PDHonline Course C611 (4 PDH)

Rainwater Harvesting Fundamentals

Instructor: John M. Rattenbury, PE, CIPE, LEEDap

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5272 Meadow Estates Drive
Fairfax, VA 22030-6658
Phone: 703-988-0088
www.PDHonline.com

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Course Content

Introduction

This course will provide the student with some detailed knowledge regarding time-tested and reliable methods of collecting, storing, transferring and treating rain water for use as flushing water (i.e. sewage conveyance), irrigation water or cooling tower make-up water. Each of these applications requires water that is relatively free from contaminants that will foul equipment or fixtures, which will not present a health risk, and is reasonably aesthetically clean. The various devices and methods described here have been in use for decades in Europe. They are very simple and help achieve water use reduction through economical means. There is still some debate in the engineering community as to whether rainwater harvesting has a good enough return on investment, or if it has any pay-back at all. However, many new construction projects either by the goals of the developer (i.e. LEED certification) or as dictated by local and state agencies are incorporating some form of rainwater harvesting. All too often, engineers are "reinventing the wheel" when designing systems, or relying on vendors who have only just gotten into the rainwater collection market. Hopefully this course will provide designers with better insight as to what works best and why.

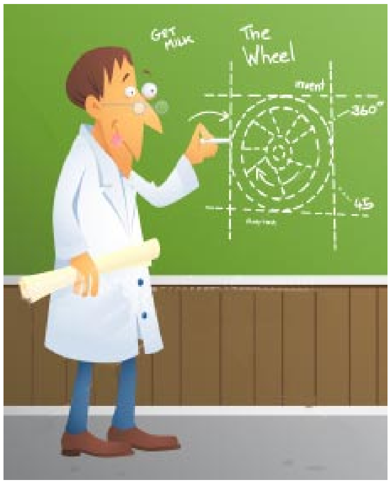

Figure 1: You before this course

In addition, the sizing of a rain water cistern has always been a mixture of art and science. At the end of this course, a method is presented that can provide reliable prediction of how much rain water can be collected in an average year. This value (the quantity of rainwater collected) is in fact a parameter that must be included in LEED Water Efficiency Credit templates to establish water use reduction percentages.

Overview

Figure 2: Global Troubles

From a global perspective, fresh water is becoming an increasingly precious resource. By some estimates, by 2025 as many as 3.4 billion people around the world will lack adequate, safe fresh water.[i] It is still easy to take water availability for granted here in the United States. However, increasing population, corruption of water by industrial and agricultural activity, steadily receding sources and climate changes conspire to reduce water availability and increase water costs. As a result, "water politics" has come closer to the forefront of public consciousness as people see their water bills rise to a significant household expense, while cities and towns manage aging distribution piping, and utilities seek out water supplies that are increasingly harder to reach. The challenges related to water conservation and efficiency have become a significant factor in plumbing system design going back to the 1990's when low-consumption fixtures became mandated by law. Since then, further incentives for water use reduction have been established through the United States Green Building Council's Leadership in Energy and Environmental Design (LEED) building certification system. Low consumption fixtures such as 1.28 gallon per flush water closets, 0.125 gallon per flush urinals and low flow sensor faucets can in many cases achieve water use reductions of up to 35%, but beyond the low-consumption fixtures prerequisites for LEED certification, additional water use reduction credits toward certification are commonly achieved through the collection of rain water as an alternative source to city water.

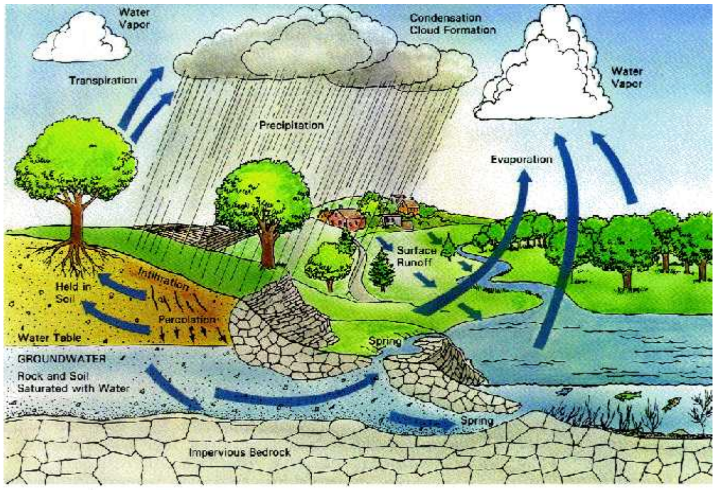

Figure 3: The Hydrologic Cycle

Rainwater harvesting is a method of collecting rain water from the roofs of buildings or other catchment surfaces and sending it to storage for future use. Although rain water is essentially purified water from the sky (i.e. condensed water vapor) as shown in the hydrologic cycle in Figure 3, when it hits the catchment surface and flows into drainage pipes, certain contaminants will be carried along. Reducing these contaminants is the key to maintaining good water quality for its use as irrigation water, fixture flushing water, and in some cases, drinking water for homes. In any rainwater harvesting application, it has been long understood that the quality of the water stored for reuse starts with the treatment of rain water before it is collected in the cistern. Other necessary steps and techniques in the collection and storage process are also important. The manner in which rain water shedding from a catchment surface is handled is a critical first step in managing stored water quality, while other methods in handling the water further ensure good quality. The central factor in any efficient and quality system is the health of the water column in the cistern. This article discusses the major concerns about stored water quality.

Contaminants that are swept along with rain include dirt, leaves and other deposited foliage, pollen, insects and wildlife deposits. If these items were to be simply deposited in a cistern and left to sit, the turbidity of the water and the general "health" of the water will degrade. Without proper care in rainwater harvesting system design, water in a cistern can easily degrade to the point of being unusable. Unfortunately, many designers inexperienced in proper rainwater harvesting design accept this situation and try to make up for poorly stored water with elaborate, expensive and unnecessary water treatment equipment at the back end. This poor practice further promotes a poor opinion of the collection, storage and use of rain water by inexperienced "experts" on water treatment. Such people incorrectly form the opinion that a cistern can only be a source of waterborne pathogens and therefore rainwater harvesting has unacceptable risks. However, a general overview of microbiology can help designers understand how certain water collection and handling methods exploit natural processes to maintain water quality and avoid conditions that lead to poor quality.

Aerobic Consumption of Organic Contaminants

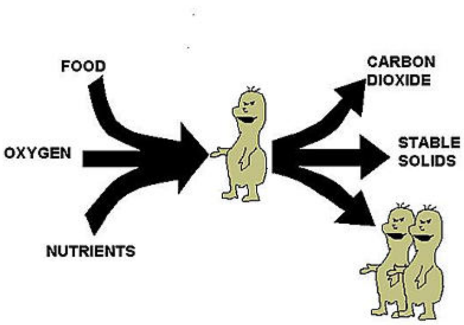

Figure 4: Aerobes (Good)

Contaminants like leaves, pollen, insects and wildlife deposits contribute what is referred to as biological oxygen demand (BOD). BOD is a measure of the organic content in water that serves as nutrients to microbial life in the water which in turn consumes oxygen through metabolism. Water typically has a certain amount of oxygen dissolved in it. Oxygen, in combination with organic nutrients, supports aerobic microbial metabolism. Aerobic bacteria use oxygen to decompose dissolved pollutants. The primary byproduct of this metabolic process is carbon dioxide. The more organic nutrients present, the longer and faster aerobic microbes feed and multiply. These microbes develop at the upper surface of the water in a tank where most oxygen is present. This aerobic process depletes the oxygen content in the water. In principle, this aerobic process is beneficial to water quality as it digests (bio-degrades) the organic matter into carbon dioxide and stable solids. As long as oxygen is present to feed this metabolic process, the water will remain clean and healthy. It is this process (in a more massive scale) that waste treatment plants use as one of the final steps to remove BOD. However, if the aerobic process continues to deplete oxygen in the water, less favorable conditions will develop.

Anaerobic Decomposition

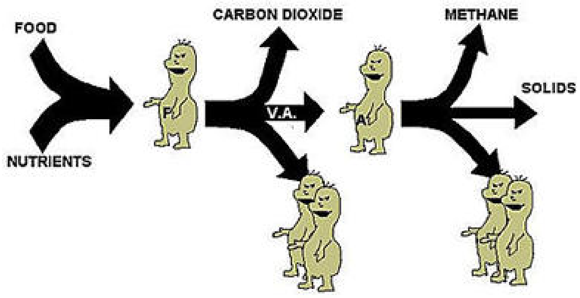

Figure 5: Anaerobes (Bad)

When oxygen is consumed faster than it can be replaced in the water, the aerobic metabolic process collapses and another microbial process flourishes. This process is anaerobic microbial metabolism. That is, microbes that do not use oxygen for growth. Like aerobic digestion, this process produces carbon dioxide as a byproduct, but it also produces methane, ammonia, acids and hydrogen sulfide. With enough organic nutrients left over after the aerobic cycle has collapsed, the anaerobic cycle is left to take over. The anaerobic process first develops at the bottom of a water storage tank where the amount of oxygen is the lowest. Although this metabolic process is used in waste treatment of sewage sludge and for production of renewable fuels, it is generally a process of decomposition that produces objectionable color and odor that is characteristic of stagnant water. Think swamp gas. Also, most intestinal pathogens are anaerobes. This anaerobic cycle in a cistern can be referred to as the water having “gone septic,” meaning an unhealthy condition of the water. Therefore, this cycle is to be minimized in cisterns and other water storage tanks.

The Four-Step Process

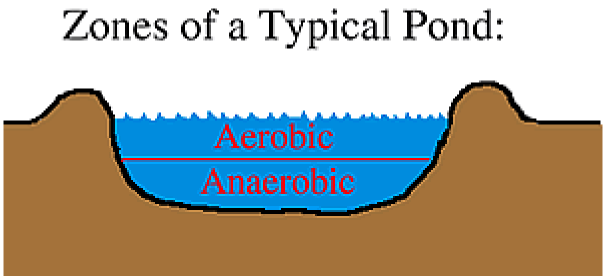

Figure 6: ...or a cistern

There are four practical ways to promote the good, aerobic microbial process and discourage the bad, anaerobic microbial process in cisterns. First, the water needs to be oxygenated. This starts with encouraging the mixture of water with air when it is captured. Second, organic content of the water needs to be minimized through proper filtration of rain water before it enters the cistern. That is, the aerobic process should be encouraged in the cistern to promote good quality, but it needs to be kept on a diet to avoid collapsing to usher in anaerobic decomposition. Third, the good aerobic metabolic process needs to be encouraged through the development of a beneficial "biofilm" on the inner surface of the cistern. Fourth, debris will inevitably enter a cistern and the biofilm will be established. The proper depositing of water and withdrawal of water should avoid disturbing both sedimentation and biofilm.

All of this microbiological theory sounds good, but what practical measures can designers employ in an effective and reliable rainwater harvesting system? If there is one central premise to be emphasized before further collection and storage methods are discussed, it is that the heart of rainwater harvesting system health is within the cistern. It is within the cistern where nature will take its course either to promote good quality water or to degrade it. Proper collection and storage measures will promote good quality and reduce the burden on further treatment equipment prior to final use. These measures include, self-cleansing mesh screens and first flush devices to reduce organics in rainwater before introduction into the cistern; proper inlet designs; proper overflow, backflow and venting; and finally proper pump suction configurations. All of these measures help promote and sustain the beneficial aerobic process and discourage anaerobic microbial growth. Certain rainwater harvesting devices on the market are available to engineers to design an effective rainwater harvesting system. What is most compelling about the methods mentioned above that will be described further is that they are essentially passive. There are no moving parts needing attention or intervention. Only a few parts need periodic cleaning and inspection. In fact, a properly designed collection and storage system for rainwater harvesting will never require that the cistern interior be cleaned during its lifetime. Further, maintaining proper water quality in the cistern reduces the size, initial expense and operating expense of further water treatment measures, particularly filters. This is most important when

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Figure 7: Rain Harvesting is not new

well meaning building developers face budget shortages. The simpler rainwater harvesting system designs are, the less they will cost and the more likely they may be to survive cost-cutting measures. From another perspective, more elaborate, expensive and mechanically driven treatment systems may consume more energy and resources than they are doing good through water conservation.

Design Fundamentals

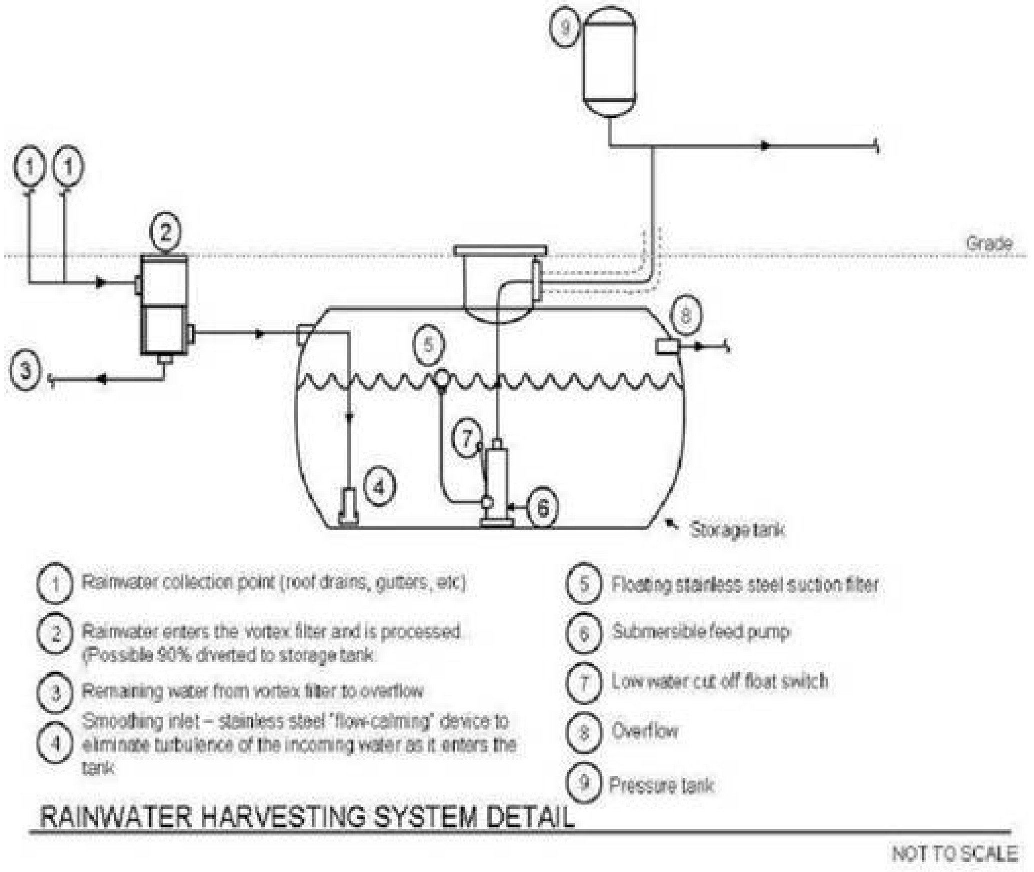


Figure 8: A Typical Rainwater Harvesting Design

In this design, water from the catchment surface(s) (1) is delivered to a first-stage screening device (2). The majority of solid contaminants are discharged out through the bottom overflow discharge (3) to a point of disposal (usually the storm system). A settling inlet (4) allows the incoming water to diffuse evenly and away from the bottom and sides of the cistern. Sometimes, depending on the size of the inlet, this diffuser is simply a 180 degree turn upward with elbows. A floating inlet (5) ensures that the best quality water in the aerobic zone is drawn from the cistern and that no settled solids or dissolved gases from the anaerobic zone are ingested. A small transfer pump (6) delivers the water to the point where it will be stored and treated in a small contact tank. An overflow outlet (8) allows excess rainwater to discharge. The pressure tank (9) is typical to any type of well pump system that manages the start and stop control of the pump (provides a cushion). These items are discussed in more detail below.

Vertical Mesh Screening

As mentioned above, rain water is essentially purified water from the sky (i.e. condensed water vapor), but when it hits a catchment surface and flows into drainage pipes, certain contaminants will be carried along. Reducing these contaminants is the key to maintaining good water quality for its use as irrigation water, fixture flushing water, and in some cases, drinking water for homes. In any rainwater harvesting application, it has been long understood that the quality of the water stored for reuse starts with the treatment of rain water before it is collected in the cistern (DIN 1989-1:2001, Sec 6.2). Other necessary steps and techniques in the collection and storage process are also important, but the manner in which rain water shedding from a catchment surface is handled is a critical first step in managing stored water quality.

Contaminants that are swept along with rain include dirt, leaves and other deposited foliage, pollen, insects and wildlife deposits. If these items were to be simply deposited in a cistern and left to sit, the turbidity of the water and the general "health" of the water would degrade.

As mentioned above there are two practical ways to promote the good, aerobic microbial process and discourage the bad, anaerobic microbial process in cisterns prior to depositing the water in the cistern as it is collected. First, the water needs to be oxygenated. This starts with encouraging the mixture of water with air when it is captured. Second, organic content of the water needs to be minimized. If the aerobic process consumes most of the organic content and produces carbon dioxide, there will be few organics left to support anaerobic microbial growth. Certain rainwater harvesting devices using self-cleaning mesh screens promote both of these goals. The screening process promotes air and water mixing while separating both inorganic and organic solids. This screening takes place not only during the course of a rainfall event, but most importantly during the first few minutes of a rainfall event where the BOD load in the water is the highest. If anything, this "first flush" effect is the most critical step of all as it disposes of the bulk of BOD burden before it gets into the cistern.

An effective method of promoting aeration (dissolved oxygen) in the captured water while separating out the bulk amounts of organic (and inorganic) debris from the collected stream is through non-clogging vertical mesh screens. These screens work due to a peculiar behavior of water where a screen tends to act as a siphon as water washes across the screen surface. These screens, however, require that water flow across the screen in a sheeting action.

A very well known principle of water flowing down vertical drainage stacks is the tendency of the water to cling or adhere to the inner wall of the pipe. For small volumes of flow, water forms a sheet along the inner wall which flows downward and leaves a center core of air. This water sheet reaches "terminal

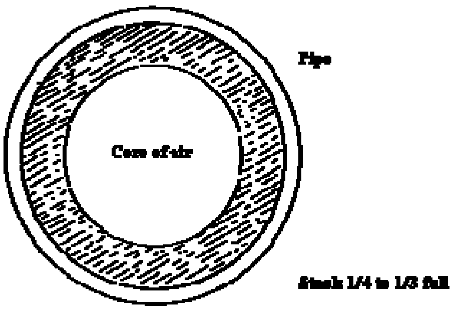


Figure 9: Vertical Stack Flow Pattern

velocity" about 12 feet downward from the point of entry into the pipe.

In this flow condition, the pipe is typically 1/4 to 1/3 full and this determines the practical limit of drainage stack sizes for sanitary waste drainage applications where the center core of air must be maintained to equalize pressures throughout the drainage system. See Figure 9 above.

This sheet flow also occurs in vertical roof drainage stacks. It is this flow principle that is exploited in the smaller vertically oriented harvesting filters. These vertical filters are in general a vertical piece of pipe at the inlet (upper housing) that separates into a narrow inner and outer chamber (lower housing) separated in the vertical by a removable mesh screen. See Figure 10.[ii]

The sheet flow that develops naturally in the piping above the filter device allows the water to evenly flow across the vertical mesh screen. The function of the mesh screen is discussed in more detail below.

Figure 10: Vertical Inlet Device

Not all roof drainage systems or conditions lend themselves to vertical filter devices, so devices with horizontal inlets and outlets are available.

Devices with a horizontal inlet cannot take advantage of the sheet flow that water naturally develops in a vertical stack. Therefore, the inlets to these devices are configured in such a way to allow the incoming water to distribute more or less evenly within the upper housing prior to washing down across the vertical mesh screen. Such horizontal inlets are configured where the inlet is placed tangentially with the outer wall of the upper housing instead of placed at the device center line.

If the centerline alignment were used, then the incoming water would simply pour in like water pours out of the neck of a bottle or pitcher and not wash across the mesh screen and the effect of the mesh screen would be defeated.

By allowing the water to enter at a tangent to the inner wall of the upper housing, the water tends to travel around the circumference of the inner wall as it simultaneously flows downward towards the mesh screen. This allows a more or less even sheet flow to develop as the water drops along the mesh screen.

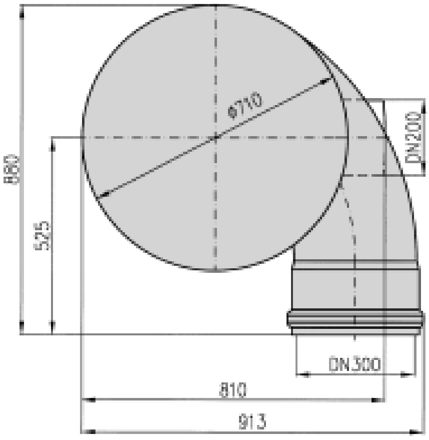


Figure 11: Horizontal Inlet Top View

This tangential entry and the resulting "swirling" pattern that the water initially follows are similar to how water might flow into a drain and is likened to a "vortex" action. As a result manufacturers of horizontal devices are given the nickname "vortex filters." However, this is a misnomer as it gives the impression that the vortex is the underlying principle of the device to separate solids from the rain water using centrifugal force. <u>This is not the case</u>. In fact, the so called vortex pattern's purpose is to establish a more uniform and stable (calmer) flow around the circumference of the upper housing before washing down and across the mesh screen. The mesh screen would otherwise be incapable of working without this uniform vertical flow. Figure 12 above is a horizontal inlet filter being tested. Note the tangential entry of the water at the top. The screen at the center of the housing is not clearly visible, but the swirling action of the water brings the water stream around the entire circumference to allow the water to pass along the surface of the screen. Note also that this screen has no bottom. That is, it does not function as a basket strainer that retains debris. This debris is discharged out the bottom of the device. The white circle at the bottom of the housing seen above is the discharge elbow at the outlet, which is typically piped to the site storm drainage system. As a result, this type of device never inhibits the flow of water in a roof drainage system, which is an important safety feature.

Figure 12: Horizontal Inlet Filter Being Tested

Vertical Mesh Screen

Both vertical and horizontal rainwater collection devices, despite their differences at the inlet condition, use a vertical mesh screen to aerate the water and remove suspended solids and similar contaminants.

In any application, the vertical mesh screen is intended to collect water during low and average rainfall events. They are not intended to function efficiently during so-called dimensional rain storms. These dimensional storms are typically the 100-year, 60-minute rainfall rates used in plumbing codes to size the drainage piping. The collection devices, however, are not designed to collect water at such a rate. It would not make any sense anyway. A 100 year storm has only by definition a one percent chance of occurring during the course of a year, whereas rainwater harvesting is intended to capture the average rainfall during the course of a year. Therefore, the mesh screen is intended to manage a lower flow rate typical of storms when it rains, for example, one half to one inch in a day. For this reason, it is better to upsize the capacity of a collection device when practical. The overall efficiency if the mesh screen is higher at lower flows.

It is important to appreciate that the vertical mesh screen collection devices are not basket strainers or other filter devices that capture or trap debris. Any device that traps debris would require frequent cleaning and would pose a possible restriction or obstruction to the flow of storm water off of a roof. In addition, the trapping of organic debris works against the goal of reducing the effects of decomposition on the quality of the water. Water washing across the trapped debris would carry away the byproducts of decomposition as well as bacteria and into the cistern. Figure 13 above shows a representative vertical mesh screen removed from the housing. The wall of the screen is a fine mesh of about 280 to 380 micron pore size through which water is drawn. Any solids in the water stream pass across the mesh and out the bottom to a point of disposal.

Figure 13: Typical Vertical Mesh Screen

It is at the more common low flows that come from the catchment surface that the mesh is most effective. As water flows in a sheet pattern across the mesh, the surface tension of water and its nature to “stick” to things causes it to pull or draw itself through the mesh and to the other side. A more simplified way of describing it would be like dragging cheese across a cheese grater.

For large volumes of flow, which typically may include the dimensional flow rates for a roof drainage piping system, the sheet flow pattern is sustained until both the disturbance of the flow of water and the velocity entering the collection device disrupt the sheet flow. In this type of turbulent pattern, most of the water entering the filter housing will not flow across the mesh screen and will instead fall straight through the filter to the bottom outlet. Thus, the efficiency of the filter screen decreases with the increase in inlet flow.

As mentioned above and as shown in the photo, the pore size of a mesh screen is about 280 to 380 microns. This is a bulk filtration step. Very fine suspended solids may pass through the screen and deposit in the cistern, but this represents only a small percentage of the BOD contaminants that influence water quality. Additional steps further manage this fine debris and prevent it from carrying over into the water reclaim system.

The action of the water passing across the mesh screen promotes the mixture of the water with air thereby providing dissolved oxygen content. The addition of oxygen to the water, as described above, is an important part of the initial treatment process. One way to think of these mesh screen devices is they add oxygen but reduce nutrients entering the cistern. This provides the good aerobic microbes a means to “breathe” but puts them on a diet.

The action of the sheet of water pulling itself through the mesh screen has been described above. This process occurs, however, only when the mesh has had the opportunity to get wet. Before this happens, when the screen is dry, the water tends to skip across and go out the bottom discharge. This initial bypass of water gives the mesh screen the capability of providing the essential “first flush” to dispose of the initial volume of water to be discharged from the catchment surface. If it has been dry for a while, the catchment surface will have leaves, pollen, insects, etc. built up on it that gets quickly carried along with the onset of a rainfall event.

The requirement for the sheet flow across the mesh screen rules out the application of siphonic roof drainage being connected directly to these devices. Siphonic roof drainage is designed to operate with the pipes fuller and at higher velocities. Although siphonic roof drainage can and has been used for rainwater harvesting, the siphonic system must be terminated (i.e. broken) to atmospheric open channel flow well before the mesh screen filter.

Configurations

The previous section describes the operating principles as well as the physical configurations of vertical mesh screen devices. This section addresses certain items regarding their installation in piping systems.

Vertical (Inline) Downspout Filters

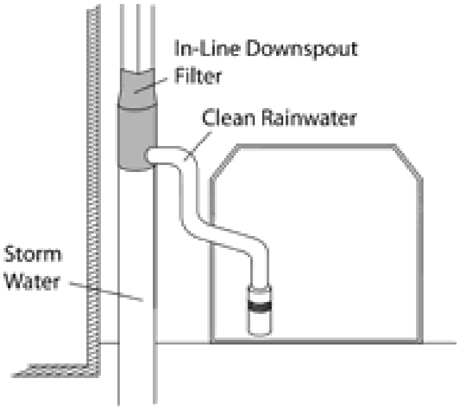


Figure 14: Vertical Device Installation

Applications: Vertical downspout filters are typically used on exterior roof downspouts, but they can be used inside as well. These devices are available in 4 inch (100mm) inlet and outlet size and have capacities limited to about 2,000 square feet of catchment surface area.

As described above, these devices are essentially “in-line” filters. The water enters the top vertically. The by-pass and discharged debris exits the bottom vertically. Depending on the application, this bottom discharge can simply discharge to grade (like a splash block) or it can connect to an underground storm drainage system as shown in Figure 14 above.

The filtered (clean) water discharges from the side of the lower housing. This discharge port is piped over to the cistern for collection of the filtered and aerated water.

Vertical devices can be used either inside or outside, but are typically installed above ground, as opposed to below grade. Horizontal devices are more appropriate for below grade installations.

Horizontal (Vortex) Filters

Applications: As noted above, in-line vertical filters are limited in capacity to about 2,000 square feet of

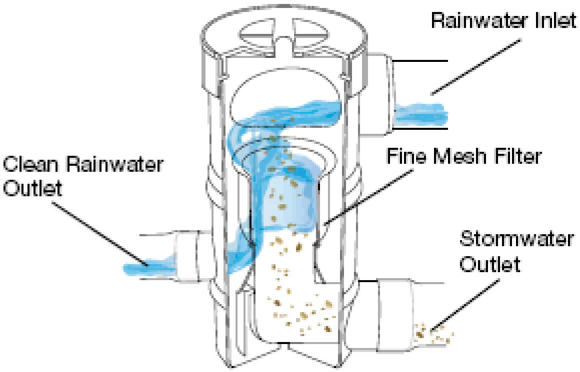


Figure 15: Horizontal Inlet Strainer

roof surface. In many rain water harvesting applications, the catchment surfaces involved are much larger and the resulting drainage piping is much larger than 4 inch (100mm). Also, restrictions in space and location may preclude the use of a vertical configuration. Many times, these devices need to be placed below grade. Thus, horizontal inlet collection devices are available to provide greater capacity and flexibility.

Such horizontal devices are available in sizes from 4 inch (100 mm) to 12 inch (300mm) with capacities ranging from 2,000 square feet to upwards of 32,000 square feet.

These devices may be installed above grade. However, they are usually applied below grade. When direct-burying these devices, the access port will need to be extended to be flush with the grading much like a manhole extension. There is typically a limit to the depth of direct-burial that the housing can withstand due to the weight of soil. This limit needs to be confirmed by the manufacturer. For example, one manufacturer limits the depth to not more than a 3.3 foot (1 meter) extension from the rim to grade. In cases where the depth needs to be lower, it is possible to install these devices in a concrete chamber.

Sizing and Area Limitations

As mentioned above, these devices come in a varying range of connection sizes and capacities. The capacities of these devices are expressed either in liter per minute (gallon per minute) flow rates or by square footage.

It is important to note that capacities listed in square footage make an assumption about the rainfall intensity that would usually be experienced on average that would result in a certain inlet flow from the specified catchment surface area. These rainfall rates are NOT the dimensional rainfall rates used to size roof drainage piping. The operational rates are more in the range of 0.5 inch (12.7 mm) per hour to 1.0 (25.4 mm) per hour. These rates are still pretty high. If one inch of rain were to fall in an hour, it is usually mentioned by the weatherman on the news. But this does not mean that the device is limited to, say, 0.5 inches per hour of roof drainage, as will be discussed further below.

Performance Charts

The operation of vertical mesh strainers used for rainwater collection varies in efficiency at varying flow

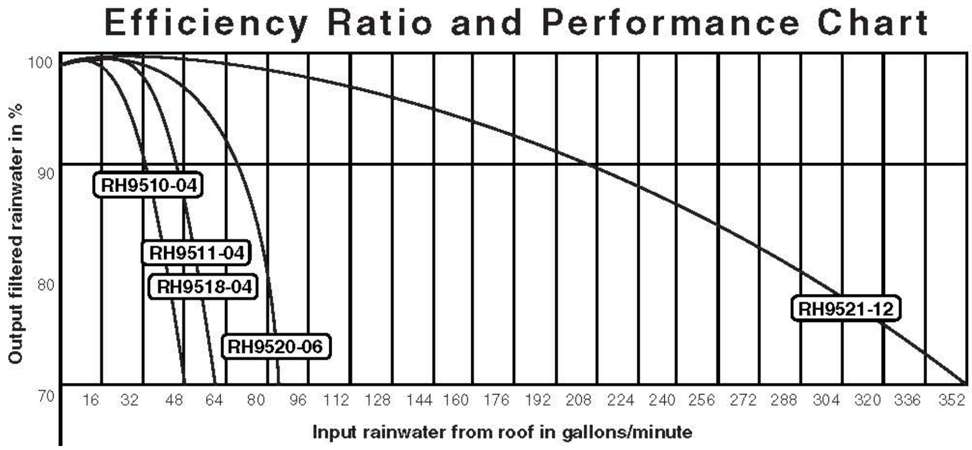


Figure 16: Sample Performance Chart

rates. Manufacturers have quantified these efficiencies over their expected range of flow, much like pump manufacturers provide performance curves for centrifugal pumps. A sample performance chart is shown in Figure 16 above.

In this chart, the efficiency of capture is plotted as flow rate across the mesh screen increases. In this sample, there are four curves for four sample devices. For each of these devices, the maximum efficiency occurs at flow rates from about 20 gpm to 30 gpm where the efficiency is around 98 percent. That means the device collects 98 percent of the water passing across the mesh screen and 2 percent bypasses. As flow rates increase, the curves show that this efficiency drops off. This makes sense because, as discussed before, as the flow rate increases, the sheeting pattern of water gets heavier and more water bypasses the screen.

In terms of selecting the size of the collector, the rated flow rates or areas should be used. In this example, take the curve labeled RH9520-06. The rated capacity of this device is listed as 5,500 square feet. Note that the efficiency curve drops off sharply after the 90 percent efficiency line. At this efficiency, the listed flow rate is about 66 gpm. A catchment surface of 5,500 square feet discharging 66 gpm of rainfall would be receiving a rainfall at a rate of 1.15 inches per hour.

Harvesting vs. Dimensional Storms

In the above example, a rainfall rate of 1.15 inches per hour is not to be confused with the dimensional rainfall capacity used to design the storm drainage system. If the plumbing code required a rainfall intensity of 4 inches per hour to design the roof drainage system, the pipe size required to drain 5,500 square feet at a one percent pitch would be 6 inches.

Well, as it happens, the inlet and bypass outlet size of the RH9520-06 device used as the above example is 6 inches. This is no coincidence. The device is intended to capture water most efficiently at average rainfall events over the course of a year. However, the device still needs to accommodate the dimensional flow capacity of a heavy storm (DIN 1989-1:2001, Sec. 6.2). In this case, most of the water will bypass and go to the storm drainage system instead of the cistern. This is not a concern since rainwater harvesting is a year-round process. It is not intended to capture water during a brief downpour that may occur only one percent of the time.

Inlets and Mounting

Vertical Devices

For vertical downspout inlets, the piping leading to the inlet must be vertical for at least 8 to 10 feet before the inlet to allow the annular sheet flow pattern to be fully developed. Any bends and turns within that vertical drop will disrupt this flow and cause excessive bypass through the device. In addition, the inlet and the device itself need to be installed plumb to ensure a proper annular sheeting pattern will develop.

Horizontal Devices

In contrast to the vertical inlet devices, the horizontal devices require a straight run of horizontal pipe ahead of the inlet. The recommended length of pipe is about 3.3 feet (1 meter). The purpose if this straight run of pipe is similar to that required for flow measurement devices in piping systems. This straight run allows the water to settle into a steady channel flow along the pipe so it enters the device "calmly" to initiate the circumferential distribution along the upper housing.

The precaution provided here is against installing a vertical pipe with an elbow discharging directly into the horizontal inlet device (see Figure 17). This configuration will produce turbulent flow and prevent the vertical mesh screen from performing properly.

The housing or body of horizontal devices also needs to be installed plumb in order to permit the even sheeting of water across the mesh screen.

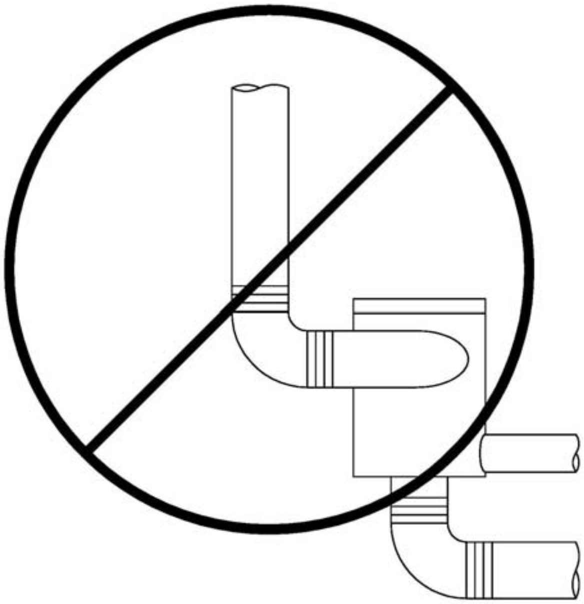


Figure 17: Improper Inlet Design

Outlets of Screening Filters

Filtered Water Outlet

The filtered (clean) water outlet discharges from the screened or clean side of the vertical mesh screen at the lower housing. The configuration of this discharge pipe at the bottom housing makes it necessary to make sure that the clean water being discharged is carried away and downstream as quickly as possible. This is opposite to how the water is supposed to approach the inlet, which is slowly and calmly by using a straight length of pipe ahead of the inlet with no elbows or other changes in direction. In other words, the device works most efficiently by processing the water as steadily as possible without either turbulence at the inlet or surcharging or "building up" at the outlet. If water is allowed to surcharge at the outlet, water will spill back through the mesh screen and drop down the bypass (dirty) water outlet.

For vertical inlet devices, an elbow pointed or angled down should be placed immediately at the clean water discharge outlet (refer to previous Figure 14 above). This ensures the water is clear of the outlet as quickly as possible.

For horizontal inlet devices above ground, an elbow pointed down should also be placed at the discharge outlet. In below ground installations, pipe depths (i.e. invert elevations) are typically critical and limiting dimensions. However, where possible it is recommended that at a minimum the invert of the outlet be dropped by placing two 45 degree elbows. This will allow the downstream pipe develop the necessary hydraulic radius while keeping the discharge outlet clear.

Stormwater Outlet (Overflow/Bypass)

Both vertical and horizontal devices have a bottom bypass outlet. This outlet is considered a waste discharge and is piped to the site storm drainage system or some other permitted point of discharge.

For the vertical inlet devices, the outlet is out the bottom directly in line with the inlet. For smaller devices serving small roof areas and where allowed, this outlet can simply spill to a splash block to grade. Otherwise, it can be piped to the storm drainage system underground.

The main concern with this discharge on the horizontal is the fact that there is a significant drop in pipe invert elevation from the inlet to the outlet. For a large device with a 12 inch inlet, the total drop in invert elevation is nearly 48 inches once the sweep of the discharge elbow is taken into account. This has to be figured into the placement of these devices relative to the available pipe depths of the storm sewer system.

Use in Storm Water Management Applications

At this point it is worth pointing out how the inlet filters and the overall collection of rainwater for use in a building or for irrigation relates to the general site storm water management. In most cases, local regulations require that a site being developed employ methods to reduce storm water runoff from the site as well as reduce point source contamination into the storm systems and waterways. It may easily be misunderstood that collecting rain off of the building alone will satisfy this requirement, but typically it does not.

The method of rain water harvesting using vertical mesh screen collection devices can be used to reduce storm water runoff quantity. By virtue of collecting over 90 percent of the rainwater and diverting it to a cistern, this method is effective in reducing overall storm water runoff from a developed site. The amount of storm water runoff reduction is a function of the size of the collecting cistern and the rate at which this collected water can be consumed and free up volume to capture the next storm event. However, this quantity captured may not satisfy the storm water reduction requirements for the entire site.

In addition to requirements for the reduction of storm water runoff from a site, there is also typically a requirement to reduce the quantity of contaminants discharged from a site. While vertical mesh screen collection devices collect water, they also discharge a small percentage of water and a bulk of the contaminants coming from the catchment surface. In this respect, this method does not directly contribute to reduction in the discharge of contaminants. If anything, these devices concentrate these contaminants to the storm system. In this situation, the vertical mesh screen devices may still be used, but the bottom bypass (dirty) discharge stream still needs to be directed to some sort of on-site retention basin or other means of treatment.

Regarding the Use of Green (Vegetated) Roofs for Rainwater Harvesting

There have been many instances where design teams seeking to maximize LEED certification points have expected to use vegetated green roofs as catchment surfaces to further collect rain water. The advice of this course provider is this: Don't do it. Vegetated roof systems and rain water collection from these surfaces simply do not work well together.

First, a vegetated roof is designed to act as a sponge to absorb rain, detain it in gravel and soil layers and undergo a process of evaporation and evapotranspiration back to the atmosphere. The net effect is the capture of anywhere from 50% to 70% of rainfall. For example, an intensive green roof would have a runoff coefficient of 0.3 (DIN 1989-1, Sec. 16.3.4, Table 3) meaning 70% of rainfall is captured and detained. This leaves little if any water to be captured for a rainwater harvesting system.

Second, whatever rain is captured off of the roof system is laden with organic contaminants, tannins, chemicals (if fertilizers are employed) and sediments. Yellow and brown discoloration of the captured water will occur with this water (DIN 1989-1, Sec. 5.2). It has been the experience of this course provider that the collection of rainwater for reuse in any application other than irrigation is not practical and will result in a poor quality system.

Therefore it is recommended that rainwater be collected only from impervious roof surfaces.

Managing Quality in the Cistern

Up to this point of the course we have discussed the importance of separating debris from collected rainwater and aeration of the water prior to entry into the cistern. The central premise, which is worth repeating, is that the overall health of a rainwater harvesting system starts with the cistern. Further discussion from this point will describe methods and devices to be used to maintain the health of the water once it is inside the cistern.

Inside the cistern, there are three practical ways to take advantage of the good, aerobic microbial process and sequester the bad, anaerobic microbial process in the cistern. First, the water entering the cistern must do so calmly and with a smooth up-flowing pattern. Second, the cistern must be able to overflow in a skimming action to draw off floating debris such as pollen and dust to allow the free surface of the water to draw in oxygen. Third, when the water is drawn from the cistern for treatment and use, it must be taken from near the free surface and not from the bottom of the cistern.

The screening device process discussed previously is one means by which entering water is allowed to calm itself. Rainwater collection is a “harvesting” process, not a “hoarding” process. Harvesting collects the low and average storm events over the course of a year. There is no expectation for the cistern to be inundated by a century storm event. The collection piping (as part of a code compliant roof drainage system) needs to be sized for the century storm event or that which is prescribed by code, but what is allowed to be collected by the screening process reduces the rate and quantity directed to the cistern while disposing of the excess. This may sound like a missed opportunity to collect more water, but the low frequency and short duration at which such strong rainfall events occurs makes the “missed opportunity" negligible. Also, as will be discussed further on, there is no need to "get greedy" and collect all you can in a massive cistern. Only a moderate size cistern can obtain the water use reduction percentages needed for most applications.

Cistern Inlet

The flow pattern by which the collected and screened rain water enters the cistern is another important and sometimes missed step. The inlet pipe should not simply terminate at the cistern wall and allow the water to cascade freely to the bottom of an empty cistern. This causes the sediment layer at the tank bottom to stir up and into suspension. Instead, the inlet pipe must be extended down to the bottom. Then the termination of the inlet pipe should be configured either with a "stilling inlet" as in Figure 18, or an upturned opening (typically two elbows for a full 180 degree turn). This creates an up-flow pattern to divert the flow away from the bottom sediment layer. When the cistern water level is low, it allows the water to burble upward and combine with oxygen from the air.

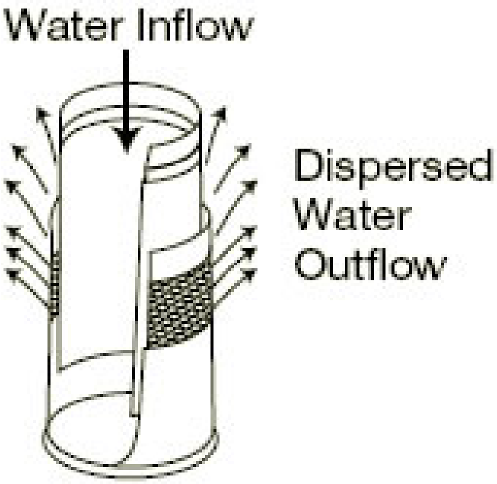


Figure 18: Stilling Inlet

Despite the first step in screening the collected rainwater ahead of the cistern, there will always be some fine sediment that will settle to the bottom. In addition, a biofilm layer will inevitably form on the inside wall of the cistern. Incidentally, this biofilm is actually beneficial to the overall water quality. It is important for the biofilm to stay where it is, attached to the inner wall. It is within this biofilm that the beneficial aerobic microbes live. Allowing the calmed, up-flow flow pattern described above assists in that goal. But in addition to sediment that settles at the bottom, some finer particulates also tend to enter into the cistern and float. Such particulates include pollen spores and dust. If allowed to accumulate, the particulate layer will tend to block the beneficial absorption of oxygen for the good aerobic metabolism below the surface. Therefore, it is important that the cistern be allowed to overflow periodically to a skimming overflow outlet, similar to what one would see in a decorative pool (see Figure 19). The skimming action tends to pull the floating particulates to the outlet to clear the water surface. This skimming outlet also needs to be configured to prevent the entry of vermin from the connected point of

Figure 19: Overflow and Backwater Device

disposal (usually the storm sewer) through a trap seal and a flapper vakve or ball check valve. This also prevents the backflow of water in the storm sewer system into the cistern. Of course, all vents and other normally opened pathways into the cistern should be screened to keep out vermin and insects.

The sizing of the cistern should be optimized to achieve the water use reduction percentage target, but not much larger. In fact, over-sizing a cistern to try to maximize the harvesting volume beyond what is actually necessary (being "greedy") will greatly increase the residence time of the water in the tank and delay skimming overflows. The better choice is to have the optimal design size to increase the frequency of overflow to get a fresher turnover of water in the cistern to promote a healthier water quality. As will be shown by two examples, past "rules of thumb" have unnecessarily oversized cisterns.

It may appear to be counter intuitive to allow both the inlet straining process and the skimming overflow process to dispose of rainwater. The rainwater cistern is being sized and configured as a water supply to substitute for city water, typically as flushing water for toilets or as irrigation or cooling tower make-up, and in some applications as drinking water. As long as the catchment area and cistern are sized to achieve the intended reduction in city water use taking into account the quantities disposed of by screening and skimming, the system is doing its job. Very seldom do rainwater harvesting systems function as both water use reduction and storm water management systems. The rainwater harvesting system can provide some storm water management in terms of site runoff reduction, but not all. Also, they are not intended for storm water quality treatment. This needs to be addressed with other low impact development methods.

Finally, now that rainwater has been collected in the cistern and there is an undisturbed biofilm and sedimentary layer, it is still important to transfer the water out properly. The typical plumbing approach to drawing water from a tank is of course to have a suction pipe at or near the tank bottom or to lower in submersible pumps that draw water from the tank bottom. But in rainwater harvesting, this is the worst way to go about it. There have actually been details out there prepared by underground tank manufacturers that include a low sump at the tank bottom to install transfer pumps. This is an example of some vendors getting in the rain water harvesting market but not understanding what they are doing. As mentioned above, any cistern is going to develop a sedimentary layer at the bottom and a biofilm on the inner wall. Tanking suction from the tank bottom will routinely draw in poor quality water that will end up requiring a higher level of treatment. Not only is the debris a concern, but the water at the tank bottom, being the furthest away from the free surface and therefore the supply of oxygen, is the most anaerobic and will typically have color and odor. The best quality water, sometimes referred to as the "sweetest" water is at the top, near the free surface. It has the highest oxygen content and the fewest particulates. Therefore any suction should be configured with a floating strainer or filter with a flexible length of hose and float assembly to allow the inlet to rise up and down with the water level (Figure 20).

Figure 20: Floating Suction

Final Treatment

Again, the overall health of a rainwater harvesting system starts with the cistern. The proper methods used to collect, store and transfer water at the cistern greatly assist the final treatment process. This section will discuss methods engineers may employ to design effective and cost efficient final treatment components. With a good cistern design, final treatment is simple.

When transferring water into a building for final use as flushing water for toilets and urinals, one of the first important principles to understand it that an interior so-called “contact” tank or “buffer” tank is necessary to provide storage and treatment (See Figure 21). Think of the exterior cistern as bulk storage and the interior tank as a treated, ready supply. Such a tank is typically sized to meet the water supply needs for a couple of hours. An efficient size is around 500 to 750 gallons and such tanks are readily available off the shelf constructed of polyethylene or fiberglass (Figure 22). Therefore, the transfer pump(s) in the cistern is (are) not sized to provide the peak flow on the demand side of the system (i.e. the toilets and urinals). The transfer rate is done slowly. A typical 0.75 horsepower cistern pump with a floating filter attachment can transfer water at a rate of around 20 gpm or so. That is 1,200 gallons per hour, which would still exceed the hourly consumption rates in most buildings.

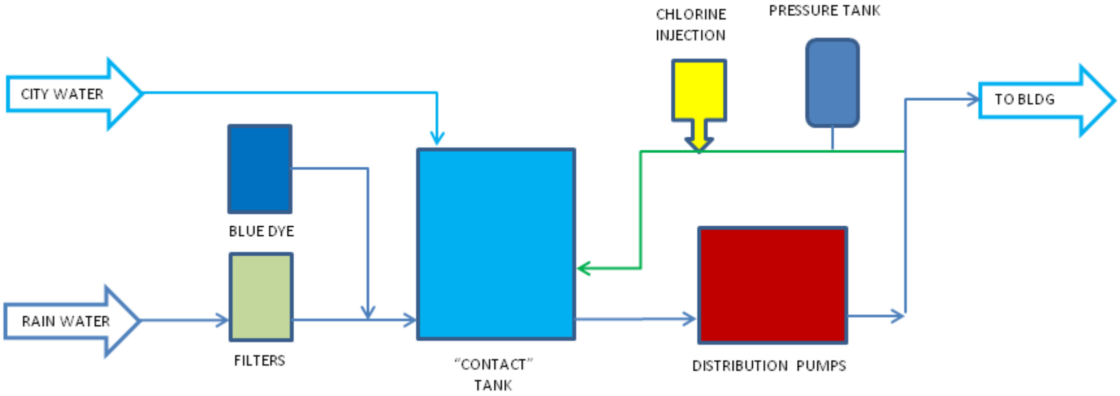


Figure 21: Typical Interior Final Treatment System

The buffer tank is central to a flushing water system and it serves several purposes. First, it provides a means of adding supplemental city water during dry periods by means of an air gap. Some jurisdictions may allow a hard-piped connection through an approved reduced pressure zone backflow preventer (RPZ) which can directly feed the flushing water system when rainwater is not available, but other jurisdictions may require an air gap. Second, the tank allows for the collection of other water sources such as

Figure 22: Typical PE Tanks

HVAC condensate and clear water waste streams such as reverse osmosis reject water. Most jurisdictions would not allow the co-mingling of rain water with tap water sources of waste such as reverse osmosis water so it would not be possible to use the cistern, which overflows to the storm sewer, to collect tap water waste streams. Third, the tank allows for the proper mixing and contact time of disinfectants before the water is distributed to the building fixtures.

As shown in Figure 21, rain water is transferred from the cistern (the “rain water” arrow) to the contact tank. As discussed above, this transfer would be made by means of a small transfer pump coupled to a floating inlet (Item 5, Figure 8, and Figure 20). The transfer rate is typically between 20 and 30 gallons per minute for most systems which allows for a steady transfer of water to the tank for a fill time of 10 to 15 minutes. This transferred water passes through a set of fine filters, typically 5 micron to remove any floating particulates that may be present.

In some jurisdictions (Massachusetts is an example), rain water used for flushing toilets and urinals in a building must be marked with a “non-toxic blue dye” to visually distinguish the water as non-potable to protect against inadvertent cross connections. The other benefit of the coloration is to provide a more consistent aesthetic appearance to the water, which can sometimes have some coloration regardless of the level of treatment. The dye is typically best injected during the filling of the tank, having established a set 20 to 30 gallon per minute fill rate, the dye can be injected proportionately with either a metering pump or an educator and achieve adequate mixing and a consistent level of coloration in the system. Injecting “on demand” as the water is sent to the distribution system can be problematic as the flow rates fluctuate dramatically. The buffer tank decouples the treatment from the fluctuations. Blue dye injection is not required in all jurisdictions, but it is considered advisable practice. It is not expensive to maintain. Such non-toxic blue dye is just common food coloring that can be purchased as a concentrate and mixed with water in a 35 gallon container. Of course dye injection is not practical for all applications, such as cooling tower make-up, laundry, and irrigation.

Other than fine particulate filtration and possible dye coloration, the only other necessary treatment precaution is disinfection. In a small household system, disinfection by ultraviolet light may be adequate. However, in larger systems and in some jurisdictions, a disinfection residual in the distribution piping system and in the buffer tank may be necessary. This involves the use of either chlorine or bromine, with chlorine being the more commonly used. With the highly variable and fluctuating flows of a flushing water system, the buffer tank’s advantage to chlorine addition becomes obvious. However, the handling of chlorine has typically been a challenge in maintaining these systems.

The handling of chlorine solutions (liquid form) can pose difficulties. Exposure to the eyes or skin can be harmful. The off gassing of the chlorine in a room can lead to odors and corrosion of metal in a room (i.e. electrical conduits, panels and pipes). Over time the chlorine solution breaks down and becomes ineffective. However, as

Figure 23: Chlorine Tablets

any swimming pool owner knows, there are much easier methods of adding chlorine. Many pools and whirlpool spas use in-line chlorine feeders using solid tablets or sticks. The same method is easily adapted to rain water treatment. As shown in Figure 21, a small side stream taken from the discharge of the distribution pumps with a flow regulating valve and solenoid valve can be used to place an in-line erosion feeder. With the placement of a chlorine sensor (an oxidation-reduction potential sensor or ORP) the level of chlorine can be monitored and controlled. Maintenance is reduced to just refilling the injector with chlorine tablets and replacement of the ORP sensor every two to three years. The level of free chlorine in the water is typically maintained between 1 to 2 parts per million (ppm). Higher concentrations would tend to be corrosive to piping systems.

Up to this point hopefully readers have been able to pick up some of the ideas discussed and will be able to incorporate them into their next designs. The equipment and design methods described in these articles have been employed by European engineers for decades. The general wisdom coming from these techniques is “let nature take its course” given favorable conditions such as removal of organic debris by first flush and inlet screening, development of biofilm in the cistern, and oxygenation of the water. Most importantly, it is too tempting to “overdesign” these systems and include complicated components that consume resources and energy to a point where the benefits of collecting rain water diminish to nothing.

Cistern Sizing

One of the most important items to consider when designing a rainwater harvesting system is determining the necessary size of the cistern. At $2 to $5 per gallon for a tank plus the costs of excavation, the cistern is one of the higher price tag components. But not only is cost a concern, but a grossly oversized tank would increase residence time in the tank leading to degrading health of the water.

One general guideline that has been used in the past, and which is documented in the European Standard DIN 1989-1:2001-10, Section 16.3.8 “Useful Volume” is to compare the annual process water (W_A) requirement (e.g. for flushing fixtures, or cooling tower makeup) with the annual yield of rainwater possible (R_A) from the catchment area size, annual average rainfall (in inches) and after accounting for losses.

The algorithm would be $V = \text{MIN}(W_A, R_A) \times 0.06$. In other words, the cistern volume is sized for 6% of either the demand (use) or the supply (rainfall), whichever is less.

For example, assume in a region that receives an annual rainfall of 42 inches on average and we have a building with a roof surface of 15,000 square feet. Taking into account losses of 15% of the annual yield due to filtration and evaporation, a total of 333,940 gallons can be theoretically captured (42in / 12 in/ft) * 0.85 * 15,000 sf = 44,625 cubic feet (333,940 gallons). But let us assume that the flushing water requirements for the building will be 1649 gallons per day Monday through Friday (260 days per year). The annual requirement for flushing water would be 428,740 gallons.

So, the minimum of the two values is the supply, 333,940 gallons. Thus, the calculated useful cistern volume would be 20,000 gallons. Accounting for loss of useful volume at the top and bottom, a tank size of 28,000 would be required.

But despite this calculation, how much water is actually used for flushing, how much is going to overflow, and how often will make-up water need to be added each year? These are all factors that need to be incorporated into LEED documentation.

Fortunately, through the accessibility of historical rainfall data throughout the country, a methodical means of tracking cistern collection, use and overflow can be performed to obtain an annual rainfall capture calculation as well as a water use reduction calculation. Such numbers are necessary to complete LEED Water Efficiency templates to apply for LEED credits. The method also shows that much smaller cistern volumes can be specified to achieve LEED goals.

First of all, historical rainfall data can be obtained through several sources. One such source is Weather Source at www.weathersource.com. This is a subscription service, but for a reasonable fee, you can obtain access to historical weather data for practically any zip code in the country. For example, the table below is a sample of some of the data for one location (Anywhere, USA):

Begin Time	End Time	Precip (in)	Cond (cf)	Captured (cf)	Loss (cf)	Inlet (cf)
1/1/1962 0:00	1/2/1962 0:00	0	0.0	0.0	0.0	0.0
1/2/1962 0:00	1/3/1962 0:00	0	0.0	0.0	0.0	0.0
1/3/1962 0:00	1/4/1962 0:00	0	0.0	0.0	0.0	0.0
1/4/1962 0:00	1/5/1962 0:00	0	0.0	0.0	0.0	0.0
1/5/1962 0:00	1/6/1962 0:00	0	0.0	0.0	0.0	0.0
1/6/1962 0:00	1/7/1962 0:00	1.31	0.0	3005.8	450.9	2554.9
1/7/1962 0:00	1/8/1962 0:00	0	0.0	0.0	0.0	0.0
1/8/1962 0:00	1/9/1962 0:00	0	0.0	0.0	0.0	0.0
1/9/1962 0:00	1/10/1962 0:00	0	0.0	0.0	0.0	0.0
1/10/1962 0:00	1/11/1962 0:00	0.04	0.0	91.8	13.8	78.0
1/11/1962 0:00	1/12/1962 0:00	0	0.0	0.0	0.0	0.0
1/12/1962 0:00	1/13/1962 0:00	0	0.0	0.0	0.0	0.0
1/13/1962 0:00	1/14/1962 0:00	0	0.0	0.0	0.0	0.0
1/14/1962 0:00	1/15/1962 0:00	0	0.0	0.0	0.0	0.0
1/15/1962 0:00	1/16/1962 0:00	0.46	0.0	1055.5	158.3	897.1
1/16/1962 0:00	1/17/1962 0:00	0	0.0	0.0	0.0	0.0
1/17/1962 0:00	1/18/1962 0:00	0	0.0	0.0	0.0	0.0
1/18/1962 0:00	1/19/1962 0:00	0	0.0	0.0	0.0	0.0
1/19/1962 0:00	1/20/1962 0:00	0.02	0.0	45.9	6.9	39.0
1/20/1962 0:00	1/21/1962 0:00	0.03	0.0	68.8	10.3	58.5

The first three columns are the raw data provided showing the quantity of precipitation in inches each day. The forth column in this example is reserved for any cooling equipment condensate that could be collected each day, but it is not used for this example. The final three columns calculate, based on the catchment surface area provided and the expected losses through the inlet screens and evaporation, the amount of water that could have been collected for that day. Although this sample shows only 21 days in January of 1962, data for, say, 50 years can be compiled. Further columns in this analysis would be used to track the level of the cistern, whether it is empty, full, or goes to overflow. Additional columns are used to track how much city water had to be used to supply the system demand if the cistern emptied out or was empty that day. These additional columns are not shown here as the calculation methods are proprietary to this writer, but almost anyone can set up a spreadsheet to do these calculations. Over a period of 50 years, the total amount of rain water captured, overflowed, used for flushing, irrigation, etc. and the amount of city water required can be added up to determine an average annual quantity. A fifty year period of historical data is a significant statistical sample that can be reasonably assumed to be representative of fifty years in the future. Although some may argue that climate change may result in different rainfall quantities, there really is no data right now to predict what will occur in the next year or next fifty years.

Figure 24: We can extrapolate beyond 12/21/2012

By setting up a summary table to enter the catchment area, selected cistern size, and water use, a quick and helpful calculator can be established using the 50 year data inventory as the back-up. An example similar to the previous sizing exercise is below.

To start, let us assume that we have a building with a full-time population of 614 (half male, half female). Using the water use methodologies in LEED to determine flushing water consumption per year, we set up the following comparison between a baseline consumption case and the design case.

Baseline Case			
Male	307		
Fixture	Use/day	gal/flush	Use
WC	1	1.6	491
UR	2	1.0	614
Female	307		
WC	3	1.6	1474
Total Use per Day		(gal):	2579
Annual Use at 260 Days per Year (gal):			670540

Design Case			
Male	307		
Fixture	Use/day	gal/flush	Use
WC	1	1.28	393
UR	2	0.125	77
Female	307		
WC	3	1.28	1179
Total Use per Day (gal):			1649
Annual Use at 260 Days per Year (gal):			428740

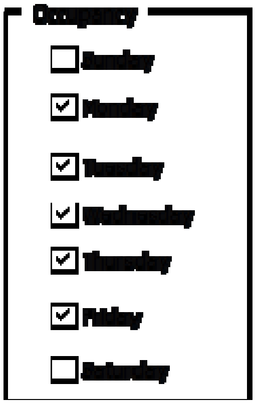
As a result, the water use reduction by water conserving fixtures alone is:

R = 1 – 428740/670540 = 0.36 (36%)

In the LEED templates, the designer is allowed to add the amount of reclaimed water used per year to further reduce the amount of potable water consumed. This calculation can be difficult due to the fact that one may not know the status of the cistern in any given day over the course of an average year. But by setting up a spreadsheet as described above, this annual average amount can be determined.

Without following a daily inventory over an historically significant (statistically significant) period, there is no reliable means of calculating the actual water use. The designer is left only with making month by month assumptions based on monthly averages. But the daily inventory method provides a far more realistic estimate of the status (volume level) of the cistern so that the cistern status of empty, full and overflow can be documented when rain is collected. This provides a more physically realistic approach to how much water the cistern contributes to process use before reaching the empty level. This inventory, represented in part above lasts for 50 years which is 18,262 days and as many rows. But the end result is a summation of all 18,262 days divided by 50 years to provide an average annual calculation. Some years receive more rain than others. Therefore, the first year of operation may or may not see the calculated results, but averaged over the lifetime of a building the results are highly likely. The spreadsheet summary below provides the results:

Rainwater Harvesting Water Use Reduction Calculation



Occupancy
☐ Sunday
☑ Monday
☑ Tuesday
☑ Wednesday
☑ Thursday
☑ Friday
☐ Saturday

Catchment Area	15000	sqft		
Cistern Volume	3000	gal		
Loss/Evaporation Factor	15.0%			
Maximum Volume	85.0%			
Minimum Volume	15.0%			
Useable Volume	70.0%			
Starting Volume	25.0%			
Water Consumed	1649	gpd	428740	gpy
			260	days/yr
Rainwater Used	**125474**	gpy		
Percent Reduction	**29.2%**			
Percent Overflow	62.4%			

In this example, the catchment area is entered by the designer (15,000 sf). The first guess of the cistern size is also entered by the designer. An evaporation/loss factor is included to account for losses through the collection screens and by evaporation off of the roof. Next, the designer may set the maximum and minimum tank volumes in terms of tank percentage. Remember, a tank (in this example 3000 gallons) cannot be used for the full volume. The tank cannot be drawn down to zero and the overflow has to be set somewhat below the top of the tank. The useable volume in this case is calculated (70%). To the right, the designer can select how many days per week the building is expected to be in operation by selecting the days. Monday through Friday represents 260 days per year. This is also a LEED template number to be entered. Next, the designer calculates the number of gallons per day expected to be consumed (1,649 gallons from the LEED calculation template we set up above), whether it is flushing fixtures, watering a lawn or supplying a cooling tower. The total in gallons per year is calculated at the right (in this case 428,740 gallons).

Through the inventory tracked day to day by the historical data and the cistern size and daily use rates, the total quantity of rainwater used to supply the system is provided (in this case 125,474 gallons each year on average) as well as the overall reduction in city water use this represents, in this case 29.2 percent. By manipulating the cistern size and catchment area, this percentage can be adjusted up or down to meet the design goal.

Does a 29.2 percent reduction seem small? It might at first glance. However, in this example for flushing toilets and urinals, the calculated reduction in water use through the selection of low-consumption fixtures is 36 percent from the baseline design case. When you add in the 125,474 gallons per year figure in the appropriate cell of the LEED template as “reclaimed water”, it will factor in an additional reduction for a total reduction of 54.7 percent which is well over the 50% reduction in sewage conveyance water for the LEED Credit WE-2 “Innovative Wastewater Technologies.” And this is achieved with a cistern only 11% the size of the cistern sized using the European Standard guidelines (i.e. 6% rule).

The listed “percentage overflow” value shows how often the cistern went into overflow due to excess rain water collected. Obtaining a high value is a good indicator of maintaining fresh water in the cistern due to the turnover of stored water with new, fresh rainwater. A very low overflow percentage indicates a tank that experiences long periods of stagnant water which is not beneficial.

By the way, what if the cistern volume of 28,000 gallons is plugged into this spreadsheet? What would the annual rainwater captured and what would be the percentage reduction? The result is 295,700 gallons of rain used a year for flushing with an overall reduction of 80%. However, the percent overflow each year is only 11.4% indicating that there are long residence times in the cistern where anaerobic decomposition can potentially take over. Now, if achieving an overall 80% reduction in water use is a goal of the project, then the 28,000 gallon cistern would be necessary. On the other hand, if achieving only the LEED points for innovative wastewater technologies by reaching 50% or just over, then the 28,000 gallon cistern would be a massive oversize and would add an unnecessary $50,000 to $70,000 to the harvesting system.

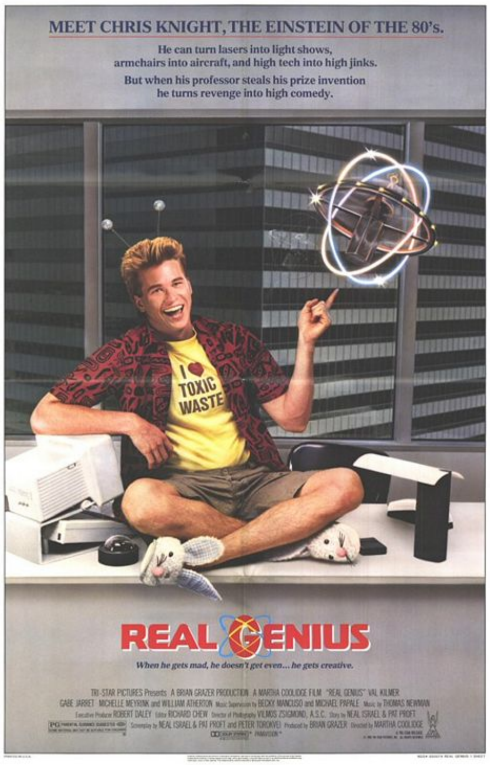


Figure 25: You, after this course

Hopefully the reader has been able to pick up on and understand the reasons for water handling and treatment methods used. Again, the described “four-step” process of collecting, storing and transferring water has been a proven method used in Europe for decades. Also, a detailed day to day inventory of cistern status is possible through spreadsheet analysis and is arguably the most reliable and rigorous analysis that can be documented for LEED certification purposes.

Rainwater harvesting is becoming more and more ubiquitous in plumbing design. Try to be the Chris Knights out there (without the I love toxic waste t-shirt).

About the Author: John Rattenbury, PE, LEEDap is an Associate at the Boston-based firm R. G. Vanderweil Engineers, LLP and he is a registered professional engineer in multiple states. He has had experience in rainwater harvesting system design going back to 1998 where he designed a system for the Ray and Maria Stata Center on the MIT campus in Cambridge, Massachusetts. He was chief engineer for the Salem, Virginia based company Rainwater Management Solutions from 2003 to 2007, where he became a close associate of Dr. Hans-Otto Wack, PhD of the Wisy AG Corporation. He is currently a committee member of the ASPE work group finalizing the Rainwater Harvesting Design and In

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[i] The Ripple Effect. Loc 163-73

[ii] All figures and photos shown are used courtesy of the Jay R. Smith Manufacturing Company, Rainwater Management Solutions, Inc., and WISY, AG.