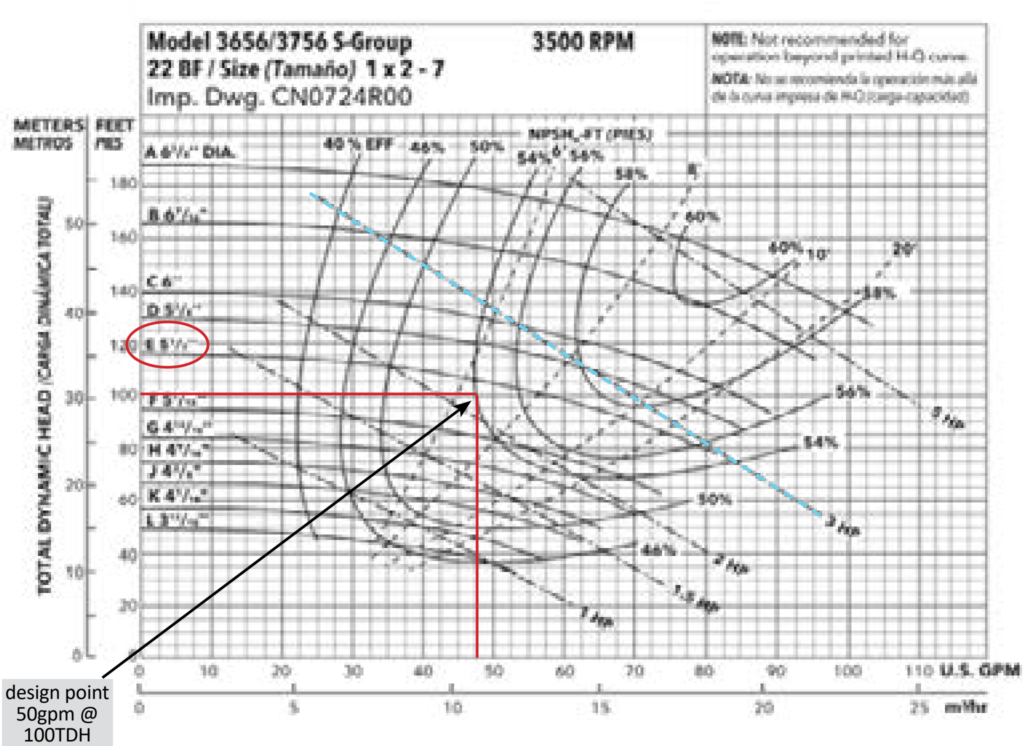
Pumps are sized to provide a flowrate and pressure to serve the expected demand of the distribution system. For example, for irrigation, the number of sprinkler heads open at any given time is what is responsible for creating the flow demand on the pump station. If a simpler system is used, it may be the number of hose bibs open at the same time. In an interior building application it may be how many toilets are flushed at the same time and their location in the building. In any case, how much water is used at any given time is what will create the demand.

To size a pump, two values are needed. Flow, commonly expressed as gallons per minute (gpm). Pressure commonly expressed as pounds per square inch (psi) or total dynamic head (TDH).

Details of how irrigation systems or interior plumbing are designed are outside of the scope of this section. **However, designers of rainwater harvesting systems need to work with the designers of the distribution system to understand the expected flow and pressure demands that the pump system will need to maintain.** System elevations, pipe lengths and friction losses all need to be considered.

The number and type of irrigation heads, hose bibs, plumbing fixtures, etc. that are expected to be in operation at any given time can be used to determine the expected demands.

Each manufacturer develops curves that show pump performance based on the desired flow rate and pressure. When selecting a pump, review the manufacturer's literature for this information. These curves will be unique to each model produced by the manufacturer.



NOTE

For water, to convert psi to TDH (in feet of head), multiply psi by 2.31 (includes unit conversions).

For example, 40 psi x 2.31 = 92.4 feet of TDH.

NOTE

An irrigation designer or engineer is often needed to complete the design of distribution piping systems and the calculations for pump station sizing.

NOTE

An example of a pump curve is shown at left. If it is known that a flowrate of 50 gpm with 100 TDH is needed to support the system design, this pump model would require a 3 horsepower (HP) motor with an "E" size impeller (selected from the next curves that are beyond the design point).

This is just one example for a specific model from one manufacturer. In practice, designers would need to use curves based on the model(s) from their desired manufacturer.

NOTE

Typical sequence of rainwater harvesting system:

1. Collection
2. Pre-filter
3. Storage
4. Pump station
5. Treatment
6. Distribution

TREATMENT METHODS

For rainwater harvesting systems, there are two common treatment methods: disc/screen filtration and disinfection. Disc and screen filtration removes total suspended solids (TSS) from the water. This is required for proper irrigation system function and/or as pre-treatment for a disinfection system. Disinfection is used to kill pathogens that may be present in the water.

Disc and Screen Filtration

Filtration systems are different from pre-filters mentioned earlier. Pre-filters are used upstream of the pump station. Filtration systems need to provide higher levels of removal, but only at lower rates of flow. So they are placed where they are only treating flow at the rate expected to pass through the distribution system (not the higher rate of inflow from a roof or other surface).

A disc filter is full of round-stacked discs that allow water to pass through but are excellent at catching organic materials. Disc filters perform more efficiently than screen filters when it comes to algae, moss and other organic materials. Because of their design, disc filters are better equipped to filter out fine particles such as bacteria, sand, chemical sludge, and slime.

Disc filters may need to be removed periodically to clean the discs. However, they can be purchased with auto flushing options.

Screen filters are typically more user-friendly and economical. These filters work well in removing solids, silt or sediment, leaves, sticks, and snails from water. They are also easily cleaned, as they do not require disassembly to clean the element. Screen filters are also offered with automatic flushing systems for self-cleaning.

For example: A typical drip irrigation system requires filtration to 100 microns to keep debris from clogging drip emitters. A 100 micron automatic filter can be installed on the pump station to keep debris out of the irrigation mainline and reduce manual cleaning of individual zone filters.

It is important that the proper flow and pressure requirements are met when using automatic filters as they will clean themselves without interruption of service to the irrigation system. Depending on the size, the pump must provide flow and pressure for cleaning and meet the irrigation demand. Consult filter manufacturer info sheets for specifications. CAUTION

Automatic scanning screen filter.
Image courtesy of VAF.

Disc filter.
Image courtesy of Netafim.

Disinfection

Depending on the end use tier (as described earlier in this section) for the non-potable water, disinfection may be needed. If disinfection is required, the most common method in rainwater systems is to utilize ultraviolet (UV) light to treat the water. UV units use 254 nanometer (nm) wavelength UV light to render organisms inactive (unable to multiply). Chlorine treatment is often used for internal building plumbing. CAUTION

There are other methods of disinfection, but these require a more detailed level of explanation than what is covered in this chapter.

Other methods of disinfection that are available (not often not practical or cost prohibitive) are:

- Reverse osmosis
- Ultra filtration
- Ozone
- Copper/Silver ion

UV systems have a water quality prerequisite for them to function properly and are sized based upon three main components:

1. Flow Rate - Flow rate should be the maximum flow rate the irrigation system is sized for, expressed in gallons per minute (gpm).
2. Ultraviolet (UV) Transmittance - UV transmittance is the UV light's ability to penetrate the water pumped through the UV unit. Items such as TSS or TDS can lower the transmittance of the water to a point where the UV unit may not function or go into alarm. UV transmittance is expressed as a percentage %.
3. Dosage - The dosage of a UV unit is how much energy is delivered into the water in order to render harmful bacteria inactive. Depending on which pathogens are being treated, each has a different inactivation level of UV light. Dosage is expressed in mJ/cm^2. Dosage can vary with UVT%.

This section ties back to the importance of pre-filtration in a rainwater harvesting system. Total Suspended Solids (TSS) can be filtered out of the water with screen filtration, while Total Dissolved Solids (TDS) cannot. An example of TDS affecting UV transmittance in a rainwater system would be water collected from a green roof or other organic surface. The tannins in water scatter the UV light and these tannins cannot be filtered out. CAUTION


Low transmittance UVT water from water harvesting system. Image courtesy of Watertronics.

NOTE

Refer back to Tables 6.03-1-1 and 6.03-1-2 on pages 5 and 6 for more information on end use tiers.

Refer back to Tables 6.03-1-3 to 6.03-1-6 on pages 7-8 for guidelines on disinfection based on end use tier.

NOTE

Refer to Table 6.03-1-8 on page 28 for dosing levels for various pathogens of concern.

NOTE

Additional information on UV systems found in ANSI/ICC B805.

Table 6.03-1-8. Data Summarized from the USEPA Workshop on UV Disinfection of Drinking Water, April 28-29, 1999

UV Disinfection of Drinking Water				
Pathogen	Average UV Dose (mJ/cm^2) Required to Inactivate			
	1-log	2-log	3-log	4-log
Cryptosporidium parvum oocysts	3.0	4.9	6.4	10
Giardia lamblia cysts	NA	<5	<10	<10
Giardia muris cysts	1.2	4.7	NA	NA
Vibrio cholerae	0.8	1.4	2.2	2.9
Escherichia coli O157:H7	1.5	2.8	4.1	5.6
Salmonella typhi	1.8-2.7	4.1-4.8	5.5-6.4	7.1-8.2
Salmonella enteritidis	5	7	9	10
Legionella pneumophila	3.1	5	6.9	9.4
Hepatitis A virus	4.1-5.5	8.2-14	12-22	16-30
Poliovirus Type 1	4-6	8.7-14	14-23	21-30
Rotavirus SA11	7.1-9.1	15-19	23-26	31-36

Source: TrojanUV, Water Confidence Table 4 (refer to that standard for more information).

CAUTION

It is important to identify the UVT% of the water in the design phase as this is where you will be sizing the UV unit. This is not always possible as some sites are new construction and there is no water sample to get. This is where the experience from the designer comes in, and it is important to hire someone who has experience in sizing these units. The water test referred to is the test used to measure the UVT% of the water and is used to size the UV unit (see disinfection paragraphs above). Pull a water sample from the most representative location you can of where the UV unit will be installed. If you have a tank installed already, grab a sample from the tank. If you only have a roof, grab one from the downspout.

The UV Destruction chart is shown in Table 6.03-1-8 above. Log reductions mean the following reduction levels:

1-Log = 90%

2-Log = 99%

3-Log = 99.9%

4-Log = 99.99%

Example:

A system is being designed to treat roof runoff for use in decorative fountains (end use tier 3 from Table 6.03.1-2 on Page 6).

From Table 6.03-1-4 on Page 7, for end use tier 3, a minimum UV treatment dose of 30 mJ/cm^2 is needed.

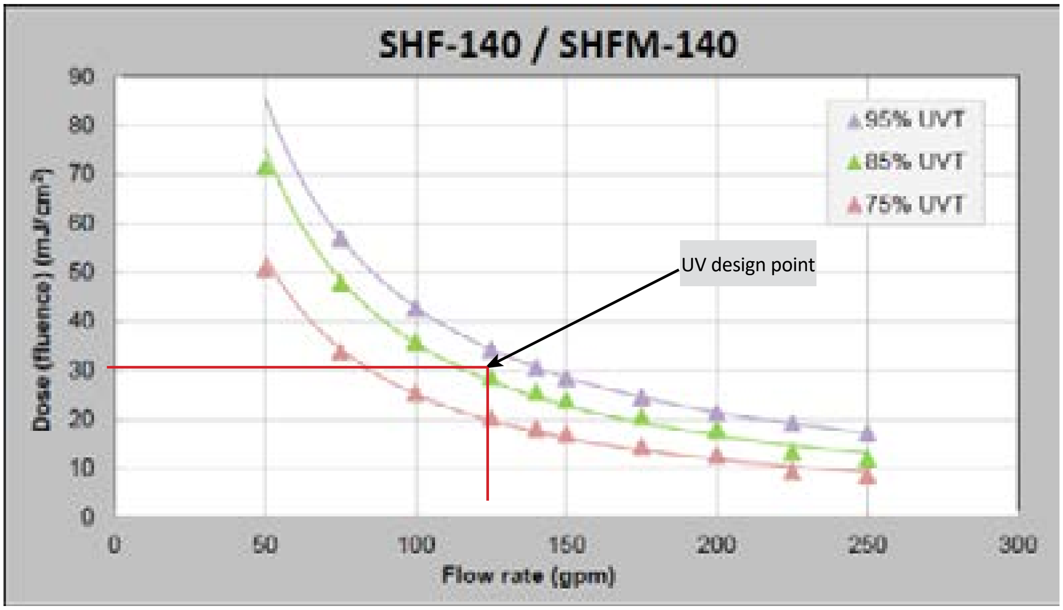
Assume the water UV transmittance from the roof has been tested and determined to be 90%.

The designer would select a specific manufacturer and model for the disinfection system. The designer would use a chart like the one below.

Select the desired dose on the left axis and then draw horizontally over to the 85% curve (since 90% transmittance exceeds 85% but is not equal or greater than 95%).

Then draw down to the bottom axis to determine the allowable flow rate, which is around 125 gpm in this example. If the design flow rate of the system is equal or less than that amount, this system is sufficient. If not, another system may need to be considered.

So for this example, the UV unit will deliver 30 mJ/cm^2 dosage into the water, as long as the flow rate is 125 gpm or less, and the UV transmittance is 85% higher.



UV Curve courtesy of Viqua.

INTEGRATION OF A BACKUP WATER SUPPLY

The designer of a system must consider what happens if the supply of harvested water is exhausted.

Depending on the application, it may be ok to wait for the next rain event to happen until irrigation can resume. In other cases, a secondary back up water supply is integrated into the system. This can be in the form of well water, city water, or other pressurized source available to the property. Here are some questions for the designer to consider:

1. Do we need a backup water source?
2. Will the backup water source go into the storage device or directly into the **water distribution system**? This will impact the requirements for the backup water source.
3. Does the backup water source have the proper flow and pressure to satisfy the water distribution system demand?

NOTE

The values for flow rate, water UV transmittance are given for this example. Usually these would be determined from the distribution system design and a water sample from the source.

SHF-140/SHFM-140 is the model number used for this example. In practice, the designer would use the chart from their selected disinfection system manufacturer.

OPTION 1: Back up water supply to fill reservoir

In the example shown in the below image, we must verify that the backup source can provide the required flow for the irrigation system. Pressure is not important as the water will be pressurized by the irrigation pump station pumping water out of the storage tank. If the backup water supply is from a potable source, a reduced pressure zone (RPZ) valve and/or a physical air gap must be utilized to prevent backflow of harvested water into the potable water supply.

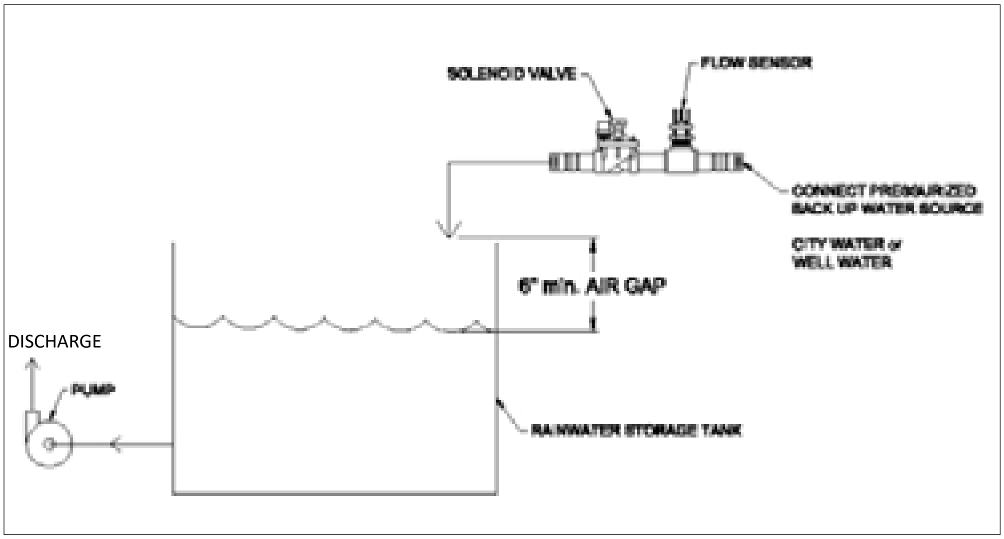


Image courtesy of Watertronics.

OPTION 2: Back up water supply is plumbed direct to distribution system

In the image below, the back up water supply is plumbed on the discharge side of the irrigation pump station. In this scenario, one must verify that the back up source has not only the flow rate required but also the pressure required to operate the irrigation system. An automated valve and level control system must be designed into the pump station to switch between sources based upon availability and/or pump station alarm status. If a potable water source is used, local codes or the water utility must allow for this type of connection. When allowed, a RPZ valve must be installed to protect the potable water supply.

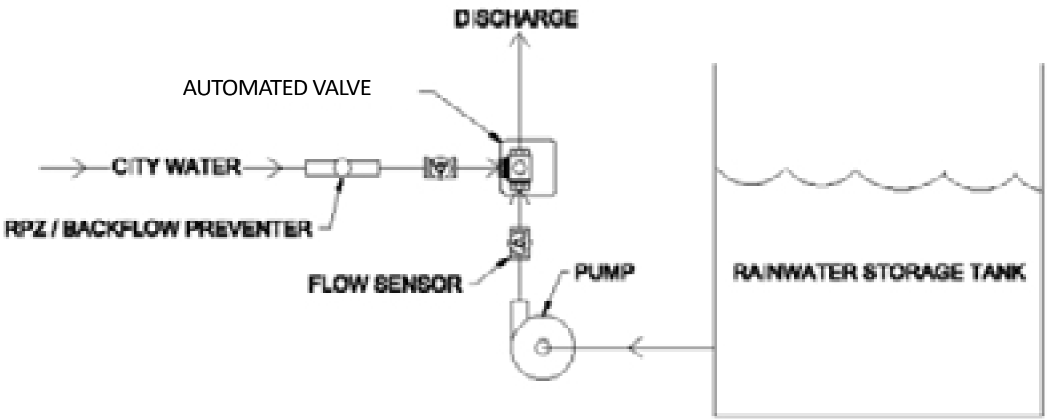


Image courtesy of Watertronics.

NON-IRRIGATION APPLICATIONS

End tier uses such as toilet flushing, vehicle washing and other non-irrigation applications usually require different treatment than irrigation end users. Multiple tanks and pump stations may be used to address water demand in buildings or other non-irrigation uses. This section will briefly review the key differences in system design and treatment.

Water Usage Profile and System Selection

Two configurations are common when harvested rainwater is used for internal uses. A direct system is where there is a storage tank and pump station that delivers the water to the needed flow and pressure directly to the application.

The second is classified as a "Day Tank" style system. The basis of this style system is to use a smaller pump within the main storage tank, and transfer and treat water at a lower rate than the building application requires and store this water in a Day Tank. Then utilizing a second pump station, pump water from the Day Tank and deliver it to the building application. The difference between irrigation water usage profile and interior building usage profile is illustrated below. The main goal of the Day Tank system is to save money on the treatment components that would be required to serve higher peak demands. The day tank allows water to be filtered or treated at a slower rate during low demand periods, then stored in a tank and ready for use during peak periods. Filters and disinfection are some of the higher cost items within a system, so the design will often be more affordable even if a second pump is needed to deliver water to the building application.

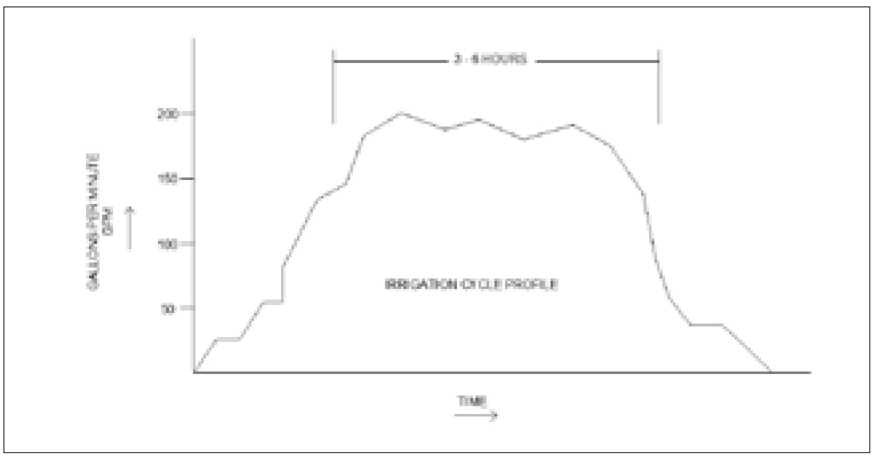


Illustration of irrigation demand.

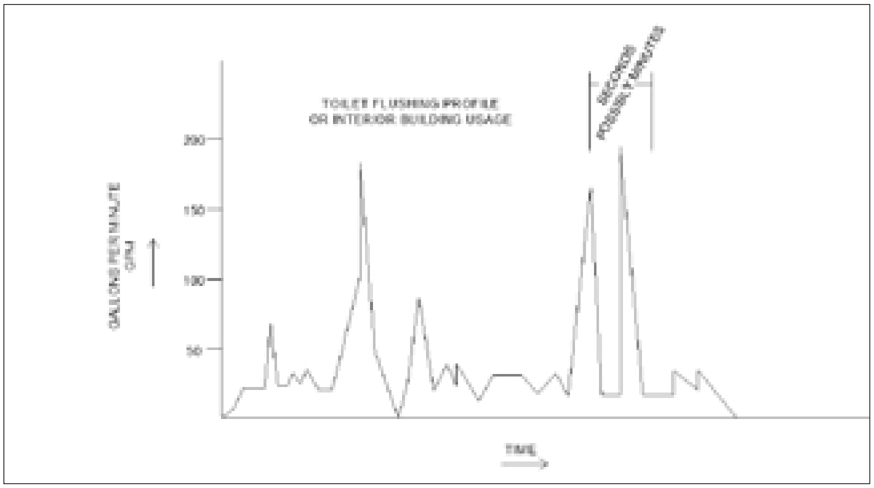


Illustration of internal building water demands.

NOTE

The graphs at left show that irrigation systems use water at a relatively constant rate, for longer periods.

Internal building plumbing usually has lower flow rates, with brief periods of high demand.

The Day Tank system is used to size treatment equipment at lower flow rates, allowing water to be stored in the Day Tank for use at high demand periods.

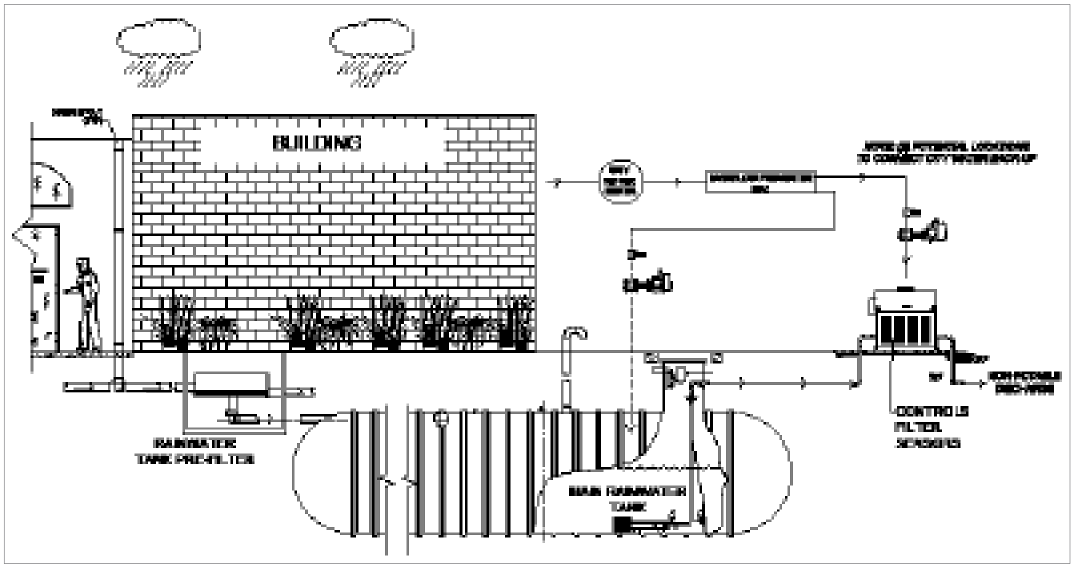


Diagram of Irrigation Application (direct style) Rainwater Harvesting System.
Image courtesy of Watertronics.

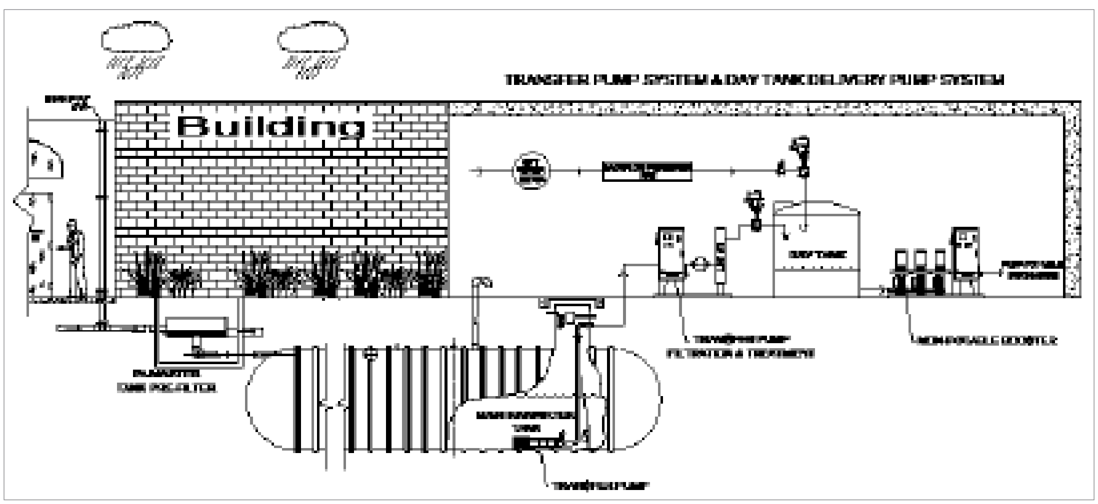


Diagram of Interior Building Application (transfer and Day tank style) Rainwater Harvesting System.
Image courtesy of Watertronics.

Chlorine Injection for Disinfection

When using water for interior building applications there are additional disinfection options that become available that are not used in irrigation applications. A residual chlorine system can be implemented to disinfect the water. An over the counter chlorine product (laundry bleach) is injected into a recirculation system of a storage tank. Chlorine reacts with items in the water and is consumed. The water is constantly recirculated through a chlorine analyzer which measures the chlorine level in the water. Once a residual level of chlorine builds up in the water, the analyzer will measure this value and turn down or stop injection. These systems are most commonly installed on the Day Tank in the example shown in this section.

Chlorine Recirculation System on Day Tank (maintains 2-3ppm residual chlorine level)

- Uses separate pump in Day Tank that will Start/Stop via timer to recirculate the water
- Water sent through CHL Analyzer (PH & CHL sensor) to measure the residual chlorine
- Dosing pump injects chlorine to maintain set point of chlorine in parts per million (PPM)

Image courtesy of Watertronics.

Dye Injection (Toilet Flushing Application)

Dye can be used to identify that water used for toilet flushing applications is non-potable. It can also be used to correct for discoloration from tannins in water from sources such as green roofs. An injection pump is included with the distribution pump station which injects the correct amount of dye into the discharge of the pump station. The injection system must be capable of varying the injection rate with the flow rate of the pump station so that as flow increases, injection rate increases, and the color consistency remains the same. The concentration of dye injected is normally around 2-10 ppm depending on the type of dye purchased.

Images courtesy of Watertronics.

DISTRIBUTION APPLICATIONS

A distribution system is an irrigation or plumbing system used to convey the harvested water to the desired use. Irrigation systems include pipes and hoses that distribute water to sprayers, bubblers or drip irrigation lines. Control systems and valves are used to regulate the timing and rate of water usage. Plumbing systems include valves and pipes that distribute flow to fixtures (such as toilets) or other uses of water.

Specific details on the design of distribution systems is not included in this section. (This section is primarily focused on the collection of rainwater and the sizing of storage components.) The design of the distribution system will influence the water demand that the harvesting system is expected to provide or supplement.

Designers of complex rainwater harvesting systems often must coordinate with other experienced professionals. Effective communication is needed to make sure the harvesting system is able to provide the needed supply and that the system can properly distribute the flow to the expected uses.

6.03-2 SIZING AND CALCULATIONS

A. COMPONENT SIZING

There are typically two stages when sizing the components of a rainwater harvesting system. **An initial feasibility stage can look at the data at the monthly level.** For each month, the amount of water harvested is compared to the expected usage demand. This will provide a high level of understanding and comparison to see how much of the irrigation water usage could be satisfied with harvested water. TARGET

For a final component sizing, the rainfall data and the irrigation data should be looked at on a daily basis. This involves detailed modeling of demand and supply, simulating performance over time. These are complicated simulations which are best done by a designer, engineer, or someone familiar with rainwater harvesting system modeling. ESSENTIAL

STEP 1 – EVALUATE WATER DEMAND

Calculating demand for irrigation systems requires one to know the plant water requirement for the crops or other plants they are irrigating. Designers need to identify the expected irrigated area, plant types in each irrigated area, irrigation watering window, precipitation, and precipitation collection area (typically a roof area).

Calculations are based on monthly evapotranspiration (ET) data for the project site, crop coefficients, and equipment type efficiency. From this, the monthly water requirement for each irrigated area can be determined. An explanation of these factors follows.

Evapotranspiration (ET)

Evapotranspiration is the amount of water that leaves the soil and plant surfaces and goes back into the atmosphere due to evaporation from the soil and transpiration through the plant material. Evapotranspiration is affected by solar radiation, humidity, temperature, and wind. It is important to use the monthly evapotranspiration numbers for the project site area. The monthly ET numbers represent a reference evapotranspiration (ET0) rate based on a hypothetical grass reference crop and provide a baseline for calculating crop water requirements. For greenhouses, select the ET factor that best represents the expected climate to be maintained within the growing area .

Crop or Plant Coefficients

Each different crop type loses water to the atmosphere at a different rate. To account for this, crop coefficients (Kc) are applied to the evapotranspiration data to find the evapotranspiration value for each crop. These coefficients vary based on the crop's growth stage. Some examples of crop coefficients are listed on the next page. A full list of crop coefficients can be found in Irrigation and Drainage Paper 56 as issued by the Food and Agriculture Organization of the United Nations (FAO), Chapter 6, Table 12.

NOTE

Iowa ET data can be found here: https://mesonet.agron.iastate.edu/agclimate/display.php?prod=10

NOTE

Irrigation and Drainage Paper 56 as issued by the Food and Agriculture Organization of the United Nations (FAO), Chapter 6, Table 12.

NOTE

The initial, mid and end values for K in Table 6.03-2-1 are based on the growth cycle for the noted crop.

NOTE

The values listed on this page are examples of crop coefficients from different tables. The designer should select the appropriate crop coefficients from current source materials and include references to their source materials with their calculations. Refer to FAO 56, Table 12 for a full list of crop coefficients.

Table 6.03-2-1: Crop Coefficients for Select Crops

Crop	K. Initial	K. Mid	K. End
Berries (bushes)	0.3	1.05	0.5
Legumes	0.4	1.15	0.55
Root Vegetables	0.5	1.10	0.95
Small Vegetables	0.7	1.05	0.95
Strawberries	0.4	0.85	0.75
Tomato	0.6	1.15	0.8
Turf Grass	0.9	0.95	0.95

Table 6.03-2-2: Other Select Plant Coefficients for Midwest Sites

Plant Type	K_c
Turf – General	0.7
Turf – Sports	0.8
Turf – Low Water Use	0.6
Shrubs	0.5
Perennials / Ground Cover	0.6
Trees	0.5
Native Grasses	0.3
Native Shurbs	0.3
Native Perennials / Ground Cover	0.4
Native Trees	0.3

Equipment Efficiency

The equipment efficiency is based off industry standards for irrigation equipment.

- Irrigation Sprays - 65% efficiency
- Irrigation Rotors - 75% efficiency
- Drip emitters - 90% efficiency

This efficiency reflects how effectively the irrigation equipment distributes irrigation water to the landscape. These factors are used in the calculations to adjust the water requirements to reflect the actual amount of water necessary to run through the irrigation system to provide the required amount needed by the landscape.

The monthly water requirement can be found by multiplying the monthly evapotranspiration value (ET_0) in inches by the crop coefficient (K_c) and then dividing by the equipment efficiency (Ee). The monthly water requirement for each landscape area can be determined and summed to form the overall water demand per month of the site.

Monthly Water Demand (inches) = ET (selected by month, inches) x Crop or Plant Coefficient (K) / Equipment Efficiency (Ee)

Non-irrigation Water Demands

For other water demands (such as internal plumbing for toilet flushing, etc.) the daily water demand would need to be determined by the plumbing designer. This is usually obtained through an understanding of the expected daily water use of those systems. These types of demands could be calculated and used to perform a water supply and demand analysis used to size the system. If non-irrigation water uses are proposed, calculate the monthly and daily demand expected for such uses. Details of how these demands are determined are not included within this section.

EXAMPLE Step 1 – Evaluate IRRIGATION Water Demand

Rainwater harvesting is being proposed to supply the water demand for a 10,000 square foot (0.23-acre) turf grass area, which will be irrigated by irrigation rotors. Monthly ET data was looked up for a location close to the site **(The ET values used here are for in this example only. Consult ET chart for actual ET rates for job site area).**

Table 6.03-2-3: Monthly ET Data
(For This Example Only)

Month	ET / Month (inches)
January	0.28
February	0.37
March	1.30
April	2.37
May	4.38
June	5.90
July	5.84
August	4.17
September	2.67
October	1.54
November	0.49
December	0.35

NOTE

For this example, the turf grass crop coefficient for initial conditions from Table 6.03-2-1 was used.

Month Water Demand (inches) = ET (selected by month, inches) x Crop / Plant Coefficient (K) / Equipment Efficiency (Ee)

For July ET = (5.84 inches) x* (Turf Grass Crop Kc = 0.9) / (Irr Rotors Ee = 0.75) = 7.0 inches of water

Applied over the 10,000 square foot area :

10,000 square-feet x 7.0 inches x (1 inch / 12 feet) = 5,840 cubic feet (CF)

5,840 CF x 7.481 (gallons / CF) = 43,689 gallons

The daily water demand for this application in July would be:

43,689 gallons / 31 days = 1,409 gallons per day

These calculations would be repeated for each month where irrigation is planned for the crops or plants to be supported, or where other water uses are planned.

Table 6.03-2-4: Calculated Water Demand
(For This Example Only)

Month	Days of Irrigation (#)	Monthly Water Demand (gallons)	Daily Water Demand (gallons)
April	15	8,865	591
May	30	32,767	1,092
June	30	44,138	1,471
July	31	43,689	1,409
August	31	31,196	1,006
September	30	19,974	666
October	15	5,760	384

(irrigation is assumed between April 16 and October 15)

If multiple plants or crops are to be used at a given site, complete similar calculations for all planting and crop areas and add to find the total irrigation demand. **This should be completed on a monthly (initial sizing) and daily (final design) basis.**

STEP 2 – GATHER SITE PRECIPITATION DATA

Collect precipitation data from a location as close to the site as possible. Historic rainfall data will be needed to simulate how the proposed system will perform in the future. **It is recommended to gather at least 5 to 10 years of recent precipitation data.** Caution must be taken if a shorter analysis period is used, as results may be skewed by unusual precipitation patterns (dry months, intense rainfall events, etc.) Selecting multiple years, makes will even out irregularities and better predict system performance. TARGET

The selected years should be consecutive and when averaged should be compared to the annual average precipitation of the site over an even longer period of time (NOAA uses about a 30 year period to determine what is a normal precipitation year). This should be done to make sure that several drought or wet years will not skew simulations. Any selected years should have complete rainfall data for the gaging station, for every day of the calendar year. ESSENTIAL

For the analysis period, calculate average monthly precipitation (for each calendar month), to be used for initial system design. Daily precipitation will be used for the final (daily) system design.

NOTE

Iowa ET data can be found here: https://mesonet.agron.iastate.edu/agclimate/display.php?prod=10

NOTE

One source of Iowa precipitation data can be found here: https://mesonet.agron.iastate.edu/agclimate/display.php?prod=10

STEP 3 – ESTIMATE THE SIZE OF THE COLLECTION AREA AND STORAGE DEVICE

The collection area may be defined by the expected size of a building or a portion of a roof surface where water can be collected from. Water can be collected from other surfaces and sources, although those may require different levels of pre-filters, filtration and treatment as mentioned earlier in this section.

As mentioned previously in this section, the amount of rainwater that can be collected from a roof is calculated as:

> Volume (gallons) = Roof area (square feet) x Rainfall (inches) x (1 foot / 12 inches) x 7.481 (gallons / CF) x Efficiency factor

Efficiency factors: Hard surface (90%), Green roof, soil, vegetated surfaces (35-50%, depending on density and vegetation)

For this step, the collected volume can be calculated as a monthly total. For more detailed design, the calculations will be repeated on a daily basis.

EXAMPLE Step 3 – Monthly Rainwater Collected

Rainwater harvesting is being proposed, with a 30,000 square foot hard surface roof used as a collection device. Based on local precipitation data collected, over a period of 10 recent years the average precipitation in June was 5.33 inches.

> Volume (gallons) = 30,000 square feet x 5.33 inches x (1 foot / 12 inches) x 7.481 (gallons / CF) x 90%
>
> Volume = 89,716 gallons

NOTE

The rainfall values in Table 6.03-2-5 are for this example only. For design, obtain precipitation data from a site close to the proposed project.

Table 6.03-2-5: Calculated Rainwater Collected
(For This Example Only)

Month	Monthly Precipitation (inches)	Potential Harvested Rainfall (gallons)
January	2.57	43,259
February	2.56	43,091
March	2.85	47,972
April	3.71	62,448
May	5.95	100,152
June	5.33	89,716
July	4.23	71,200
August	3.57	60,091
September	4.01	67,497
October	4.80	80,795
November	1.76	29,625
December	2.46	41,407

STEP 4 – COMPLETE A DAILY PERFORMANCE ANALYSIS

Daily simulation will provide a more accurate evaluation of system performance. It will also allow designers to evaluate system efficiencies, understanding how changes in tank size or collection area my impact the need to supplement the system with water from other sources (such as potable water). This can allow designers to compare designs with owners to understand the potential costs to install and maintain the system, along with the potential savings of reduced supply of supplemented watering. These calculations can be completed for different sizes of collection areas and storage devices to evaluate the costs and benefits of different design alternatives.

As these daily analyses are completed, a few points to emphasize:

- For outdoor irrigation applications in Iowa, water use should be expected from the last half of April through the first half of October. There would be no irrigation demand in these settings outside of those periods. TARGET
- The frequency of irrigation should be considered in design. This may require discussions with the expected owner and/or system operator. For example, they may choose to irrigate 5 days a week to avoid irrigation on weekends. Some local jurisdictions may limit irrigation to certain days of the week. ESSENTIAL
- It should be assumed that there is no irrigation demand on days with rainfall, or for a day or two following a rainfall event which exceeds a cutoff point based on monthly ET. This will simulate the use of smart irrigation control systems. Even if a smart irrigation control is not expected to be used, it will simulate saturated site conditions, where more runoff would be expected (less use by the plants or crops). ESSENTIAL
- Assume an initial volume in the storage device (1,000 gallons for example), as a certain portion of the tank will often be filled for initial startup and testing. IDEAL
- If the tank is full, any collected rainfall will be expected to overflow out of the system (will not be captured and used).

EXAMPLE Step 4 – Daily Performance Analysis

Rainwater harvesting is being proposed, with a 30,000 square foot hard surface roof used as a collection device. Rainfall data and irrigation demands are as provided in the example table below. For this simulation, a 30,000-gallon tank was proposed. The initial volume in the tank was set to 1,000 gallons. Based on the simulation of the previous months, the expected tank volume at the end of day on April 30, 2022, was 28,340 gallons.

This type of simulation would be continued for all years where rainfall data was collected.

NOTE

Historic rainfall data is being used, but this is not a simulation of an existing system. Since we can't exactly predict future rainfall and the random nature of rainfall patterns, historic rainfall data is used to simulate how a proposed system would have performed if it had been in place over several recent years.

NOTE

The rainfall values in Table 6.03-2-6 are for this example only. For design, use data based on site conditions.

Table 6.03-2-6: Example of Storage Device Storage Simulation

Column	1	2	3	4	5	6	7
Date	Day	Rainfall (inches)	Rainfall (gallons)	Inflow from Other Sources (gallons)	Irrigation Demands (gallons)	Net Increase or Decrease in Storage Device Volume (gallons)	Storage Device Volume (gallons)
start							28,340
5/1/22	S					0	28,340
5/2/22	M				4179	-4,179	24,161
5/3/22	Tu				4179	-4,179	19,982
5/4/22	W				4179	-4,179	15,803
5/5/22	Th				4179	-4,179	11,624
5/6/22	F				4179	-4,179	7,445
5/7/22	S					0	7,445
5/8/22	S					0	7,445
5/9/22	M				4179	-4,179	3,266
5/10/22	Tu	1.00	18,703			18,703	21,969
5/11/22	W					0	21,969
5/12/22	Th					0	21,969
5/13/22	F				4179	-4,179	17,790
5/14/22	S	0.50	9,350			9,351	27,141
5/15/22	S					0	27,141

A few notes about the previous table:

- The volume of rainfall in Column 3 is calculated similar to the methods listed in Step 3, this time for a singular daily rainfall event.
- Any inflow from other water sources (AC condensation water, for example) could be entered in Column 4. For this example, it is assumed that no such inflow is expected.
- Irrigation demand in Column 5, would be based on calculation of monthly irrigation demand (similar to examples shown for Step 1).
- Column 6 is the net increase or decrease in storage device storage.
- Column 7 is the total water stored in the storage device at the end of the calendar day.
- It is assumed for this example, that irrigation only occurs Monday through Friday (no irrigation on Saturdays or Sundays). No irrigation on 5/7, 5/8, 5/14 and 5/15.
- Irrigation was not needed for two days following the observed rain events. No irrigation on 5/11 and 5/12.
- Based on this part of the simulation, the tank is expected to be empty at the end of May 9th. Another source of water would have been needed to complete irrigation on that day (about 913 gallons from potable water source).

These types of calculations would be repeated for all days within all the calendar years of the simulation period. Keep in mind that there would be no irrigation demand expected from October 16 to April 15th each year. During those periods, once the storage device is full any rainwater or snowmelt collected would overflow out of the system and not be used.

STEP 5 – COMPARE RESULTS OF THE SIMULATION AND SELECT FINAL DESIGN ELEMENTS

The calculations in Step 4 can be repeated for different sizes of collection areas and storage devices to evaluate the costs and benefits of different design alternatives. For each alternative (combination of collection area and storage device size), a comparison table with this type of information should be prepared. The following table is an example of results for one design with a simulation period of 7 years for a specific site.

This information can be used to compare the costs for different collection areas, storage device sizes and other expenses such as purchase of potable water for irrigation.

Table 6.03-2-7: Example of Storage Device Storage Simulation Results

1	2	3	4	5	6	7	8	9
Storage Device Volume	Harvested Rainfall Collected	Water from Other Sources	Total Harvested Rainfall Used	Total Potable Water Used	Total Irrigation Water	Total Overflow	% Harvested Rainfall Used	% Irrigation Demand Met By Harvested Water
(gallons)	(gallons)	(gallons)	(gallons)	(gallons)	(gallons)	(gallons)	(%)	(%)
20,000	2,558,297	0	1,472,304	1,290,354	2,762,657	1,080,494	57.55%	53.29%
25,000	2,558,297	0	1,592,029	1,170,629	2,762,657	958,720	62.23%	57.63%
30,000	2,558,297	0	1,671,609	1,091,048	2,762,657	879.139	65.34%	60.51%
40,000	2,558,297	0	1,773,756	988,901	2,762,657	776,992	69.33%	64.20%
60,000	2,558,297	0	1,948,302	814,355	2,762,657	602,447	76.16%	70.52%

Data in Columns 1 to 7 will be the results of the completed multi-year simulations. The totals in Table 6.03-2-7 represent the overall totals for all years simulated combined (not average monthly or annual totals).

The value for "% Harvested Rainfall Used" in Column 8 is calculated from:

% Harvested Rainfall Used = Total Harvested Rainfall Used (gallons) / Harvested Rainfall Collected (gallons)

The value in Column 8 (% Harvested Rainfall Used) can be used in the next part of this section, to evaluate how a rainfall harvesting system compares to meeting goals related to treating the Water Quality volume (WQv).

The value in Column 9 is found by dividing Column 4 (total harvested rainfall used) by Column 6 (total irrigation water used).

B. UNIFIED SIZING CRITERIA CALCULATION METHODS

The elements of ISWMM's Unified Sizing Criteria (USC) which are most likely to be partially or fully addressed by rainwater harvesting practices are the Recharge volume (Rev) and Water Quality volume (WQv). These elements are focused on the collection, treatment and runoff reduction of the smallest and most commonly occurring rainfall events.

Typically, these elements are evaluated by showing that a single rainfall event of a certain size can be addressed. For example, the Water Quality event in Iowa is defined as a 1.25-inch rainfall event. Approximately 90% of all runoff producing rainfall events in Iowa are equal or less than this amount. Stormwater best management practices (BMPs) that are able to capture, treat, filter and/or infiltrate runoff from those events are expected to provide the desired levels of water quality benefits, as described in the Stormwater Criteria (Section 1.04) and Unified Sizing Criteria (Section 3.01) sections of ISWMM.

To evaluate these elements of the USC for rainwater harvesting systems, some different approaches are necessary, compared to how other BMPs are evaluated. Harvesting systems are designed to collect and store a specific volume of water, based on expected demand. The storage device fills up during rain events and will draw down based on demand until the next event partially or fully refills the available storage. Sizing the storage device requires a simulation of the ongoing water balance of the system. This is best done by reviewing at historic rainfall patterns and water use over the course of several years.

Other types of water quality BMPs are usually sized to capture the runoff from the 1.25-inch event, typically having the ability to temporarily store that volume of runoff until it can be treated, infiltrated or slowly released. However, rainwater harvesting systems aren't sized to have free space set aside for temporary storage of a single rainfall event. There may not be the demand or control methods to use the runoff from a single WQv rainfall event to empty that volume from the storage device before the next storm event occurs. For that reason, the following evaluation procedures are described:

WATER QUALITY VOLUME EVALUATION PROCEDURE

Step 1 – Complete a daily analysis of rainfall and water usage to determine the amount of harvested rainwater expected to be collected and used by the system. This daily simulation should be used for final design and evaluation of WQv credits. This should be completed by modeling how the proposed system would have performed using at least 5 years of recent rainfall data (additional years of simulation would be encouraged). Refer to Part A of this subsection for more information on completing these calculations.

Step 2 – From the daily analysis, determine the percentage of harvested rainfall that is expected to be used for irrigation or non-irrigation uses. This is the portion of the total rainfall captured by the collection surface that ends up being used on-site and does not result in runoff.

Step 3 – Compare the percentage of harvested rainfall used found in Step 2 to the annual volume expected to be generated by storm events equal or less than the Water Quality volume (1.25 inches).

From Table C3-S2-2 in the Rainfall and Runoff Analysis Section of ISWMM, storms generating less than 1.25 inches of rainfall in Iowa happen about 90% of the time, but they made up **69.67%** of the annual average rainfall volume (based on the site location and data collected below). Rainwater harvesting systems that capture and use at least this portion of the runoff they collect can be treated as fully meeting the WQv volume requirements for the collection area (roof or other surface used to harvest rainwater). In a typical year, these systems should be capturing and using a similar volume of runoff to those generated by WQv events.

If the system collects and uses less than this amount, partial credit should be given for the portion of the WQv treated.

NOTE

Simulating performance based on historic rainfall patterns allows the designer to understand how a proposed system would have performed over a period of several years based on real precipitation events.

Table 6.03-2-8 - Rainfall Summary for Ames, Iowa (1960-2006)
(adapted from Table C3-S2-2)

Storm Event Rainfall Depth	Number of Events Recorded	Cumulative Frequency	Average Annual Rainfall Volume	Cumulative Percentage of Average Annual Rainfall
(inches)	#	%	(inches)	%
0.01 - 0.10	1363	**	2.30	
0.11 - 0.25	651	32.57%	2.98	10.18%
0.26 - 0.50	596	62.38%	5.66	29.51%
0.51 - 0.75	262	75.49%	4.21	43.89%
0.76 - 1.00	182	84.59%	4.08	57.82%
1.01 - 1.25	**120**	**90.60%**	**3.47**	**69.67%**
1.26 - 1.50	73	94.25%	2.57	78.45%
1.51 - 1.75	37	96.10%	1.56	83.78%
1.76 - 2.00	32	97.70%	1.52	88.97%
2.01 - 3.00	35	99.45%	2.14	96.28%
3.01 - 4.00	8	99.85%	0.70	98.67%
4.01 - 5.00	1	99.90%	0.11	99.04%
5.01 - 6.00	2	100.00%	0.28	100.00%
6.01 +	0	100.00%	0.00	100.00%
Total Events > 0.10 inches	1999	**	29.28	**
Total Events	3362		31.58	

** Rainfall events that are less than 0.10 inches are considered "non-runoff producing" and are excluded from cumulative frequency and percentage of annual average runoff totals

Column 1 (from left) includes ranges for different observed storm events at this location.

Column 2 is the number of rainfall events observed within each range during the noted period of record.

Column 3 is the percentage of all storm events during the period of record that had a rainfall volume within each range. (Note that for the purposes of determining the WQv storm event frequency, rainfall events of less than 0.10 inch were ignored, as those are considered too small to generage runoff.)

Column 4 is the average annual rainfall over the period of record generated by the storm events in each category.

Column 5 is the cumulative percentage of all rainfall volume over the period of record that was generated by storm events that are within or smaller than a given range. (Volume from storm events that were less than .10 inch in volume were not included.)

For example, storm events from 0.10 to 1.25 inches resulted in 20.40 inches of average annual rainfall volume. All storms larger than 0.10 inches totaled 29.28 inches. Therefore, the cumulative percentage of volume generated by events between 0.10 and 1.25 inches is 20.40 inches / 29.28 inches = 69.67&.

Step 4 – Calculate the WQv volume from the collection area considered to be treated by the rainwater harvesting system.

The WQv volume generated from the collection area can be found by the equations from the Small Storm Hydrology section of ISWMM.

Step 4a – Calculate the runoff coefficient:

Rv = 0.05 + 0.009 (I); where I = impervious cover

Step 4b – Calculate the WQv volume expected to be generated by the collection area:

WQv (cubic feet) = Rv x 1.25 inches x Collection Area (square feet) x (1/12 inches per foot)

Step 4c – Calculate the WQv volume considered as treated by the rainwater harvesting system:

WQv (from Step 4b, in cubic feet) x % WQv treated (from Step 3) = WQv treated (cubic feet)

If the percentage of harvested rainfall used found in Step 2 exceeds 69.67%, then the WQv volume found in Step 4 would be considered fully satisfied. If not, partial credit can be given, and downstream practices could be sized to account for the remaining overflow volume. ESSENTIAL

RECHARGE VOLUME EVALUATION PROCEDURE

A similar procedure can be followed to evaluate compliance with local Recharge volume standards. Different local jurisdictions have adopted various target rainfall depths for the Rev event, usually ranging from 0.50 to 1.00 inches.

To evaluate compliance with Rev requirements, Steps 1 and 2 of the previous procedure would be the same for the Rev event as those described for the WQv event. For Step 3, the annual volume of all events equal or less than the Rev event will vary, based on the local standard.

The values listed in Table 6.03-2-9 are based on the calculations shown in Table 6.03-2-8.

Table 6.03-2-9. Recharge Volume Annual Rainfall Values

Rev Storm Event	Cumulative Percentage of Annual Rainfall Volume
0.50 inches	29.51 %
0.75 inches	43.89 %
1.00 inches	57.82 %

LARGER STORM EVENTS

Since water levels in the storage device may vary, there is not any certainty that a specific volume of rainfall will always be captured by the rainwater harvesting system. If the storage device is full when a rain event occurs, all runoff would bypass the tank and proceed along the expected overflow route. For this reason, rates and volumes of runoff for events larger than the WQv should be calculated using typical methods as described in the Rational Method and TR-55 Methodology Sections of ISWMM.

NOTE

Recharge volume (Rev) is explained in ISWMM Section 3.01 (Unified Sizing Criteria)

NOTE

The results on the tables on these pages are for these examples only and should not be assumed to be the results for the design of other sites.

C. UNIFIED SIZING CRITERIA DESIGN EXAMPLES

WATER QUALITY VOLUME DESIGN EXAMPLE

Example scenario: Rainwater is being collected from a roof area of 30,000 square feet (0.69 acres), it is being used to provide irrigation to site landscaped areas.

Step 1 – Complete a daily analysis of rainfall and water uses to determine the amount of harvested rainwater expected to be collected and used by the system. A daily simulation should be used for final design and evaluation of WQv credits. This should be completed by modeling how the proposed system would have performed using at least 5 years of recent rainfall data (additional years of simulation would be encouraged). Refer to Part A of this subsection for more information on completing these calculations.

Assume that a daily analysis of the system was completed with the following results:

Table 6.03-2-10. Example of Storage Device Simulation Results (2018-2024)(given for this example)

1	2	3	4	5	6	7	8
Storage Device Volume	Harvested Rainfall Collected	Water from Other Sources	Total Harvested Rainfall Used	Total Potable Water Used	Total Irrigation Water	Total Overflow	% Harvested Rainfall Used
(gallons)	(gallons)	(gallons)	(gallons)	(gallons)	(gallons)	(gallons)	(%)
20,000	2,558,297	0	1,472,304	1,290,354	2,762,657	1,080,494	57.55%
25,000	2,558,297	0	1,592,029	1,170,629	2,762,657	958,720	62.23%
30,000	2,558,297	0	1,671,609	1,091,048	2,762,657	879.139	65.34%
40,000	2,558,297	0	1,773,756	988,901	2,762,657	776,992	69.33%
60,000	2,558,297	0	1,948,302	814,355	2,762,657	602,447	76.16%

The analysis was based on a seven-year period from the beginning of calendar year 2018 through the end of calendar year 2024. This analysis looked at different storage device volume options, for the same collection areas (30,000 square feet).

Data in Columns 1 to 7 will be the results of the completed multi-year simulations. The totals in Table 6.03-2-10 represent the overall totals for all years simulated combined (not average monthly or annual totals).

The value for "% Harvested Rainfall Used" in Column 8 is calculated from:

% Harvested Rainfall Used = Total Harvested Rainfall Used (gallons) / Harvested Rainfall Collected (gallons)

Column 8 = Column 4 / Column 2

For example, for a 30,000 gallon storage device based on the simulation results:

1,671,609 gallons / 2,558,297 gallons = 65.34%

Step 2 – From the daily analysis, determine the percentage of harvested rainfall that is used for irrigation or non-irrigation uses. This is the portion of the total rainfall captured by the collection surface that ends up being used on-site and does not result in runoff.

From Table 6.03-2-11, the percentage of harvested rainfall will vary based on the size of the storage volume device selected. The options are summarized below (from Column 8 of Table 6.03-2-10):

Table 6.03-2-11. Storage Device Volume Options

Storage Device Volume	% Harvested Rainfall Used
(gallons)	(%)
20,000	57.55%
25,000	62.23%
30,000	65.34%
40,000	69.33%
60,000	76.16%

Step 3 – Compare the percentage of harvested rainfall used found in Step 2 to the annual volume expected to be generated by storm events equal or less than the Water Quality volume (1.25 inches).

Using the values in this example, the following percentages of the WQv for the 30,000 square foot roof area would be considered treated by the rainwater harvesting system:

Table 6.03-2-12. Portion of Collection Area WQv Treated

Storage Device Volume	% Harvested Rainfall Used	WQv Treated
(gallons)	(%)	(%)
20,000	57.55%	82.6 %
25,000	62.23%	89.3 %
30,000	65.34%	93.8 %
40,000	69.33%	99.5 %
60,000	76.16%	100 %

The values above were computed in the following manner:

% WQv Treated = % Harvested Rainfall Used / (WQv Cumulative Annual Percentage of Rainfall Events = 69.67 %)

For example, for a 40,000-gallon storage device from the simulation results above:

% WQv Treated = 69.33 % / 69.67 % = 99.5 %

Selecting a 40,000-gallon storage device would treat nearly 100% of the WQv for the collection area. Smaller storage devices would treat a smaller portion of the WQv.

NOTE

The value for WQv Cumulative Annual Percentage of Rainfall Events (69.67%) is found in Table 6.03-2-8.

Step 4 – Calculate the WQv volume from the collection area considered to be treated by the rainwater harvesting system.

The WQv volume generated from the collection area can be found by the equations from the Small Storm Hydrology section of ISWMM.

Step 4a – Calculate the runoff coefficient:

Rv = 0.05 + 0.009 (I); where I = impervious cover

For this example, the collection area is a roof, which is 100% impervious. Therefore,

Rv = 0.05 + 0.009 (100) = 0.95

Step 4b – Calculate the WQv volume expected to be generated by the collection area:

WQv (cubic feet) = Rv x 1.25 inches x Collection Area (square feet) x (1/12 inches per foot)

WQv = 0.95 x 1.25 inches x 30,000 square feet x (1/12 inches per foot)

WQv = 2,969 cubic feet

Step 4c – Calculate the WQv volume considered as treated by the rainwater harvesting system:

WQv treated = WQv (from Step 4b, in cubic feet) x % WQv treated (from Step 3)

For a 40,000-gallon storage device:

WQv treated = 2,969 cubic feet x 99.5 % = 2,954 cubic feet

Values for other storage device volume options are listed in the table below:

Table 6.03-2-13. Portion of Collection Area WQv Treated

Storage Device Volume	% WQv Treated	WQv Treated	Remaining WQv to be Treated
(gallons)	(%)	(%)	(cubic feet)
20,000	82.6 %	2,452	517
25,000	89.3 %	2,651	318
30,000	93.8 %	2,785	184
40,000	99.5 %	2,954	15
60,000	100 %	2,969	0

The Remaining WQv to be Treated in Table 6.03-2-13 is found by subtracting the WQv Treated from the Required WQv for the Collection Area. For example, for a 40,000-gallon storage device, based on the simulation results above:

WQv for Collection Area (from Step 4b) = 2,969 cubic feet

WQv Treated = 2,954 cubic feet

Remaining WQv to be Treated = 2,969 cubic feet – 2,954 cubic feet = 15 cubic feet

In this example, the proposed rainwater harvesting system with a 40,000-gallon storage device would be credited as providing 2,954 cubic feet of the WQv for the roof collection area. The remaining 15 cubic feet could be addressed by a downstream water quality best management practice (or practices), unless the local jurisdiction chose to disregard such a small shortage. The system could be designed so that overflows from the collection system would be directed to downstream water quality BMPs, which would need to be sized to address the water quality volume (including the WQv of any other areas that drain to those BMP).

The designer could use the information completed in the daily simulations and these calculations, to balance the costs of the proposed rainwater harvesting system against any savings from reduced purchased water use or installing other stormwater BMPs to address the treated volume.

RECHARGE VOLUME DESIGN EXAMPLE

Example scenario: The same site conditions as the WQV example – rainwater is being collected from a roof area of 30,000 square feet (0.69 acres). It is given that local jurisdictional requirements are based on a 1.00-inch rainfall event.

Steps 1 and 2 would be the same as shown in the WQv example.

Step 3 – Compare this value to the annual volume expected to be generated by storm events equal or less than the Recharge Volume event (1.00 inches for this example).

Table 6.03-2-14. Portion of Collection Area WQv Treated

Storage Device Volume	% Harvested Rainfall Used	% WQv Treated
(gallons)	(%)	(%)
20,000	57.55%	99.5 %
25,000	62.23%	100 %
30,000	65.34%	100 %
40,000	69.33%	100 %
60,000	76.16%	100 %

Using the values in this example, the following percentages of the Rev for the 30,000 square foot roof area would be considered treated by the rainwater harvesting system:

The values above were computed in the following manner:

% WQv Treated = % Harvested Rainfall Used / (Rev Cumulative Annual Percentage of Rainfall Events)

For example, for a 20,000-gallon storage device:

% WQv Treated = 57.55 % / 57.82 % = 99.5%

NOTE

For a Rev Cumulative Annual Percentage of Rainfall Events, refer to Table 6.03-2-9 on page 46.

For this example, a Rev target of 1.00 inches was given. From the table, the cumulative annual percentage of rainfall events equal to or smaller than 1.00 inches is 57.82%.

Step 4 – Calculate the Rev volume from the collection area considered to be treated by the rainwater harvesting system.

The Rev volume generated from the collection area can be found by the equations from the Small Storm Hydrology section of ISWMM.

Step 4a – Calculate the runoff coefficient, which is the same as solved for the WQv example.

Rv = 0.05 + 0.009 (100) = 0.95

Step 4b – Calculate the Rev volume expected to be generated by the collection area:

Rev (cubic feet) = Rv x Rev rain event (inches) x Collection Area (square feet) x (1/12 inches per foot)

Rev = 0.95 x 1.00 inches x 30,000 square feet x (1/12 inches per foot)

Rev = 2,375 cubic feet

Step 4c – Calculate the Rev volume considered as treated by the rainwater harvesting system:

Rev treated = Rev (from Step 4b, in cubic feet) x % Rev treated (from Step 3)

Rev treated = 2,375 cubic feet x 99.5% = 2,363 cubic feet

The Remaining Rev to be Treated is found by subtracting the Rev Treated from the Required Rev for the Collection Area.

For example, for a 20,000-gallon storage device, based on the simulation results above:

Rev for Collection Area (from Step 4b) = 2,375 cubic feet

Rev Treated = 2,363 cubic feet

Remaining WQv to be Treated = 2,375 cubic feet – 2,363 cubic feet = 12 cubic feet

In this example, if a 20,000-gallon storage device were selected, the proposed rainwater harvesting system would be credited as providing 2,363 cubic feet of the Rev for the roof collection area. The remaining 12 cubic feet would need to be addressed by a downstream best management practice (or practices), unless the local jurisdiction chose to ignore such a small amount. The system could be designed so that overflows from the collection system would be directed to downstream BMPs, which would need to be properly sized and designed to address the recharge volume (including the Rev of any other areas that drain to those BMPs).

In this example, if a 25,000-gallon storage device or larger were selected, the Recharge Volume requirements would be fully satisfied.

6.03-3 CONSTRUCTION

A. EROSION AND SEDIMENT CONTROL

If the rainwater harvesting system is part of a project whose total disturbed area exceeds one acre (including all parts of a common plan of development) a stormwater pollution prevention plan (SWPPP) is required by state and federal law to be prepared.

Prior to construction, coverage under the State of Iowa's NPDES General Permit No. 2 shall be obtained (or, if required, coverage through an individual permit).

The SWPPP document will meet state and local regulatory requirements and will detail the structural and non-structural pollution prevention best management practices (BMPs) that are to be employed at the site.

The rainwater harvesting system is not intended to act as part of erosion or sediment control during the construction project. Effort should be made to keep any debris or construction debris out of the rainwater harvesting storage device.

B. CONSTRUCTION SEQUENCING

Rainwater harvesting systems are primarily installed during the infrastructure phase of a new construction project. Tanks, pumps, and pre-filters integrate into the sites drainage system and should be scheduled to coincide with the system installation.

Rainwater Harvesting systems installed on existing buildings should be broken up into **above or below ground components so installation can be coordinated** on similar construction schedules.

NOTE

During construction observation, make sure high voltage (AC voltage) wires are not run in the same conduit as sensor or low voltage wires. High voltage will be inducted onto low voltage wires and cause false alarms or errors in your pump stations operating system. Always follow NEC and local electrical codes. If unsure of where to land wires, contact the manufacturer.

C. CONSTRUCTION OBSERVATION

A designated representative of the owner or engineer of record should observe construction operations on a frequent basis to confirm the following:

- The rainwater harvesting system design, operation, and components matches the final construction documents.
- All materials arrive on site free of damage.
- All elevations of inlets, overflow, bury depths, and concrete pads are per plan.
- Site power and electrical service size matches construction drawings and equipment purchased. Verify site power prior to purchasing equipment.
- Follow all component manufacturers installation instructions.
- Roof drains or site drains that are connected to a tank or storage vessel should be diverted to an alternate destination during construction. Do not allow construction debris into storage tank/vessel.
- Complete a walk-through with the designer and contractor to identify any items which are not in compliance with project requirements. Document said issues in a punch list and confirm when all such items are installed.
- As needed by the local jurisdiction, author a letter of acceptance noting either conformance with construction documents, or any allowed deviation thereof.
- Obtain a first time start up report from system manufacturer at time of acceptance.

D. POST-CONSTRUCTION

Provide a complete set of as built drawings to the owner of the system at time of completion. Provide operator training of the system and communicate an ongoing monthly or yearly reporting or testing requirements per manufacturer's recommendations.

6.03-4 MAINTENANCE

Prior to First Time Start Up:

Clean ALL debris from storage tank. Debris accumulates inside tanks during the installation and construction process, this debris is NOT present during normal operating and design conditions. Rainwater harvesting systems are NOT designed to handle construction debris and/or chemicals, or any other material not present or accounted for during normal operating conditions. Ensure water in storage tank has not gone anaerobic from said debris or long periods of storage due to long construction/installation process.

Ensure tank pre-filter screen is clean and functional, and not occluded from construction debris.

Ensure wiring from all remote components have been landed at appropriate location in control panel. Piping system should be clean and ready to accept water. Insure any debris from construction or fabrication is removed from pipes to avoid plugging. Flush the system. ESSENTIAL

Typical Maintenance Requirements ESSENTIAL	
Pre-Filter	Monthly: Visually inspect rainwater pre-filter to ensure it is free from debris and is in proper working condition. This time interval can decrease after owner/operator has a familiarity with their system. Yearly: Remove filter element clean with pressurized water.
Storage Tank	Yearly: pump down tank, assess debris collection in tank, clean as required.
Pump Station	Monthly: Inspect pump station for any leaks. Verify no active alarms are present. Review pressure and flow readings, compare with design conditions. Yearly: Calibrate sensors per mfg. instructions. Test pressure relief valve operation and setting. Grease motor (if applicable)
Discharge Filter	Monthly: Review pressure loss across filter, perform manual flush cycle if applicable. If excessive pressure loss across filter is shown, clean filter and consult manufacturer. Yearly: Disassemble filter, clean main element by hand with pressurized water. Check internal rotating assemblies (if applicable)
Filters and Disinfection Systems	Monthly: Ensure no active alarms are present on ancillary treatment items. Consult manufacturer's maintenance instructions.
Water Quality	First 3 Months: Take a water sample from both the storage tank and at point of use. Visually inspect for any irregularities. Rainwater harvesting systems are dynamic pieces of machinery, subject to daily changes in weather and environment. Some examples include, but not limited to: Bird droppings, excessive air borne pollen count, dust, roof material leeching, pipe breaks. This time interval can be extended after the user has familiarity with the system, but a monthly inspection is good practice when commissioning a new system. Sample yearly as needed after proof of proper operation. At least annually, test small crop irrigation for E-coli per FDA pre harvest water protocol.

NOTE

Items/materials that will dissolve in water WILL affect water quality, and the performance of the system. Remember, anything that has gone down the roof drain will end up in the storage tank! Whenever possible allow the first rain event to by-pass the tank and act as a flush of the piping system before putting rainwater harvesting system into operation.

6.03-5 SIGNAGE RECOMMENDATIONS

All access points for **non-potable water** should be identified with proper signage that indicates "non-potable water, do not drink".

Sprinkler heads and valves should be identified with purple colored ID tags.

A general property identification sign should be placed near entrance indicating property is irrigated with non-potable water.

All tank access should be labeled as confined space entry.

Examples of OSHA signage.

Image courtesy of Rainharvest.

6.03-6 GLOSSARY

Air Conditioning Condensate Water	Water produced by an air conditioner from humidity in the air condensing on the evaporator coil on an air conditioner
Backflow Preventor	A device that does not allow reverse flow of water through it. Often required to protect a potable water system from a non-potable water system. Note: Double Check and RPZ Reduced Pressure Zone are types of backflow preventors
Blackwater	Water containing human waste
Booster Pump Station	A pump station designed to take in pressurized water and boost it to a higher pressure
Filter	A device that removes suspended solids from water (generally greater than 1 micron. For smaller than 1 micron see membrane filtration)
Flooded Suction Pump Station	A pump station designed to pump water from a storage tank or other vessel where the water level is always higher than the inlet of the pump station.
Green Roof	A roof containing soil and/or media designed to grow various plantings and installed on the roof top of a structure
Greywater	Water that is discharged from sinks, showers, and laundry. Contains soaps, surfactants, possible bodily fluids. Does not include water containing human waste (see blackwater)
Ground Water	Water from a drilled well or water collected from building foundation drainage
Membrane Filtration	A device that can remove suspended solids from water smaller than 1 micron (ie. Ultra Filtration, Micro Filtration)
Non-potable Water	Water not safe for human consumption. (ie...rainwater, stormwater, grey water, black water)
Potable Water	Water safe for human consumption
Pre-Harvest Water	Water used for irrigation of food crops while still on the plant or planted in the ground. Does not include water for processing, packaging, or any process post harvest of crop
Pump	A device used to pressure water or increase the pressure of water at a given flow rate
Pump Station	A piece of equipment containing pump, valves, filters, controls, and sensors all required to operate a given pump(s) for the intended application
Rainwater	Collected water from natural precipitation
Reverse Osmosis	A device that can remove dissolved solids from water. Reverse Osmosis is also a membrane filter, however usually requires Ultra Filtration or Micro Filtration ahead of the Reverse Osmosis System
Storage Tank (or storage vessel)	A liquid retention tank connected to a plumbing system or an irrigation system Note: storage tanks are also known as cisterns
Stormwater	Rainwater that is not roof run off. This includes: rain/snow melt that flows over land and/or impervious surfaces (ie..parking lots, sidewalks, streets, driveways, vegetative roofs, landscape/ hardscape)
Submersible Pump Station	A pump station designed where the pump and motor are submerged in water. Note: Various types of submersible pumps are known as Submersible Turbine, Sump Pump, Trash Pump, Effluent Pump.
Suction Lift Pump Station	A pump station designed to pump water from a storage tank or vessel where the water level is always lower than the inlet of the pump station. Note: this pump station has limitations due to atmospheric pressure and physics that only allow water to lifted a certain amount. Consult engineer to properly size this pump station.
Surface Water	All water that is open to atmosphere (ie... Lakes, rivers, streams, ponds, reservoirs)
Tank Pre-Filter	A device installed in the gravity piping system that filters the water prior to entering the storage tank
Tannins	Organic materials that can be found in water and can affect its taste, color, and quality
Water Distribution System	An assembly of pipes, valves, sprinklers, and/or other related components designed to deliver the water from its source to its intended end use.

6.03-7 RESOURCES

ANSI / ICC 805: Rainwater Harvesting Systems: https://www.fda.gov/food/food-safety-modernization-act-fsma/fsma-final-rule-produce-safety#:~:text=The%20Produce%20Safety%A20rule%20establishes%2C%20for%20the%20first,to%20implement%20the%20FDA%20Food%20Safety%20Modernization%20Act

Crop evapotranspiration - Guidelines for crop water requirements. FAO Irrigation and Drainage paper 56. Chapter 6, Table 12.
Chapter 6 - ETc - Single crop coefficient (Kc)

FSMA Final Rule on Produce Safety | FDA:
https://codes.iccsafe.org/content/CSAB8052022P1

National Engineering Handbook – Part 623 Irrigation, Chapter 7 Microirrigation:
https://directives.nrcs.usda.gov//sites/default/files2/1720457402/Chapter%207%20-%20Microirrigation.pdf

2202 CSA B805-22?ICC 805-2022 Rainwater Harvesting Systems, 2024 International Code Council, Inc.
https://codes.iccsafe.org/content/CSAB8052022P1

- 7 Subsystem Design and Installation, Table 7.1
- 8 Water Quality, Table 8.3
- 8 Water Quality, Table 8.4

Watertronics SkyHarvester System Product Data
https://watertronics.com/

6.03-8 APPENDIX

WHERE TO BUY SYSTEMS AND COMPONENTS

Below is a list of major manufacturers of rainwater harvesting systems:

Watertronics – Hartland, WI https://watertronics.com/

RainHarvest – Atlanta, GA https://www.rainharvest.com/

Watts Water – Global https://www.watts.com/products/water-quality-rainwater-harvesting-solutions/rainwater-harvesting/rainwater-harvesting-systems

Water Control Corp – Ramsey, MN https://watercontrolinc.com/

Precision Pumping – Idaho & South Carolina https://gopps.com/applications/water-harvesting/

Below is a list of major tank manufacturers:

Xerxes – Tipton, IA https://xerxes.com/

Ace Roto Mold – Hospers, IA https://www.denhartogindustries.com/divisions/ace-roto-mold/

Snyder Industries – Lincoln, NE https://www.snydernet.com/

Norwesco – Mound, MN https://www.norwesco.com/

Water Storage Tanks – Austin, TX https://waterstoragetanksinc.com/

Pioneer Water Tanks – San Marcos, TX https://pioneerwatertanksamerica.com/

Atlantis – Australia http://www.atlantis-america.com/flo-tank/

NOTE

This list is provided for informational purposes only and is not exhaustive. Inclusion does not constitute an endorsement or recommendation of any manufacturer.

KEY DESIGN PARAMETER CHECKLIST

There are important aspects of this manual to consider when jurisdictions seek to create stormwater ordinances or policies that reference or adopt this manual. The Iowa Department of Natural Resources (IDNR) is responsible for the creation and maintenance of this manual, working with a technical committee of local volunteers. However, regulation and enforcement of post-construction stormwater management is primarily left to local jurisdictions.

Therefore, the IDNR does not enforce as requirements, the sizing and design criteria set for this document. For this reason, the language used within this manual has purposefully been written as a guideline, rather than a standard. This means certain language that conveys something is required (i.e. shall, must, etc.) is generally avoided. This has the potential to leave "gray areas" as to what may be interpreted to be required and what is recommended or optional, if this manual is adopted and referenced by local jurisdictions as a standard.

Throughout this section, different design parameters or considerations have been grouped into key categories:

ESSENTIAL

An element of the design of a BMP seen as critical to its proper performance, operation or aesthetics. **These aspects should be most important for inclusion and compliance and should rarely be deviated from.**

TARGET

An element of the design of a BMP seen as important to its proper performance, operation or aesthetics. **These aspects should be included in designs, if at all possible.** However, there is more flexibility to allow deviations if it can be demonstrated that it is infeasible to meet the requirement at a given location, or if a certain requirement is in conflict with other requirements. **Designers should explain any reason for deviation from targets, for the consideration of the jurisdiction as part of their review.**

IDEAL

An element of the design of a BMP seen as the recommended approach for its proper performance, operation or aesthetics. Designers are encouraged to include these in designs as best practice. However, these items are seen as less critical as those noted as essentials or targets.

CAUTION

These are notes or design guidance to highlight items for the designers' careful consideration.

ADVISORY

These are practices, techniques or potential deviations from the design ethic that should be avoided in most circumstances.

ESSENTIAL

1. Designers should evaluate the water quality of the captured water in each system and compare to water quality requirements for each application as well as any possible public health risks. (page 2)

2. When utilizing below ground tanks, ground water elevations must be evaluated and a buoyancy calculation must be performed to ensure storage tank will not rise out of the ground. (page 3)

3. Risks such as wind loading, flood risk, etc. should be considered when designing above ground storage systems. (page 3)

4. Check for local design and plumbing codes for separation or setback requirements when storage systems, pipes or other elements are going to be located near utilities or structures. (page 3)

5. When designing tank pre-filters, it is important to select a rainfall rate that represents a common occurrence for the site. Normally, a 2- to 5-year rainfall return rate is selected. (page 13)

6. Design plans should include notes to inform the Owner's Representative if contaminated soils are unexpectedly encountered during construction. In such a case, tank materials may need to be changed if FRP, HDPE or PVC materials had been specified. (page 17)

7. For above ground tanks installed outdoors, it is important to purchase a tank color that limits light into tank, such as black or dark green to limit algal growth. (page 19)

8. For a final component sizing, the rainfall data and the irrigation data should be looked at on a daily basis. This involves detailed modeling of demand and supply, simulating performance over time. (page 35)

9. The selected years should be consecutive and when averaged should be compared to the annual average precipitation of the site over an even longer period of time (NOAA uses about a 30 year period to determine what is a normal precipitation year). This should be done to make sure that several drought or wet years will not skew simulations. Any selected years should have complete rainfall data for the gaging station, for every day of the calendar year. (page 39)

10. The frequency of irrigation should be considered in design. This may require discussions with the expected owner and or system operator. For example, they may choose to irrigate 5 days a week to avoid irrigation on weekends. Some local jurisdictions may limit irrigation to certain days of the week. (page 41)

11. It should be assumed that there is no irrigation demand on days with rainfall, or for a day or two following a rainfall event which exceeds a cutoff point based on monthly ET. This will simulate the use of smart irrigation control systems. Even if a smart irrigation control is not expected to be used, it will simulate saturated site conditions, where more runoff would be expected (less use by the plants or crops). (page 41)

12. If the percentage of harvested rainfall used found in Step 2 exceeds 69.67% (the cumulative percentage of rainfall volume from rainfall events less than 1.25”), then the WQv volume found in Step 4 would be considered fully satisfied. If not, partial credit can be given, and downstream practices could be sized to account for the remaining overflow volume. (page 47)

13. Refer to the list of “Prior to First Time Startup” items. (page 56)

14. Refer to the Table of “Typical Maintenance Items”. (page 56).

TARGET

1. When collecting water from parking lot surfaces, it is important to utilize a hydrodynamic separator, as these types of pre-filters also utilize a way to separate hydrocarbons from the water in addition to removing TSS from the water. (page 11)

2. An initial feasibility stage can look at the data at the monthly level. Compare the monthly water harvested to monthly irrigation water required. This will provide a high level of understanding and comparison to see how much of the irrigation water usage could be satisfied with harvested water. (page 35)

3. It is recommended to gather at least 5 to 10 years of recent precipitation data. Caution must be taken if a shorter analysis period is used, as results may be skewed by unusual precipitation patterns (dry months, intense rainfall events, etc.) Selecting multiple years will even out irregularities and better predict system performance. (page 39)

4. For outdoor irrigation applications in Iowa, water use should be expected from the last half of April through the first half of October. There would be no irrigation demand in these settings outside of those periods. (page 41)

IDEAL

1. If multiple collection surfaces are present (roofs and parking lots/landscape areas, for example), it might be advisable to have separate storage devices to have them in proximity to the collection source or to provide for different levels of disinfection or treatment, based on the collection source. In such a case, separate pumps and treatment systems would be needed. (page 15)

2. Assume an initial volume in the storage device (1,000 gallons for example), as a certain portion of the tank will often be filled for initial startup and testing. (page 41)

CAUTION

1. Generally, if the water surface is more than 10 feet vertically lower from the pump station, a suction lift pump will not work. Suction line design and priming methods are other requirements to evaluate when utilizing this pumping application. (page 23)

2. It is important that the proper flow and pressure requirements are met when using automatic filters as they will clean themselves without interruption of service to the irrigation system. Depending on the size, the pump must provide flow and pressure for cleaning and meet the irrigation demand. Consult filter manufacturer info sheets for specifications. (page 26)

3. If disinfection is required, the most common method in rainwater systems is to utilize ultraviolet (UV) light to treat the water. UV units use 254 nanometer (nm) wavelength UV light to render organisms inactive (unable to multiply). Chlorine treatment is often used for internal building plumbing. (page 27)

4. An example of TDS affecting UV transmittance in a rainwater system would be water collected from a green roof or other organic surface. The tannins in water scatter the UV light and these tannins cannot be filtered out. (page 27)

5. It is important to identify the UVT% of the water in the design phase as this is where you will be sizing the UV unit. (page 28)

ADVISORY

None listed in this section.