

SAN FRANCISCO

# rainwater harvesting manual

for non-potable residential uses

*April 2016 Version - Updates will be published as necessary*

A dark blue silhouette of the San Francisco skyline, including various buildings and a prominent tower with a spire, positioned above the title.

SAN FRANCISCO

# rainwater harvesting manual

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# CONTENTS

Introduction	1
Background	1
Why Harvest Rainwater?	2
Planning Your Rainwater Harvesting System	5
Site Analysis	6
Water Budget	7
Designing Your Rainwater Harvesting System	13
Catchment	14
Conveyance	15
Downspout Disconnection	16
Debris Removal	17
Storage	19
Water Treatment	24
Distribution & Use	24
Toilet Flushing	26

Permitting	29
Permit Requirements	30
Operation and Maintenance	33
Catchment Surface	34
Conveyance Elements	34
Storage Tanks	35
Distribution System	37
Treatment System	37
Backflow Prevention Assembly	37
Glossary	41



*Rainwater harvesting system at local residence*

# Introduction

The San Francisco Rainwater Harvesting Manual for non-potable residential uses is a technical guide for residential rainwater harvesting in San Francisco. After reading this manual, you will be able to plan and design your own rainwater harvesting system and feel confident permitting it through the San Francisco Department of Building Inspections' Plumbing Inspection Division (DBI/PID). While this guide focuses on residential roof-based rainwater harvesting systems, some of the information presented is relevant to larger commercial systems as well.

Since 2008, the San Francisco Public Utilities Commission (SFPUC) has offered a variety of rebates and incentives to residents to encourage rainwater harvesting. The Residential Rain Barrel Program provides rain barrel rebates to residents. Additionally, the SFPUC has partnered with the City's Community Challenge Grant Program to offer Urban Watershed Stewardship Grants for community-based projects which help manage stormwater using ecologically based strategies, including rainwater harvesting. These programs not only help to reduce San Francisco's potable water demand and impact on the sewer system, but also educate residents about the City's water and wastewater systems.

For the latest on rainwater harvesting incentives, visit <http://sfwater.org/rainwater> and <http://sfwater.org/watershedgrants>.



*Photo Courtesy of Christina Berteau*

## Background

Rainwater harvesting is the practice of collecting and using rainwater from above grade hard surfaces, such as roofs, to be used as an alternative water source. It is an age-old technology; communities in ancient Rome were designed with individual cisterns and paved courtyards, which captured rainwater to augment supply from the city's aqueducts. Today, rainwater harvesting is growing in popularity as people look for ways to use water resources more wisely.

In 2005, City staff amended San Francisco's plumbing code via Ordinance 137-05, making it possible to disconnect downspouts from the combined sewer system and direct rainwater to alternative locations such as rain gardens, rain barrels, and cisterns. This led to the 2008 Memorandum of Understanding (MOU) between the SFPUC, Department of Building Inspection's Plumbing Inspection Division (DBI/PID), and Department of Public Health (DPH) which defined each department's role with respect to rainwater harvesting and set forth their consensus about rainwater harvesting system components and permitting requirements. In 2013, the California Plumbing Code incorporated Chapter 17, which established statewide requirements for non-potable rainwater catchment systems. The information in this manual is developed from the requirements of Chapter 17, which replaced the MOU and has been adopted by DBI/PID.

## Why Harvest Rainwater?

Throughout the United States, potable water is used for almost all water needs, such as drinking, showering, sanitation, laundry, irrigation, and manufacturing. However, water of such high-quality is not necessary for all applications. For example, water used for irrigation does not need to be potable. Rainwater is a relatively high-quality source of water and is an excellent option for broadening our water portfolio, allowing the quality of water to be matched to its intended use.



*Rainwater harvesting cisterns at a school in Portland, Oregon*

San Francisco allows the use of rainwater for outdoor and indoor non-potable applications. Indoor non-potable uses for rainwater include **toilet flushing, laundry, and heating and cooling**. Typical outdoor non-potable uses include **irrigation, ornamental waters (such as ponds, fountains, and other water features), and vehicle washing**. This manual focuses on non-potable residential outdoor irrigation and toilet flushing. For permitting processes associated with different uses, contact DBI/PID at <http://sfdbi.org/plumbinginspection>, or call (415) 558-6570.

Rainwater harvesting is a simple and practical way for the average citizen to engage in watershed stewardship. The following chapters of this document describe the planning and design processes for rainwater harvesting projects, explains how to obtain permits for a system, and provides guidance for operating and maintaining systems.

One of the many ways to enhance your awareness of water in your life is to install a rainwater harvesting system. Other tips for conserving water and reducing water pollution are presented in Appendix B. Planning a rainwater



*Photo Courtesy of Oakland Rain Barrel Program*

harvesting system helps you understand where your water is coming from, what affects its quality, how you use it, and where it goes after you use it. If every household in San Francisco used just four barrels of captured rainwater for irrigation, over 71 million gallons of our high quality drinking water could be used

**Graywater recycling is another way to reduce potable consumption. To view the SFPUC Graywater Design Manual, please visit: <http://sfwater.org/graywater>.**

## References

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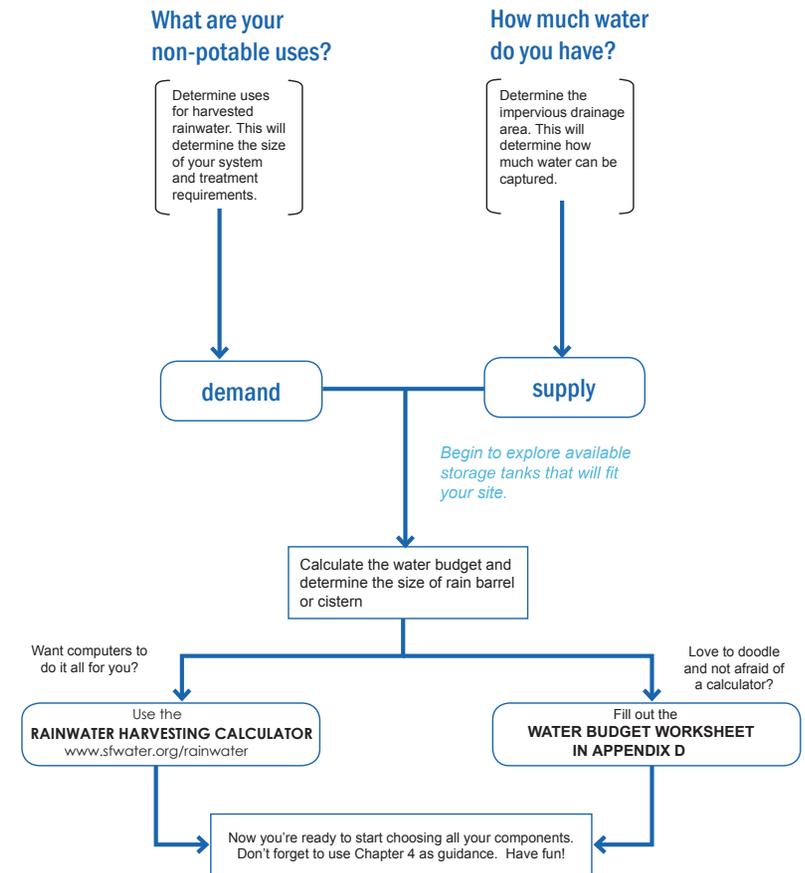
*Rain Barrels at Free Farm, San Francisco, CA.  
Photo Courtesy of Tap the Sky*

# Planning Your Rainwater Harvesting System

Planning a system begins with conducting a site analysis and completing a water budget. The decision about how much water to capture is affected by the desired uses for the rainwater, property characteristics, and project budget. These factors will determine the size of the storage tank and where it can be located. These site-specific considerations help to determine the type and size of each rainwater harvesting system (See Figure 1). The SFPUC has developed a Rainwater Harvesting Calculator to assist in this process. Please visit <http://sfwater.org/rainwater> to download the calculator.

The two main steps to planning your rainwater harvesting system are:

1. Site analysis
2. Water budget



*Figure 1. Decision Tree to plan your rainwater harvesting system.*

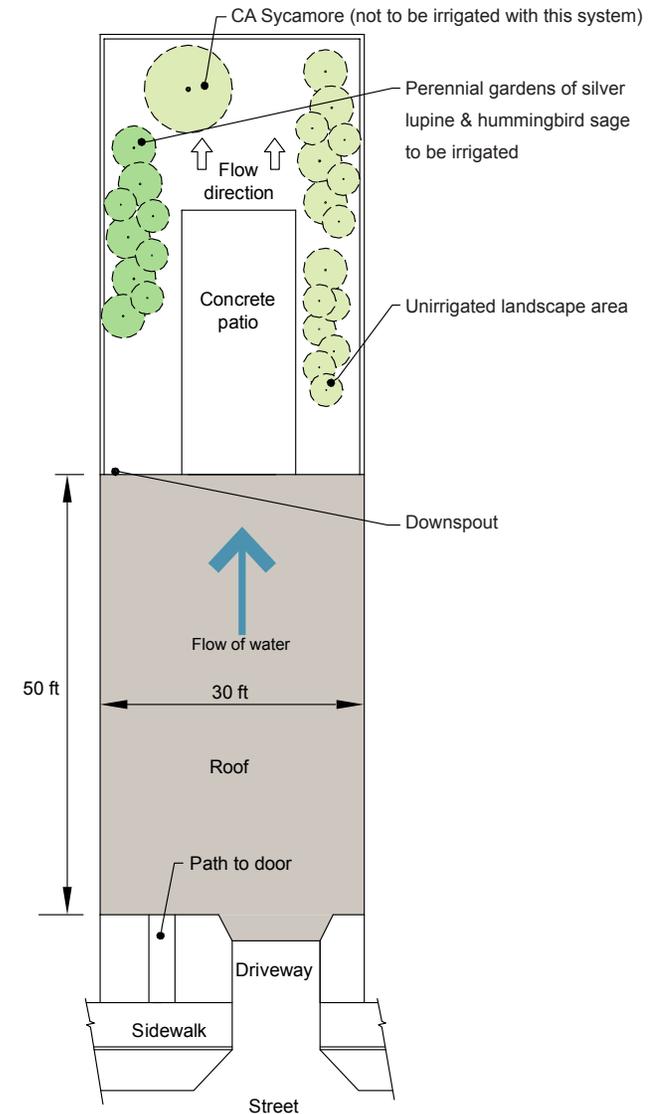
## Step I: Site Analysis

The first step in planning a rainwater harvesting system is to make a site plan. Prepare a map of the site showing high and low points and major site elements (existing structures, trees, large patches of vegetation or planted areas). The map can be hand-drawn for small residential projects or generated with design tools (such as AutoCAD). For an easy way to develop a site plan, locate your house on Google Earth (<http://earth.google.com>). You can use the program's measuring tools to estimate the dimensions of your property and catchment areas, such as a roof or patio.

After the basic map has been prepared, add existing drainage flow patterns. To do this, observe the site during rainfall and note existing drainage paths, places where water ponds or flows quickly, where water goes as it runs off your site, and whether water flows onto the site from adjacent property (Figure 2). Sketching and/or noting existing conditions assists in the design of a rainwater harvesting system that optimally captures runoff and fits into the construction or renovation project as cost-effectively as possible.

### What are the pre-existing conditions on your site?

- Catchment area (roof) material, condition, and possible sources of contamination (e.g. bird droppings)
- Gutter material and condition
- Location of downspouts
- Location of area drains, if any
- Slope, drainage, and flow direction
- Soil type



**Figure 2.** Example site analysis of a typical developed residential lot in San Francisco's Mission District.

### What are the components of your system and how will it be laid out on your site?

- Number and size of storage tanks needed
- Possible location(s) of storage tank(s)
- Relative elevation of the collection, storage, and application systems

### How might your system affect the surrounding area or infrastructure?

- Views to and from the site that might be affected by the project
- Adjacent land uses that might affect or be affected by the project
- Location of utilities (water, sewer, and electrical), whether they would affect or be affected by the project, and access issues, if applicable

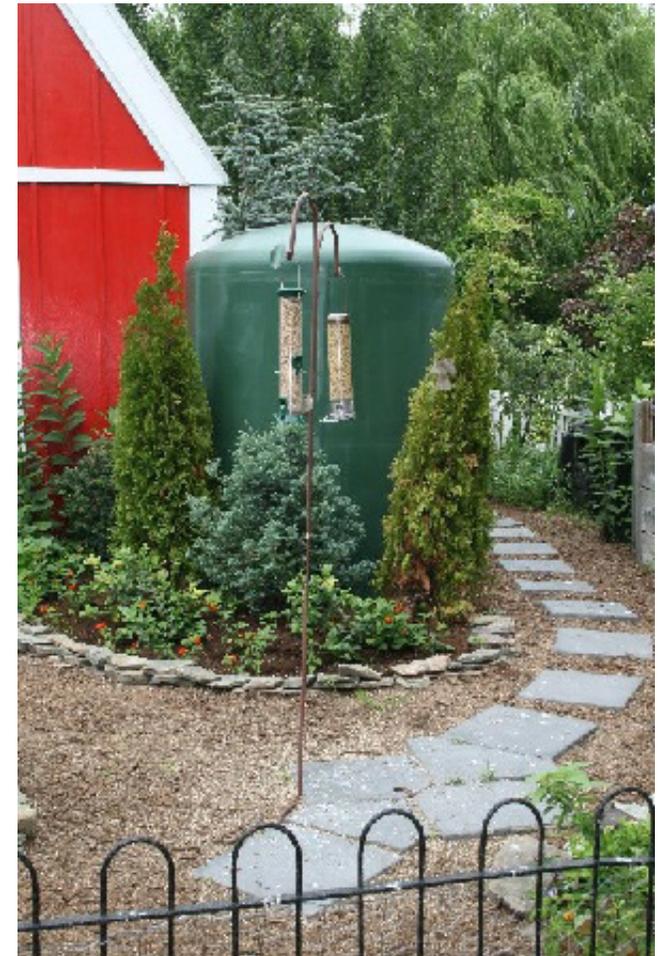
Conducting a thorough site analysis will help you plan and design a site specific rainwater harvesting system that best utilizes existing conditions to capture and use rainwater.

## Step 2: Water Budget

Once the site analysis has been conducted, the next step is to decide what size and type of system is appropriate for your site. A water budget analysis is used to determine the size of a system and includes an average of the site's water demand and water supply, while also considering local rainfall patterns.

**Demand** is the sum of the planned uses of captured rainwater. For example, if you will be using the rainwater for both toilet flushing and irrigation, the total demand is the sum of rainwater needed for those two uses.

If water is intended for outdoor irrigation, a factor called the landscape coefficient must be included in your calculations to account for the varied water needs of plants. The landscape coefficient will provide information on water lost to evaporation and transpiration in a landscaped area. The landscape coefficient is determined by the species type, density of plantings and microclimate in which vegetation is planted.



*Cistern placement at a residential property*

**Supply** is the total volume of rainwater your site can generate and is determined by the size of the catchment area and rainfall.

When determining the total water available, it is important to consider the percentage of rainfall that will be lost to infiltration, evaporation, and absorption. While this percentage varies depending on the characteristics of the catchment area, a runoff coefficient of .85 is commonly used for roof runoff.

**It is important to be aware that most systems designed for non-potable residential uses will not store the entire water supply due to various restrictions like cistern size and budget. Therefore, it is important to appropriately manage the overflow by directing it to a rain garden or an approved drain.**

**The Water Budget** incorporates local rainfall data and climatic factors into estimated supply and demand calculations to correctly size your system.

To select an appropriate amount of storage capacity, estimated water demand and water supply must be considered in relation to rainfall distribution, historical span of dry days, and evapotranspiration (ET<sub>o</sub>) rates. As San Francisco receives most of its rainfall between October and April, it is necessary to consider this range in sizing your system and planning for potential make-up water during dry months.

The SFPUC's Rainwater Harvesting Calculator will help you calculate the above factors; visit <http://sfwater.org/rainwater> to download the calculator. The calculator includes automated spreadsheets that enable the user to easily calculate indoor and outdoor demand, supply, and water budget.

If you would like a step-by-step process of how to calculate your site's water supply, water demand, and water budget without using the SFPUC's Rainwater Harvesting Calculator, see Appendix D.

On average, over 16 billion gallons of rainwater falls on San Francisco every year. Imagine if we could capture and store a large portion of that water and reuse it for non-potable uses.

## Example Calculations

To illustrate basic calculations for water demand and water supply, the Mission District home in Figure 2 is used as an example on the following pages.

For the purposes of this example, a rainwater harvesting system will be designed to irrigate one landscaped area within the site. Appendices C and D illustrate advanced calculations to design a larger system that incorporates irrigation for all landscaped areas within the site.

### Example Calculation of Irrigation Demand

The following inputs were used in the SFPUC Rainwater Harvesting Calculator (see snapshot, Figure 4) to demonstrate basic calculations for the irrigation demand of the chosen landscaped area.

Area = 20 ft x 10 ft = **200 ft<sup>2</sup>** of landscaped area calculated from site plan

Species Factor,  $k_s = 0.3$  for the low irrigation needs of the chosen species

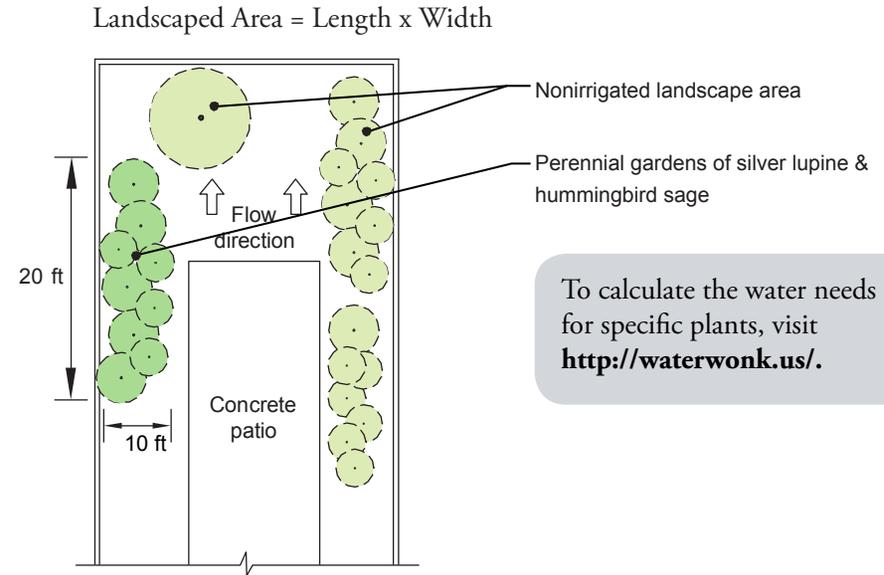
Density Factor,  $k_d = 1.0$  for average density of species, this is measured by 70 - 95 percent ground cover within landscaped area

Microclimate Factor,  $k_{mc} = 1.0$ , as the site is located in an area with average wind and heat

Irrigation Efficiency = **0.90** for a drip irrigation system

Site Location = Eastern SF, as the site is located in the Mission District

For more information on selecting *k* factors, visit "A Guide to Estimating Irrigation Water Needs of Landscape Plantings in California" at <http://www.water.ca.gov/wateruseefficiency/docs/wucols00.pdf>.



To calculate the water needs for specific plants, visit <http://waterwonk.us/>.

Figure 3. Dimensions of landscaped area for example site.

### Irrigation Demand

Turf/Crop Area to be Irrigated		ft <sup>2</sup>							gal/mo	
Crop Coefficient - Kc			cool season grasses = 0.8, warm season grasses = 0.6. Please see CIMIS publication for more information.							33
Landscape Area to be Irrigated	200	ft <sup>2</sup>							42	
Species Factor - $k_s$	0.3		<0.1 for very low, 0.1-0.3 for low, 0.4-0.6 for medium, 0.7-0.9 for high. See p. 62-99 of Guide (DWR 2000).							94
Density Factor - $k_d$	1.0		0.5-0.9 for low, 1 for average, 1.1-1.3 for high. See p. 18 of Guide (DWR 2000).							136
Microclimate Factor - $k_{mc}$	1.0		0.5-0.9 for low, 1 for average, 1.1-1.4 for high. See p. 19 of Guide (DWR 2000).							178
Landscape Coefficient - $K_L$	0.3		$K_L = k_s * k_d * k_{mc}$							207
Total Irrigation Area	200	ft <sup>2</sup>							205	
Average Coefficient	0.30								191	
Irrigation Efficiency	0.90		Estimated efficiencies are 0.70 to 0.85 for spray, 0.9 for drip, 0.95 for subsurface drip.							159
Site Location (ETo Zone)	Eastern SF		Select Western if located in the Richmond, Sunset, or Lake Merced areas of San Francisco							104
									57	
									28	
									<b>1,436</b>	

Figure 4. Screen shot of the SFPUC Rainwater Harvesting Calculator with example user inputs (green cells) and calculated irrigation demand by month.

## Example Calculation of Water Supply and Water Budget

Calculating the available water supply requires three variables: runoff coefficient and rainfall rate, which are determined within the SFPUC rainwater harvesting calculator, and catchment/drainage area, which must be calculated by hand. The below inputs (see snapshot, Figure 6) were used to determine the water supply and water budget.

**Impervious Drainage Area** = 30 ft x 50 ft x 1/2 = **750 ft<sup>2</sup>** of catchment area as rainwater is only being captured from one side of the tented roof.

**Circular Cistern** chosen with Diameter = **5 1/2 ft** and Depth = **4 ft**. Sizing adjusted through trial-and-error to meet site constraints and performance goals.

$$\text{Catchment Area} = \text{Length} \times \text{Width}$$

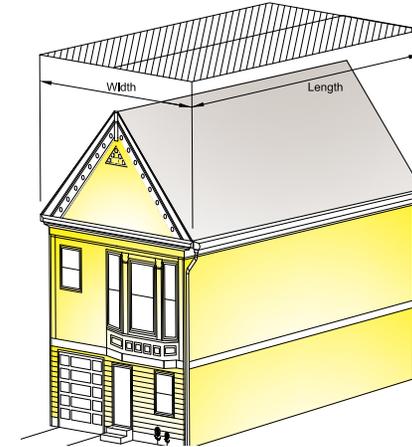
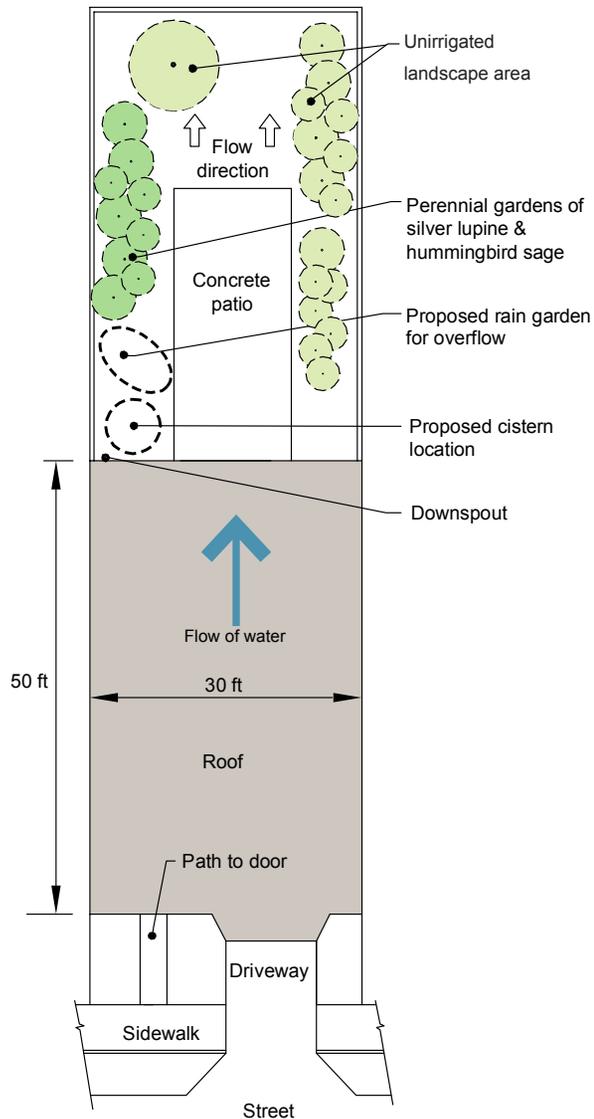


Figure 5. Catchment area for example site.

## Cistern Design and Performance

Impervious Drainage Area	750	ft <sup>2</sup> (Enter roof area, paved area, etc. that drain to cistern.)	
Pervious Drainage Area		ft <sup>2</sup> (Enter allowed pervious areas that drain to cistern. This is not recommended.)	
Avg. Runoff Coefficient	0.85	Recommend 0.85 for roofs. Please refer to page 93 of the Stormwater Design Guidelines for other values.	
Shape of Cistern Footprint	Circular	Select Circular or Rectangular	
Cistern Diameter	5.50	ft	
N/A		ft	
Cistern Depth	4.00	ft	
Depth of Additional Detention		ft (Enter the depth of any additional detention storage within the cistern footprint)	
Detention Orifice Diameter		in	
Cistern Surface Area	24	square ft	Adjust the cistern size until the desired performance is achieved (e.g., CSS performance measures met or 100% of runoff captured). Annual cistern performance is summarized in Step 4 while the 10-year daily precipitation data and the daily cistern performance over an average wet season are shown in the graphs below. The "Available Cistern Volume prior to Design Storm Event" is used as the starting volume for the calculations to evaluate performance during the 1- and 2-yr 24 hr design storms in the "CSS BMP Sizing Calculator". Check results in Steps 5 and 6 of the "CSS BMP Sizing Calculator".
Cistern Volume	711	gallons	
Detention Volume	0	gallons	
Average Volume in Cistern prior to each Rainy-Season Storm Event	651	gallons	
<b>Available Cistern Volume prior to Design Storm Event</b>	<b>60</b>	<b>gallons</b>	
Average Annual Runoff Captured and Reused	14%	Average annual percentage of runoff captured in the cistern for reuse onsite	
Ave. Annual Non-Potable Demand <b>Met</b> by Rainwater Harvesting	83%	Average annual percentage of non-potable water demand supplied by water captured in the cistern for reuse	

Figure 6. Screenshot of the SFPUC Rainwater Harvesting Calculator with example user inputs (green cells) and cistern performance outputs (white cells).



**Figure 7.** Example site plan of a typical developed residential lot in San Francisco's Mission District.

## Example Calculation Summary

The cistern at the Mission District residence will capture 14% of the annual runoff, meeting 83% of its non-potable demands. Any cistern overflows occurring during large storm events will be directed to a proposed raingarden on-site.

## References

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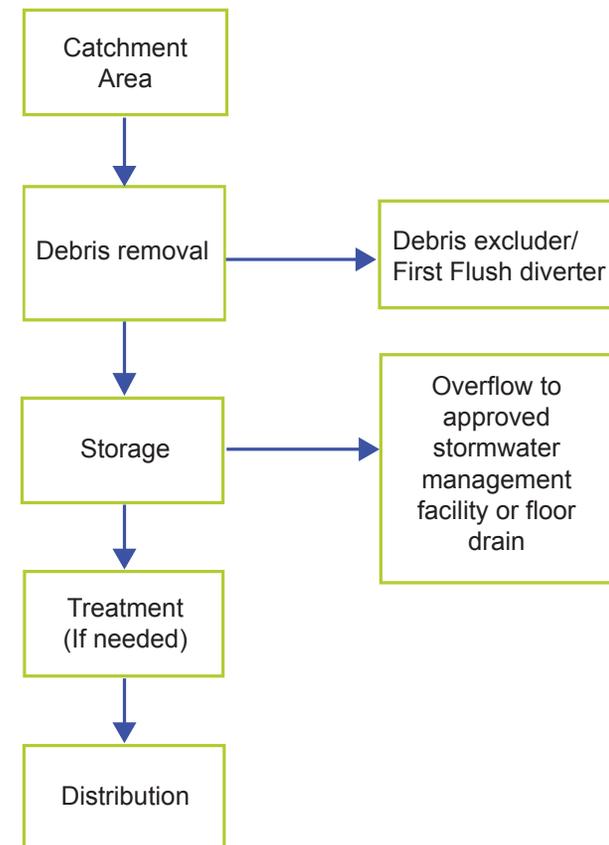
*Rainwater system completed by Dig Cooperative for the Oakland Rain Barrel Program.*

# Designing Your Rainwater Harvesting System

Rainwater harvesting systems begin at the point of collection and end at the point of use of an approved plumbing fixture. A rainwater harvesting system typically consists of six basic components (Figure 8):

1. Catchment area: the surface upon which the rain falls.
2. Conveyance: channels or pipes that transport water from the catchment area to storage.
3. Debris removal: device that filters and removes contaminants and debris.
4. Storage: cisterns or tanks in which collected rainwater is stored.
5. Treatment: filtering and/or other physical/chemical treatment to the level of purity needed for the intended use.
6. Distribution: the system that delivers the rainwater, either by gravity or pump, to its point of use.

Each of these components is discussed in this section. When designing your system, check in with DBI/PID to confirm compliance.



**Figure 8.** Components of a rainwater harvesting system.



*Clay shingle roof*



*Tile and asphalt shingle roof*



*Tar and gravel roof*



*Treated galvanized roof*

A **catchment area** is the total area of a landscape that drains to a particular site or drainage. As used in rainwater harvesting practice, catchment area refers to the area, such as a roof, that drains to a rainwater storage system.

## Catchment

The quality of captured rainwater depends, in part, upon catchment texture: the highest water quality comes from smooth, impervious catchment surfaces. Impervious materials improve the efficiency of rainwater catchment systems by absorbing less water and reducing the chance for microbes and debris to collect in the pores and/or seams of the catchment surface. Smoother surfaces also allow the rainwater to flow faster and thus “clean” the catchment area. Metal, clay, and concrete tile roofing will generate the cleanest water.

Some roofing material is not appropriate for rainwater harvesting, and older roofs can negatively affect water quality due to leaching. Rainwater should not be harvested from roofs with copper or treated with fungicides or herbicides. Also, roofs entirely covered in untreated metal, such as galvanized roofs, should not be used without treatment to remove the zinc, which can harm vegetation. (Zinc is used to kill moss on roofs.) Because rainwater is slightly acidic (pH between 5.0 and 6.5), it dissolves minerals from the catchment surface and carries them into the storage system. Water for irrigating edibles or that will come into contact with humans should not be collected from roofs containing untreated zinc coatings, copper, asbestos sheets, or from roofs with lead flashings, painted with lead-based paints, or containing fungicides, algacides, or any other biocide compound. These types of materials can release a variety of organic and inorganic chemicals as they age and can present a health threat if consumed. If you have any questions regarding your roof material and if it is appropriate for rainwater harvesting, check with DBI/PID at <http://sfdbi.org/plumbinginspection>, or call (415) 558-6570.

In San Francisco, common roofing materials are asphalt shingle, tile, and tar and gravel. Building owners should assess the type and condition of their catchment surfaces to see if they are appropriate for the intended use of the captured rainwater. Table 1 lists common roofing materials and their suitability for rainwater harvesting.

**Table 1.** Suitability of roofing materials.

Roof Material	Suitable for Collection
Tile	Yes
Metal: treated to remove zinc	Yes
Membrane with waterproof coatings	Yes
Galvalume	Yes
Concrete	Yes
Asphalt shingle	Yes
Tar and gravel*	Yes
Metal: galvanized or copper	No
Wood (treated)	No
Any material with lead flashing, painted with lead-based paint, or containing asbestos	No

\*Note: Newly installed tar-and-gravel roofs can leach chemicals into rainwater. Rainwater collected from tar-and-gravel roofs should not be used for watering vegetables (or any other plant to be consumed) until the roof is at least one year old.

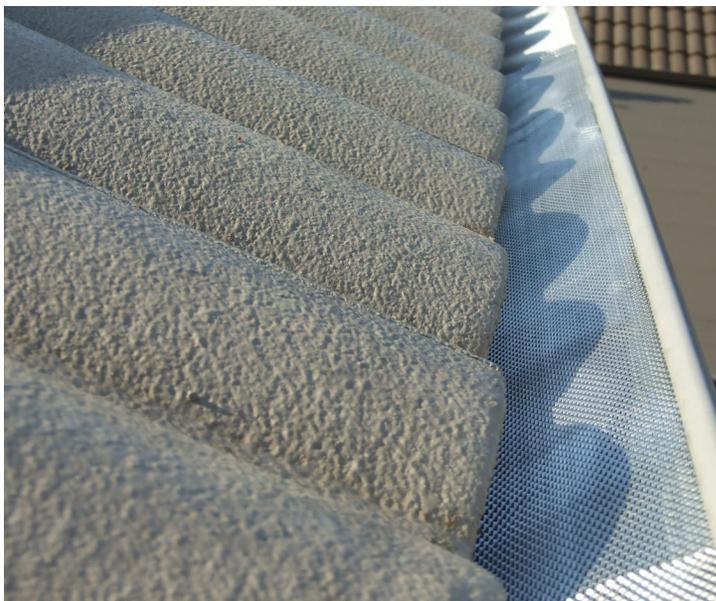
## Conveyance

Rainwater is usually conveyed from the catchment area to cisterns or rain barrels by gutters connected to downspouts. Gutters that convey rainwater for harvesting must comply with the most recent edition of the California Plumbing Code (<http://www.iapmo.org/Pages/2013CaliforniaPlumbingCode.aspx>). It is important to avoid joint seams in a gutter system, because they can catch debris and promote the growth of bacteria and algae. For this reason, a half round gutter is better than a square one, which is more likely to catch debris.

Gutters should have an outer edge higher than the roof-side edge, have splash guards at roof valleys, and slope towards downspouts. Seamless gutters should slope at approximately one-sixteenth inch per 10-foot length of gutter, and all gutters should be installed in accordance with the manufacturer's guidelines for hangers and connection points (approximately one bracket every 30 inches).

## San Francisco requirements for rainwater conveyance systems:

- Installation of gutters, leaders, downspouts, piping, fittings, valves, and screens must comply with the most current edition of the California Plumbing Code.
- All plumbing materials must be listed with a recognized testing agency such as ANSI (<http://ansi.org/>), NSF International (<http://nsf.org/>), IAPMO (<http://codes.iapmo.org/>).
- Conveyance systems must have debris removal devices installed according to manufacturer's instructions,



**Screened gutter.** Leaf screens are typically one-quarter-inch mesh screen set in metal frames.

If replacing your gutters, consider using full length gutter screens. For screens to continue to be effective, they must be cleaned regularly. An established cleaning regimen will prevent debris build up, which can be a fire hazard, act as a growing medium for bacteria, and/or block water from entering the gutter.

Downspouts convey water from gutters to the storage tank. The number of downspouts needed depends on the surface area of the roof and intensity of rainfall. As a general rule, a 3- to 4-inch downspout accommodates about 1,200 square feet of roof area. Angles in the downspout pipe should not exceed 45 degrees to reduce the likelihood of debris accumulating in the angles and blocking rainwater flows. Downspouts can be fitted with filtration devices such as rain heads and leaf eaters, which exclude leaves and debris. Downspouts are the most common means of moving water from a raised surface to a storage facility.

## Downspout Disconnection and Tie-ins

Most downspouts in San Francisco connect directly to the City's sewer system and may need to be disconnected to allow for rainwater harvesting. If necessary, downspouts should be disconnected high enough above the cistern or rain barrel so that an elbow and additional pipe section can be added and still allow the rainwater to flow downward by gravity to the storage tank. **The lower section of the downspout should be cut near the ground surface and sealed with a cast iron pipe cap with a no-hub band to prevent sewer gases from escaping or sewage backing up and overflowing through the cut pipe.**

Many downspouts in San Francisco are not readily accessible on the outside of a building near the storage tank. Some downspouts are on the street-side of the building with no ready route to the backyard. Others are located inside a building's walls. These situations require site-specific solutions and often consultation with a plumbing professional. Here are some possible scenarios and solutions:

- Buildings with garages below street grade often have the downspout connecting to sewer laterals on the ceiling of the garage. Downspout(s) can be disconnected there and routed to the desired location. A downward slope from downspout to tank is required so that water does not back up into the downspout.

- If a downspout is within a building's wall but near the location of the storage tank, the wall can be opened to access the pipe. (If the pipe is in an interior wall, disconnection is less feasible because of increased cost and potential disruption to the building.) This option should be discussed with a professional plumber to identify the most appropriate and cost-effective solution and to minimize the amount of reconstruction necessary.
- If a downspout is located within a building's wall and in an inaccessible location, it might be possible to cap the top of the downspout at roof level and redirect rainwater to a new downspout.

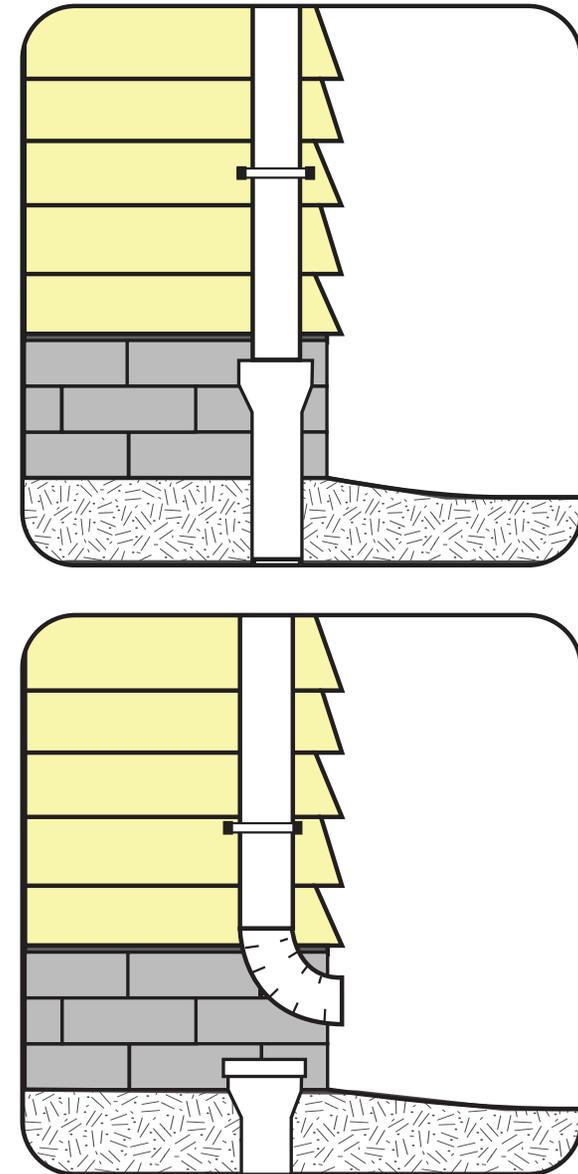
Downspouts can be disconnected by the homeowner or a professional plumber; DBI/PID will check for a proper seal of the capped sewer line during final inspection for a rainwater harvesting permit.

Some packaged rain barrel systems do not require you to disconnect your downspout, but have the necessary tools and instructions to apply a downspout diverter or tie-in. This consists of punching a hole in the downspout and adding a diversion connector to move water from the downspout into the storage tank. Check the items included in a packaged system for downspout connection types.

## Debris Removal

As rainwater travels across a catchment surface, it can pick up leaves and debris. Chapter 17 of the 2013 California Plumbing Code requires systems to be equipped with debris removal devices to prevent this debris from entering the storage tank. Common devices for debris removal include screens on gutters, debris excluders on downspouts and first-flush diverters on the downspout connection. Water quality and minimum treatment depend on the end use of the collected rainwater. When designing debris removal for your system, refer to Table 2 on page 22 for minimum treatment and water quality for each approved end use.

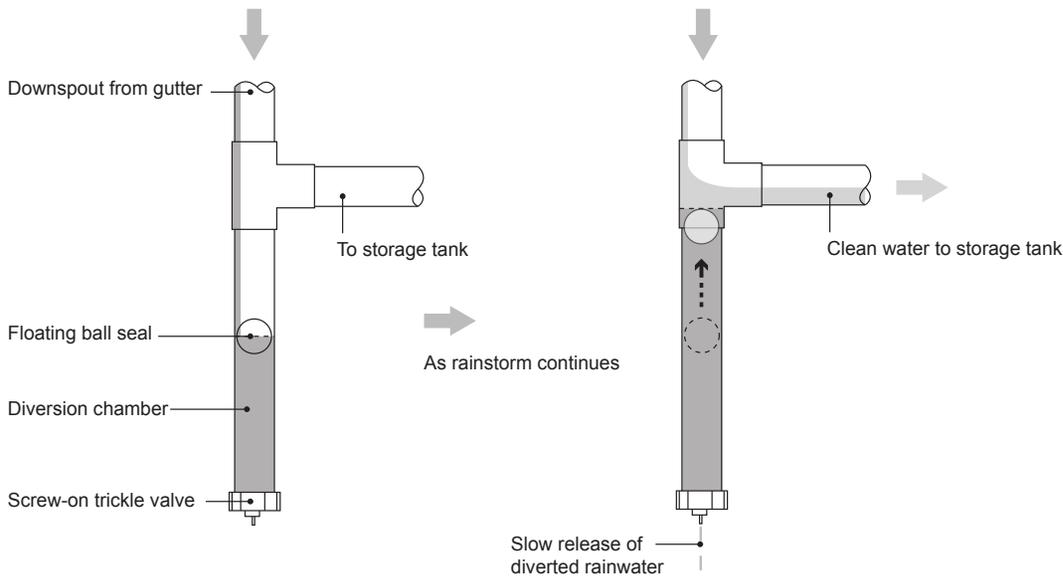
Debris excluders or similar devices will prevent the accumulation of leaves, needles, and other debris from entering the storage tank. In addition to larger debris, rainwater can dissolve or pick up materials too fine for the screens to filter out. To catch these



*Figure 9. A connected downspout (top) and a disconnected downspout (bottom).*

pollutants, the first portion of rainwater from any rain event that flows off the catchment area should be diverted, or “flushed,” from the storage tank. This “first-flush” of water, which carries the highest concentration of dust, pollen, animal feces, pesticides and/or other airborne residues, should be diverted from the storage tank to ensure higher quality water enters the tank.

Many types of first-flush diverters are readily available; all must be installed “upstream” of the storage tank. The simplest first-flush diverter consists of a PVC standpipe connected to a downspout. The standpipe acts as a storage device to collect the initial rainwater runoff; after it fills up, cleaner rainwater flows into the storage tank.



**Figure 10.** Floating ball first-flush diverter.



*Packaged system with Downspout diverter*  
 Photo Courtesy of Oakland Rain Barrel Program



*Rain head and First flush diverter*  
 www.fubiz.net

A ball-valve first-flush system is a common system that is similar to a standpipe first-flush system except it has a floating ball that seals off the top of the diverter pipe when the pipe is full, allowing clean water to move into the storage tank (Figure 6). More refined first-flush systems can include removable filter inserts that provide additional filtration.

## Storage

### Cisterns and Rain Barrels

Wide selections of storage tanks are available. In addition to the tank itself, components include a water inlet, water outlet, overflow pipe, access hatch, and means of draining (Figure 8). A storage tank can be made of stone, steel, concrete, ferrocement (steel-reinforced cement), plastic, or fiberglass. A storage tank should be opaque, durable, able to withstand the forces of standing water, watertight, clean, have a smooth inside, be sealed with a non-toxic joint sealant, and easy to operate. A tight cover is essential to prevent evaporation and mosquito breeding and to keep out other insects, birds, lizards, frogs, and rodents. Tanks should be opaque to prevent the growth of algae inside them.

The size and type of storage needed is dictated by several variables: rainfall quantities, water use demand, duration between rainfall events, catchment surface runoff coefficient, tank aesthetics, space availability, and budget. An important consideration for San Francisco buildings is whether a storage tank can fit through the available access to the desired location; in some cases, a crane might be needed.

The term “cistern” generally applies to storage tanks with a capacity greater than 100 gallons. Rain barrels typically have a capacity of less than 100 gallons (Figure 7). Rain barrels can be linked together to increase storage capacity. For optimal performance, rainwater collected in barrels/cisterns should be used between each rain event to provide capacity for capturing rainwater from the next rain event. By capturing water during every storm and then using it before the next rain, the sewer system benefits during every rain event.

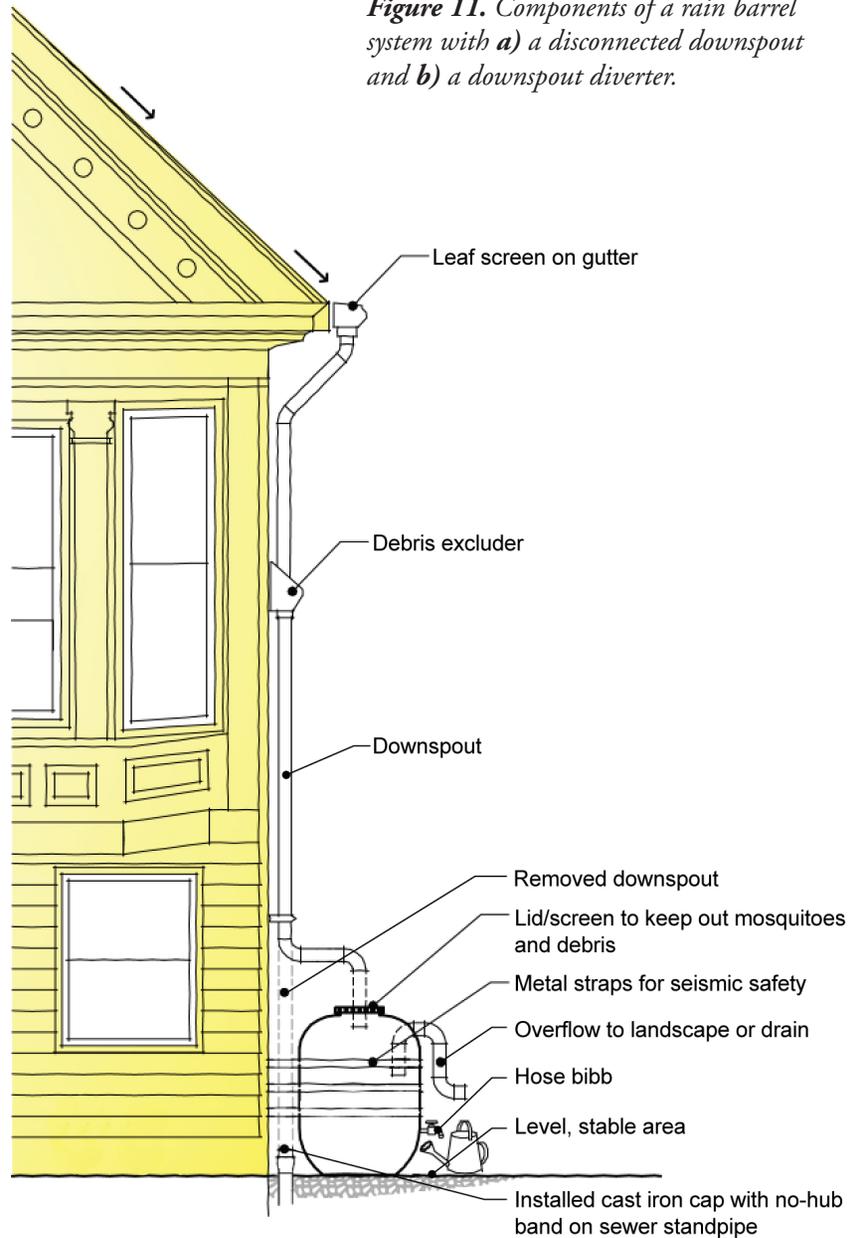


*Linked rain barrels*



*Underground storage tank at a local residence*

**Figure 11.** Components of a rain barrel system with **a)** a disconnected downspout and **b)** a downspout diverter.

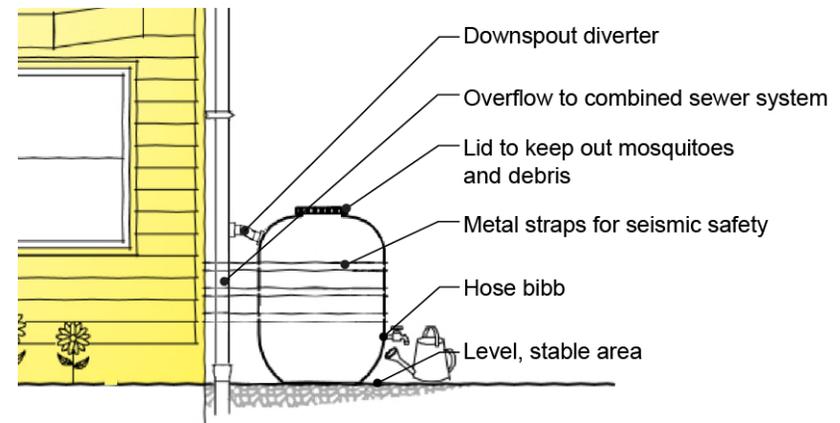


### Location

Rainwater storage should be placed as close to the catchment area as possible to reduce the distance the water must travel and thus the contamination potential. Tanks should also be located as close to the desired use as possible. If an alternate water supply or municipal make-up water is planned, then the tank should also be close to that source.

### Foundations

All tanks, whether above ground or below ground, need a firm foundation to support both the tanks and the water in them. The foundation needs to be located away from stormwater runoff from other parts of the site to avoid erosion. Above-ground tanks need to be placed on a stable, level pad with the water load evenly distributed. The pad can be a hard ground, pea gravel, sand, or concrete. For tanks over 500 gallons, a concrete pad or compacted gravel foundation is needed (they weigh over 4,000 pounds when full). Before installation, check the manufacturers recommendation for the foundation of your specific storage tank. Steep slopes should be avoided. Below-ground tanks might need to be anchored if the water table is high or back-filled with pea gravel if soil is prone to shrinking and swelling. In daisy-chained rain barrel systems, the barrels should generally be at the same level, but it is essential that “downstream” barrels not be at a higher elevation than “upstream” barrels to promote proper overflow.



## Seismic Safety

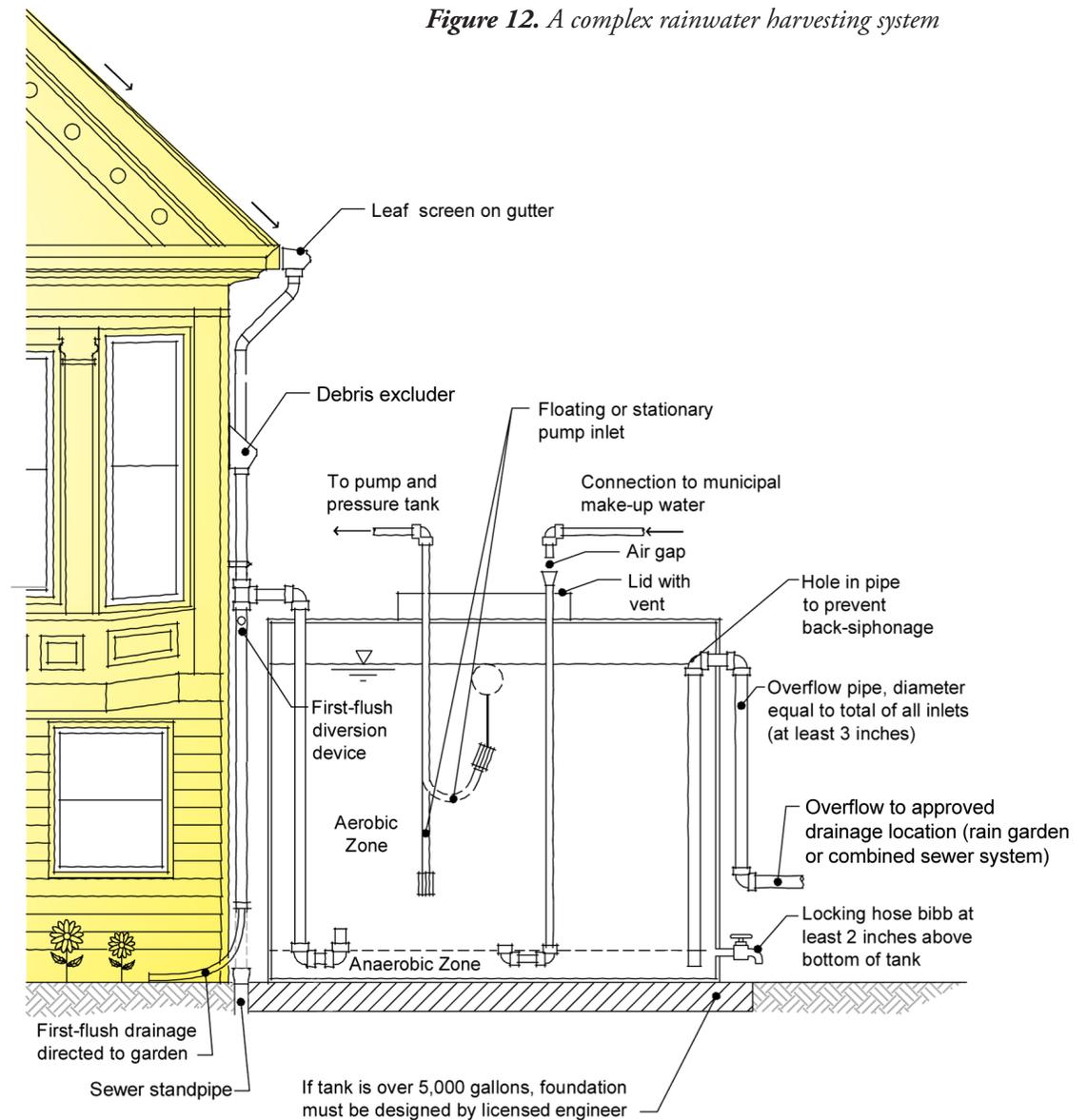
Seismic safety is a concern for all types of building projects in San Francisco. One gallon of water weighs a little over 8 pounds, so a 100-gallon rain barrel weighs over 800 pounds. Therefore, rain barrels must be appropriately secured. DBI/PID recommends securing rainbarrels to a structural wall with metal straps, similar to those used on a hot water tank. The location and number of straps will vary depending on size and shape of the storage tank. (Figure 7).

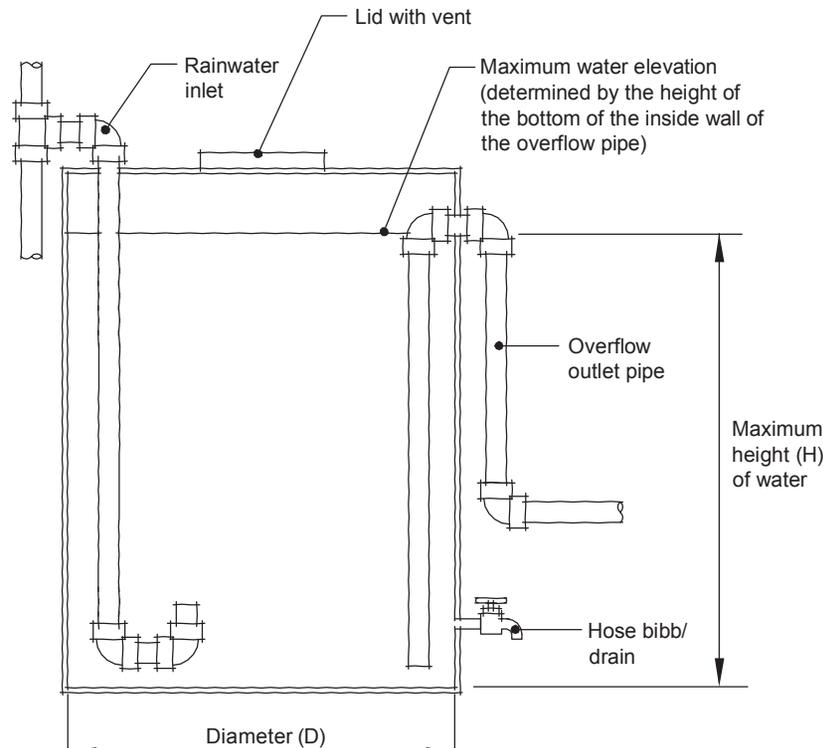
Storage tanks with capacity up to 5,000 gallons must have a maximum height-to-width ratio of 2:1 and must be installed on a foundation or platform in accordance with the California Building Code. Storage tanks over 5,000 gallons require a licensed engineer to prepare the system and an additional permit from DBI/PID.

## Water Inlets

For rain barrels, rainwater should enter into the top of the barrel (Figure 7). For cisterns, rainwater should enter the tank at the bottom, preferably through a water turbulence calming inlet (Figure 8) that will direct the water upward to minimize disturbance of the bottom anaerobic/sediment layer. Having the water enter at the bottom maintains the fully aged water near the surface, introduces oxygen near the anaerobic layer, and improves the overall aeration of the water in the tank.

Water can either be pumped from a tank or discharged through a valve by gravity. If it is to be pumped out, a floating pump intake is preferred, as it takes advantage of the natural stratification in storage tanks, avoiding the surface film and removing the fully aged water, which is the cleanest water in the tank.





**Figure 13.** Effective capacity of a storage tank.

**Design Tip:** The capacity of a cistern or rain barrel is the volume between the floor of the tank and the invert (bottom of the inside pipe wall) of the overflow pipe (Figure 9). The overflow outlet pipe invert is typically installed 10 to 12 inches below the top of the tank, so the top 10 to 12 inches of air-space should not be considered storage capacity. One reason for this excess space is to allow for the expansion and contraction of water due to seasonal temperature changes.

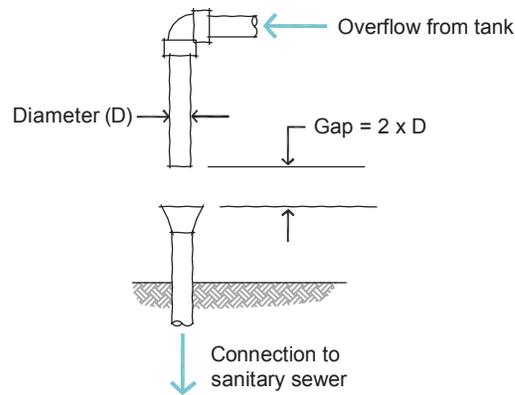
### Mosquito Protection

Mosquito protection is one of the main differences between cisterns and rain barrels. Mosquitoes are a concern with rain barrels, since some barrels have screen lids instead of tight impervious lids. Screens with a mesh size of less than 1 millimeter are effective at excluding mosquitoes; if necessary, mosquitoes can also be controlled with a biological pesticide (the bacterium *Bacillus thuringiensis* ssp. *israelensis*, abbreviated “Bti”) that kills mosquito larvae but is non-toxic to other insects, humans and wildlife. Such pesticides are sold as granules or “dunks” that last from two to four weeks.

### Make-Up Water and Backflow Prevention

If the stored water is primarily used for irrigation, it is recommended that make-up water is not used as it mixes potable water with non-potable water, disrupts the energy of the pressurized water, and requires backflow prevention. An alternative solution is to run parallel drip irrigation systems, where one is connected to the rainwater storage tank, and the other is connected to the city’s potable water system.

If make-up water is to be used, a Reduced Pressure Principle Backflow Prevention (RP) Device must be installed within 25 feet of the municipal water meter, with no fixtures between the assembly and the water meter. Additionally, an Isolation RP or an approved air gap must be present at the point where the make-up water enters the storage vessel. The RP must be easily accessible for reviewing and maintenance. An air gap is a physical separation between the supply pipe and storage vessel. The 2013 California Plumbing Code requires a minimum air gap of two times the inlet diameter (Figure 15) and no less than 1 inch, as measured to the overflow level. A typical air gap in a rainwater storage tank is 3 to 5 inches. (Note: Backflow prevention assemblies must be tested every year by a licensed professional, and results must be reported to the SFPUC’s Water Quality Division. For complete requirements and more information on backflow protection, locate the *Required Levels of Backflow Protection for Non-Potable Water Systems* document at <http://sfwater.org/np>.)



**Figure 14.** Overflow directed to the sewer with air gap.

### Overflow Outlet

All rainwater storage tanks must be equipped with an overflow outlet pipe that is directed towards an approved drainage location. The inlet of the overflow line should be placed to maintain the maximum high water line in the storage tank. The overflow can be directed to a landscaped area (e.g., to a permitted rain garden), additional cisterns or rain barrels, or to the municipal sewer system through an approved drain. If directed to the combined sewer system or an approved drain, the overflow outlet must be equipped with an air gap to prevent backflow. If directed to a rain garden or other approved stormwater feature, the feature should be sited at least 10 feet away from the tank and building foundations. Overflow pipes that discharge above ground need some means of stopping rodents and insects from entering the storage system. Fine screens (less than 1 mm mesh size) should be placed over the end of pipes that discharge above ground.



*Overflow directed to a rain garden at Lafayette Elementary*



*Overflow directed to an approved drain at Garden for the Environment*

## Water Treatment

Chapter 17 of the California Plumbing Code requires a minimum treatment and minimum water quality standard depending on the application of the harvested rainwater. The system designer is responsible for choosing the level of filtration needed to protect the proposed distribution system and must meet all requirements. For many applications, a debris excluder must be installed on the downspout to prevent plant material from entering the storage tank. Additionally, a 100-micron filter may be required, and should be installed between the storage tank and the irrigation lines and upstream of the pump. For certain applications, filtration and disinfection may be needed. Please refer to Table 2 for minimum treatment and water quality for each approved end use.

## Distribution & Use

Stored rainwater can be distributed by gravity flow or by pumping. Gravity is only effective if the storage tank is higher than the intended delivery point. If a gravity fed system is not possible and pumping is needed, the pump should be located near the tank and at or below the tank's outlet invert. The outlet invert is the lowest level of the interior of the pipe, where the water flow line resides. Ensuring the pump's inlet invert is lower than the tank's outlet invert will allow water to gravity feed to the pipe. If a pump must be installed higher than the tank's outlet invert, a submersible pump is recommended.

Application	Minimum Treatment	Minimum Water Quality
Car washing	Debris excluder	N/A
	100-micron filter	
Surface, subsurface and drip irrigation	Debris excluder	N/A
	100-micron filter	
Spray irrigation where the maximum storage volume is less than 360 gallons	Debris excluder	N/A
Spray irrigation where the maximum storage volume is equal to or greater than 360 gallons	Debris excluder	Escherichia coli:< 100 CFU/ 100 ml Turbidity :< 10 NTU
Toilet flushing, clothes washing, and trap priming	Debris excluder	Escherichia coli:< 100 CFU/ 100 ml
	100-micron filter	Turbidity :< 10 NTU
Ornamental fountains, aquariums, fish tanks, and other water features	Debris excluder	Escherichia coli:< 100 CFU/ 100 ml Turbidity :< 10 NTU

**Table 2.** Minimum treatment and water quality for rainwater (2013 California Plumbing Code, Chapter 17).



*Filling a watering can with a hose bibb*



*Drip irrigation system in planter*

## Irrigation

Collected rainwater is best distributed via gravity with a soaker garden hose, standard non pressure compensating drip emitters, or in a vessel such as a watering can with access from a hose bibb. To maximize the efficiency of gravity feeding:

- Use non-pressure-compensating emitters.
- Elevate the water source to increase pressure.
- Oversize any long lengths of tubing to reduce friction losses.
- Experiment by setting up part of the system and testing it before adding more rows or length.

If a subsurface drip irrigation system is to be used, or the water is to be pumped, then a 100-micron filter should be installed between the storage tank and the irrigation lines and upstream of the pump. Pump pressure ranges should be considered when choosing the most appropriate pump for your system. Standard municipal water supply pressures are typically 40 to 80 pounds per square inch (psi), while standard irrigation systems require 20 psi. It is important that the pump selected meet the water pressure desired for the intended use of the rainwater.

Many pumps are able to provide water to the irrigation system at a pre-determined pressure: 30 to 50 psi for sprinkler systems or 10 to 40 psi for drip systems. If irrigation system requirements are below the pump pressure range, a pressure reducer is necessary. Please note that gravity systems gain .43 psi per vertical foot of drop, so a few feet of elevation may make an emitter work. For timed irrigation discharge, a battery ball valve timer can be added to the connection. This device opens and closes with zero psi, while regular irrigation valves or battery-powered timers often do not open with gravity pressure.

For other types of irrigation, specifically spray irrigation systems, a minimum water quality standard may be required. See Table 2 for requirements.

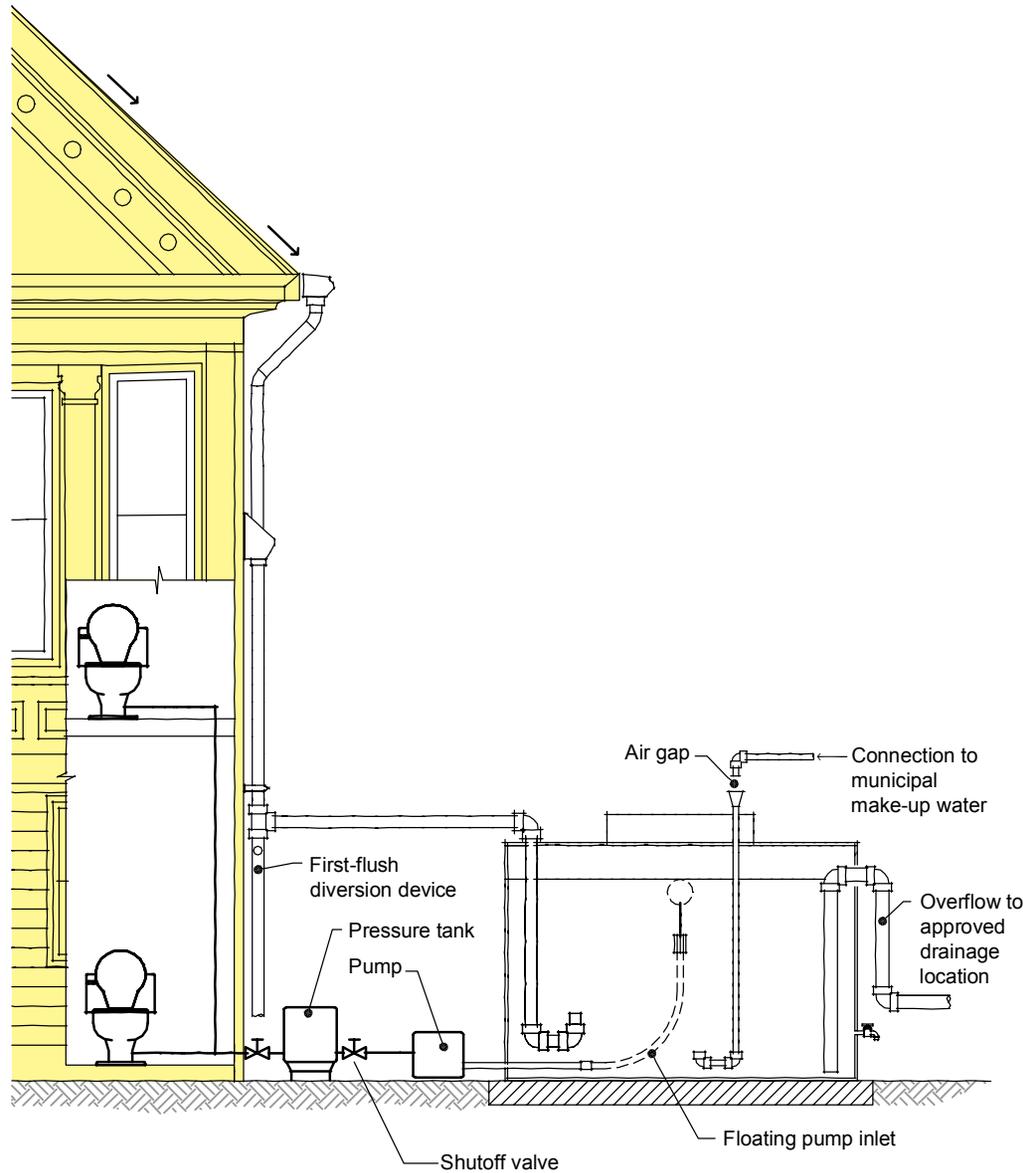


Figure 15. Rain water plumbed to toilet fixtures (treatment system not)

## Toilet Flushing

Rainwater is an appropriate water source for toilet flushing and can eliminate the need for municipal water for half the year or more, depending on the size of the tank and the toilet demand. To use harvested rainwater for toilet flushing, it is necessary to install dual plumbing, where one set of pipes carries the treated rainwater for toilet flushing, while a different set of pipes carries potable water for other uses. This is to prevent any mixing of the harvested rainwater with the potable water system or the sewer system. The installation of a dual plumbing system will establish a plumbing line that will deliver rainwater from the storage tank to the toilet. In most cases, municipal water would be required to supplement the rainwater during the dry months. DBI/PID requires that make-up water be added to the distribution system with appropriate backflow prevention – an air gap or isolation RP at the point of connection in addition to a Reduced Pressure Principle Backflow Prevention (RP) Device within 25 feet of the municipal water meter. Chapter 17 of the California Plumbing Code also requires a minimum treatment and water quality standards for harvested rainwater that is to be used for toilet flushing. (see Table 2 for requirements)

All systems for indoor use must be designed by a licensed professional. Pumps can be used to extract water from above-ground and below-ground storage tanks. Submersible or at-grade pumps can be used in any rainwater storage system. Self-priming pumps with floating filter intakes and automatic shutoffs—for times when water levels are insufficient—are optimal equipment. All components of a rainwater harvesting system should be installed according to manufacturer guidelines, and the owner/operator must ensure that all components are working properly and meet municipal codes.

## References

Forbes, Kieth A. *Bermuda's Architecture*. Available at <http://www.bermuda-online.org/architecture.htm>

<http://www.dripirrigation.ca/>

Meinzen, Stacey, 2009. *Rainwater Harvesting Policies throughout the US*. Website by Climate Action Plans. Available at <http://www.climateactionplans.com/2009/07/rainwater-harvesting-policies-throughout-the-us/>

### Rainwater Harvesting & Solar Cells

Photovoltaic panels on a building's roof can complement a rainwater harvesting system by providing a smooth, impervious surface for capturing rainwater. Solar panels can be used to shade storage tanks while generating renewable energy to power electrical components of the system, such as pumps, or supply electricity for other building needs.

### Rainwater Harvesting and Vegetated Roofs

Vegetated roofs and rainwater harvesting systems can mutually benefit each other. During rainy weather, the vegetation and underlying soil absorb some of the rainfall, pre-filter rainwater before it enters the roof gutters, and delay flows to the combined sewer. During dry weather, rainwater harvesting systems can be used to irrigate roof vegetation. Additional requirements and review may be necessary for these systems due to the increase in organic matter. Contact the SFPUC for specific requirements.



*Photo Courtesy of Oakland Rain Barrel Program*



PRODUCT NUMBER  
BLPT 660 / TS 540

**RAINWATER**

*Storage Tank at Alice Fong Yu Elementary*

# Permitting

Permitting for rainwater harvesting systems must conform to the requirements of DBI/PID and the California Plumbing Code. Be aware that other codes may apply depending on the design of the system.

Chapter 17 of the 2013 California Plumbing Code specifies allowable uses of harvested rainwater and sets forth guidance on permitting requirements for rainwater harvesting systems. This document encourages the use of rainwater for non-potable applications and contains treatment requirements for harvested rainwater (see Table 2).

DBI/PID issues all permits necessary to install a rainwater harvesting system in a single or dual family home. The Department of Public Health reviews permit applications for uses of rainwater in multi-family (3 units and up) and commercial projects. For more information on the permitting process for multi-family and commercial projects, please visit [www.sfwater.org/NP](http://www.sfwater.org/NP). The SFPUC creates and distributes guidance material, and provides technical and financial assistance for larger projects.



*Photo Courtesy of Oakland Rain Barrel Program*



*Cisterns at Clarendon Elementary School*

## Permit Requirements

### **If your downspout is connected to the sewer system:**

- You will need a permit from the DBI/PID. Permit requirements include a basic site map identifying the location(s) of your rain barrel or cistern and the intended destination for overflow (a drain, garden, etc.) and a fee, which covers the permit and site visit by a DBI/PID inspector.
- Contact DBI/PID to begin the permitting process. More information can be found at <http://sfdbi.org/plumbinginspection>; by phone (415) 558-6570 between 7:30 am and 5:00 pm, Monday through Friday; or in person at 1660 Mission Street, Third Floor, Front Desk

### **If your downspout is already disconnected from the sewer system:**

- You do not need a permit from DBI/PID, as long as your rain barrel or cistern meets the following requirements: (SFPUC still recommends consulting with DBI)
  - Under 5,000 gallons
  - The height to width ratio is less than 2-to-1
  - The system does not require electrical power or a make-up water supply connection
  - The storage tank is supported directly on grade
  - The harvested rainwater is only used for outdoor non-spray irrigation with a maximum capacity of 5,000 gallons
  - The harvested rainwater is used for spray irrigation with a maximum storage capacity of 360 gallons

Permits are required for rainwater harvesting systems under the following circumstances:

- Rainwater serves indoor fixtures, regardless of storage tank size. Plumbing permit required.

- System uses pumps or other electrical equipment or controls. Electrical permit(s) required.
- Cistern is larger than 5,000 gallons. Footings and/or foundations are required and must be designed by a structural engineer for seismic safety. Building permit(s) required.
- Project is being proposed to comply with the San Francisco Stormwater Management Ordinance. These projects require SFPUC review and approval.
- System installation involves grading. Grading and erosion control permit(s) could be required.

Whether or not a permit is required, rainwater harvesting systems using rain barrels or cisterns must comply with the following requirements:

- Rain barrels and cisterns must have a secured lid or screen to prevent access to the stored water.
- Openings must be screened with a 100-micron mesh.
- Must have an overflow pipe. Overflow must not discharge water across a public right-of-way or cause nuisance flows to adjacent properties. Overflow must be directed to an approved drain or rain garden. Overflow to the sewer must include an air gap.
- Must be labeled with "CAUTION: NONPOTABLE RAINWATER, DO NOT DRINK." Must have the following sticker or stencil by any hose bibb:



- Must be sited in a stable, flat, and preferably shady area.
- Must be secured to a structural wall by metal straps.
- Tanks must be opaque, water tight, and made of durable materials.



*Rainwater harvesting system at a local residence*



*Checking the lids on the Southeast Treatment Plant rain barrels*

# Operation and Maintenance

The performance of a rainwater harvesting system and the quality of the water are directly related to regular maintenance of the system. Property owners need to pay close attention to their systems to ensure that they are working correctly. Occasionally, the system operator should observe the system when it is raining to make sure all components are working as planned. It is a good idea to prepare a system-specific Operation and Maintenance Manual so that when the property owner changes, the new owner will understand the system. Keeping a storage log and monitoring water usage provides information to properly maintain the existing system and can also act as a foundation for future augmentations to the system. For detailed monitoring, property owners might like to add a water meter to track usage.

This chapter describes maintenance tasks that should be conducted on a routine basis. Guidance is provided for a generic system; activities should be tailored to each specific system. There is a diagram at the end of this chapter indicating where maintenance is required and a table summarizing maintenance recommendations.



*Linked Rain Barrels at Garden For the Environment*

## Catchment Surface

Inspect the catchment area every six months, before and after the rainy season, to check the surface for debris and algae growth as well as obstructions, such as broken or dislodged roof tiles or cracks in the surface. Repair the catchment area as needed to maintain flows and minimize the loss of rainwater. Keep a clean roof and install appropriate debris removal devices on gutters. If the surface is dirty or has algal growth, disconnect downspouts from the rainwater system, wash the surface using plain or soapy water, treat to remove algae if necessary, and rinse thoroughly. Finally, reconnect downspout.

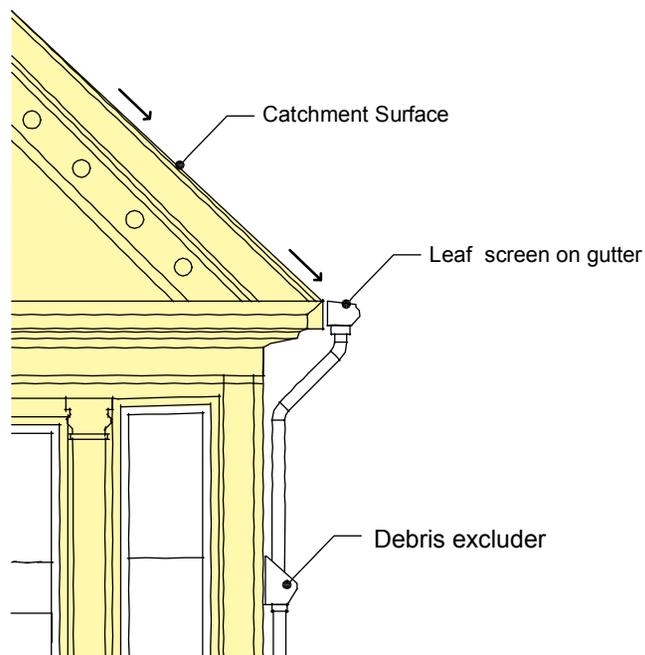
## Conveyance Elements

### Gutters and Downspouts

Inspect gutters and downspouts every six months and check all clips and brackets to see if they are secure and unbroken; if not, repair. Check that the slope of gutters maintains positive drainage. Remove accumulated debris and clogs. Where vegetation overhangs gutters, inspect them every three months for leaf accumulation, rust, and mold. If rust or mold is present and would adversely affect the intended use of the water, disconnect the downspouts from the storage tank and treat the gutters as needed to remove the rust and mold. Reconnect downspouts when work is completed. Trim trees and vines away from gutters to maintain a minimum 24-inch clear zone. Check downspout for animal intrusions, clogs, or overgrowth that could obstruct positive drainage.

### Debris Removal

Clean filters with warm soapy water or rinse well every three to six months. Check that the drop from gutter to downspout remains vertical. Run water in the downspouts and observe where the water falls. If most of the water does not land in the middle and towards the back of the leaf and debris filter screen on rain heads, adjust the location of the downspout. All debris removal devices should be installed and monitored according to manufacturer's instructions.



**Figure 16.** It is essential that the components of your rainwater harvesting system be inspected regularly

## First-Flush Diverters

Contaminated water in first-flush diverters should drain automatically. However, diverters should be checked after each rainfall event to ensure that they do not contain standing water; if so, they should be drained manually. If petroleum absorbent pillows are added to the first-flush chamber, they should be inspected for saturation/absorption capacity every year to evaluate the quantity of oily materials washed off the catchment surface to the first-flush device. Multiple petroleum pillows might be needed; follow manufacturer's guidelines.

## Storage Tanks

### Above ground tanks

Inspect all inlets and outlets before and after each rain event to remove blockages or repair broken parts. Clean all screens. Inspect access lids to ensure seals are tight enough to deter insects and animals. Inspect above-grade tank sides for damage and leaks, and repair any problem areas. Check foundation/base for any settling or cracking, initially after each rain event, eventually on a yearly basis. Check equipment every six months to assess working condition. Maintain an air gap if a make-up water source is used.

### Below-grade tanks

Inspect accessible components every three months or if a sudden change in water storage is observed. Empty below-grade tanks periodically (every three to five years) to check for leaks, waterproofing damage, and structural damage. The best time to check below-grade tanks is during dry periods, when the tank is empty, and before the rainy season starts.



*First flush diverter*  
[www.poly-mart.com](http://www.poly-mart.com)



*Downspout connection with debris excluder*



*Screening the rain barrel*



*Local resident checking the screens of his rain barrels*

## All tanks

Keeping logs of water usage can help identify leaks in both above-ground and below-ground tanks and can help the operator/homeowner plan for future water requirements.

All storage tanks should be flushed out and sprayed down at least once a year. The water in a storage system should be continually moving through the system, so that the water only stands in the tank for extended periods during dry spells, when no new water enters the tank. If the pre-filtration is working properly, very little sediment should enter the tank with rainwater. No sediment or debris should enter a tank from the municipal make-up water supply that might be needed during dry periods.

In properly working, healthy tanks—with proper filtration and no photosynthesis—a beneficial biofilm forms on the sides and bottom of the tank. This biofilm removes bacteria from the tank water, keeping the water clear and odor-free. Additional cleaning may be required if debris is allowed to enter the tank and anaerobic conditions create foul-smelling water. If a tank does require cleaning, confined space procedures should be followed, proper personal protective equipment should be used, ventilation in the tank should be maintained, and an outside observer should be present. Tank cleaning procedures, chemical mixtures used, and dates of cleaning should be recorded for future knowledge. The tasks for cleaning a tank are as follows:

- Drain the tank.
- Disconnect all electrical devices (if any).
- Spray down walls and tank bottom with soap and water or any non-toxic household cleaner.
- Allow sprayed surfaces to dry.
- Rinse thoroughly until soap and debris are removed through the tank drain.

## Distribution System

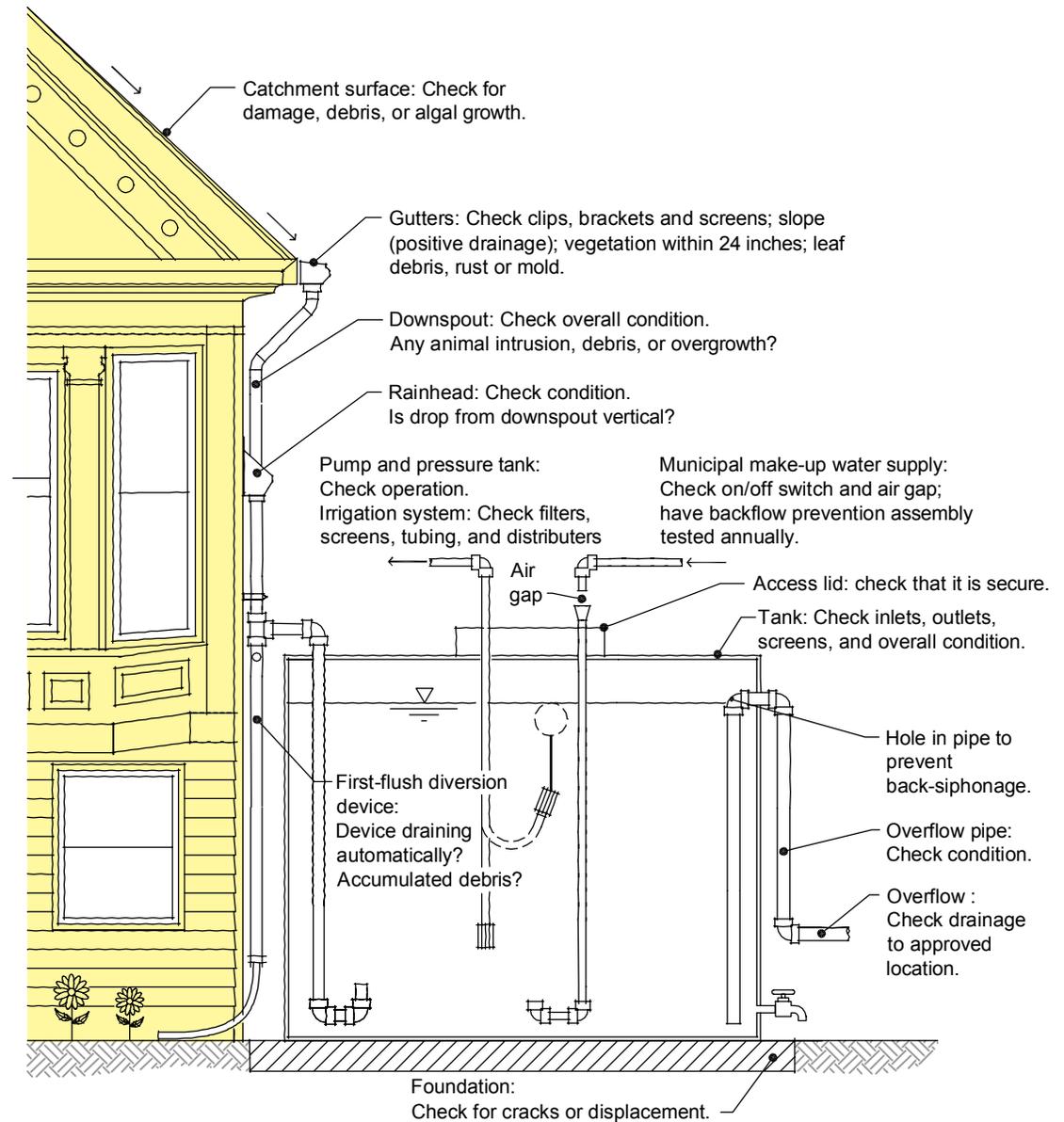
Inspect pumps located outside a storage tank, pressure tanks, and irrigation equipment to be sure all components are working properly. Inspect gravity flow pipes and overflow pipes before rain events to eliminate blockages that might have developed during dry periods.

## Treatment System

Filter systems for irrigation water, such as sand or bag filters or string cartridges, should be checked monthly during the rainy season. Empty filter screens and inspect them for damage. Inspect sand filters for buildup of debris; if the sand filter is clogged, backwash it to remove debris. (Back washing reverses the flow in the filter to push collected debris out in the same direction that it entered the filter; instructions for back washing should be included with the filter purchase.) Performing back washing during dry periods allows the backwash water to be used for irrigation. Replace bag filters as recommended by the manufacturer. Follow manufacturer recommendations for maintenance of filters and disinfection systems.

## Backflow Prevention Assembly

If the rainwater harvesting system includes municipal make-up water, an air gap or backflow prevention assembly must be installed on the municipal water line. If an assembly is installed, the device must be tested every year by a licensed professional, and results must be reported to the SFPUC's Water Quality Division.



*Figure 17. Inspect your rainwater harvesting system regularly.*

**Table 3.** Summary of recommended operation and maintenance activities.

<b>Component</b>	<b>Activity</b>	<b>Recommended Schedule</b>
<b>Catchment surface</b>	Inspect and repair or clean as necessary	Semi-annually (beginning and end of rainy season)
<b>Gutters</b>	<p>Inspect and repair or clean as necessary:</p> <ul style="list-style-type: none"> <li>• Condition and security of clips and brackets.</li> <li>• Slope of gutters (positive drainage).</li> <li>• Condition of screens and presence of debris or clogs.</li> <li>• Presence of trees or vines with 24 inches of gutters.</li> </ul> <p>Flush gutters (and downspouts) once all debris is removed to wash away remaining dirt or debris.</p>	<p>Semi-annually (beginning and end of rainy season)</p> <p>Where vegetation overhangs gutters, every three months</p>
<b>Downspouts</b>	<p>Inspect and repair or clean as necessary:</p> <ul style="list-style-type: none"> <li>• Animal intrusions or clogs.</li> <li>• Debris accumulation or damage.</li> </ul> <p>Flush downspouts (and gutters) once all debris is removed to wash away remaining dirt or debris.</p> <p>Check for overgrowth that obstructs positive drainage.</p>	<p>Semi-annually (beginning and end of rainy season)</p> <p>Every two weeks during growing periods</p>
<b>Debris excluders</b>	<ul style="list-style-type: none"> <li>• Clean filters with warm soapy water or rinse well.</li> <li>• Check that the drop from gutter to downspout remains vertical: adjust location of downspout as necessary.</li> </ul>	Every three to six months, including at beginning and end of rainy season
<b>First-Flush Diverters</b>	Standpipes and roof washers: Check that device drains automatically; repair if necessary.	After each rain event
<b>Storage Tanks, above-grade</b>	<p>Inspect and repair or clean as necessary:</p> <ul style="list-style-type: none"> <li>• Inlets and outlets</li> <li>• Screens</li> <li>• Access lids</li> <li>• Sides of tank</li> </ul>	Before and after each rain event

**Table 3 . Summary of recommended operation and maintenance activities (continued).**

<b>Component</b>	<b>Activity</b>	<b>Recommended Schedule</b>
	Inspect and repair as necessary working equipment, such as an alternative water supply on/off switch.	Every six months
	Maintain an air gap if make-up water is used.	
	Inspect foundation/base and repair as necessary	Initially after each rain event, then annually
<b>Storage tanks, below grade</b>	Inspect and repair or clean as necessary: <ul style="list-style-type: none"> <li>• Inlets and outlets</li> <li>• Screens</li> <li>• Access lids</li> </ul>	Every three months or if a sudden change in water s observed
	Empty and check for leaks and waterproofing or structural damage.	Every three to five years, during dry periods and bef of rainy season
<b>All tanks</b>	If water becomes foul-smelling, drain and clean. Follow confined space procedures if necessary.	As necessary; should not be required if system is we designed and maintained
<b>Distribution system</b>	Inspect and repair or clean as necessary: <ul style="list-style-type: none"> <li>• Pumps</li> <li>• Pressure tanks</li> <li>• Irrigation equipment</li> <li>• Gravity flow pipes</li> <li>• Overflow pipes</li> </ul>	Every six months    Before every rain event
<b>Treatment systems for irrigation</b>	Inspect and repair, replace, or clean as necessary: <ul style="list-style-type: none"> <li>• Sand filters</li> <li>• Bag filters</li> <li>• Mesh screens</li> <li>• Cartridge filters</li> </ul>	Monthly during rainy season



# Glossary

Aerobic	Living in or depending on the presence of oxygen.
Anaerobic	Lacking oxygen.
Backflow preventer	A device that prevents water from flowing backward in a pipe, thereby protecting water supplies from contamination. A Reduced Pressure Principle (RP) Backflow Prevention Device and an air gap are the only approved measures for rainwater harvesting tanks.
Catchment	Any structure or land feature that catches water
Cistern	A reservoir or tank for holding water; as used in this document, a tank for storing rainwater.
Coefficient, landscape ( $K_L$ )	A coefficient that expresses the amount of water lost from vegetation in a landscaped area via evaporation and transpiration. The landscape coefficient depends on plant type, quantity, and location. Used for estimating water needs for landscape plantings.
Coefficient, runoff (C)	A coefficient relating the amount of runoff to the amount of precipitation received.
Debris excluder	Device installed on the downspout to prevent the accumulation of leaves, needles, other debris and sediment from entering the storage tank.
Drip irrigation	An irrigation strategy applying water via an emitter to the root zone of a plant at a rate slow enough (usually less than 3 gallons per hour) to allow the soil to absorb it without runoff.
Evaporation	The process of a liquid becoming a vapor.
Evapotranspiration	The combination of water transpired from plants and evaporated from soil and plant surfaces.

Factor, density ( $K_d$ )	One of three factors used to calculate the landscape coefficient. Reflects the effect of vegetation density on water loss from a hydrozone.
Factor, microclimate ( $K_{mc}$ )	One of three factors used to calculate the landscape coefficient. Reflects the effect of microclimate on water loss from a hydrozone.
Factor, species ( $K_s$ )	One of three factors used to calculate the landscape coefficient. Reflects the water loss from a hydrozone due to plant species composition.
First flush diverter	A device that collects and diverts the initial rain that falls on a catchment surface, removing both debris and soluble pollutants.
Rain barrel	A small tank for holding water. As defined in the San Francisco Memorandum of Understanding, a rain barrel has a maximum capacity of 100 gallons.
Rainwater	Water that falls as drops from clouds in the sky.
Rainwater harvesting	The collection, storage, treatment, and use of rainwater.
Site plan	A detailed plan that depicts the location of improvements on a piece of land; as used in this document, the site plan should contain all information required by reviewing agencies.
Transpiration	Evaporation of water from the parts of plants exposed to the air, especially leaves but also stems, flowers, and roots.
Turbidity	Cloudiness of a fluid caused by suspended matter or impurities.
Water budget	The relation of “water supply” and “water demand.” The first step in sizing a rainwater harvesting system.
Water demand	All water used on a project site; can include indoor and outdoor potable and non-potable uses. In terms of rainwater harvesting, the sum of the desired uses of the captured rainwater.
Water quality	The physical, biological, and chemical properties of water.
Water supply	All water entering a project site; can include on-site rainfall, runoff from adjacent sites, graywater, recycled water, and potable water. In terms of rainwater harvesting, all water entering a project site that can be captured for reuse; can include on-site rainfall, runoff from adjacent sites, and graywater. Determined by catchment area and rainfall.
Watershed	The total drainage area that contributes runoff to a particular location, which could be a stream, lake, ocean, or bay.