


Harvesting, Storing, and Treating Rainwater for Domestic Indoor Use

Texas Commission on Environmental Quality

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Preface

This publication offers guidance for individuals who want to install a rainwater harvesting and treatment system to supply potable drinking water for a single household. It is designed to augment the information contained in two publications from the Texas Water Development Board (TWDB): *The Texas Manual on Rainwater Harvesting* and *Rainwater Harvesting Potential and Guidelines for Texas.*

This "informational guidance" document does not apply to systems that will serve 15 or more connections (such as homes, apartments, or businesses) or to those that serve 25 people or more for at least 60 days each year. These large systems are regulated by various state and federal agencies and must meet special requirements that apply to public water systems. For information about the requirements that apply to public water systems, contact the TCEQ's public drinking water program, at 512-239-4691.

Terms Used in This Guide

In this document, the term "potable water" refers to water that is used for drinking, food preparation, hand washing, dish washing, bathing, or any other purpose that could possibly result in the ingestion of the water or its touching the skin. It does not include water that is used only for watering the lawn, washing clothes, or flushing toilets.

"We" or "our," as used in this guide, refer to the Texas Commission on Environmental Quality (TCEQ)—specifically, the Public Drinking Water Section of the Water Supply Division. And "you" refers to the person or entity that is developing or using a rainwater collection and treatment system.

There are also numerous references to various ANSI/NSF standards and NSF protocols throughout this guidance. When we refer to an "ANSI/NSF standard," we are identifying a specific standard that was developed jointly by the American National Standards Institute (ANSI) and the National Sanitation Foundation (NSF). When we mention NSF protocols, we are referring to a testing protocol used by the National Sanitation Foundation.

Other Guidance Documents

There are a number of other guidance documents that you may find helpful when developing your rainwater harvesting and treatment system. These publications include:

The Texas Manual on Rainwater Harvesting.
This document is published by the Texas Water Development Board. A copy can be downloaded from the web page <www.twdb.state.tx.us/iwt/rainwater/docs.html>. We will refer to it here as the "TWDB Manual."

Rainwater Harvesting Potential and Guidelines for Texas.
This document was developed in 2006 by the Texas Rainwater Harvesting Evaluation Committee and is published by the Texas Water Development Board. You can download a copy from the same web page, <www.twdb.state.tx.us/iwt/rainwater/docs.html> (click on "RWHEC Draft Report"). We will refer to it here as the "Committee Report."

Guidelines on Rainwater Catchment Systems for Hawai'i.
This document is published by the College of Tropical Agriculture and Human Resources at the University of Hawaii at Manoa. You can download a copy of this document from the web page <www.ctahr.hawaii.edu/oc/freepubs/pdf/RM-12.pdf>. We will frequently refer to it here as the "Hawaii Guidelines."

Glossary

air gap. The atmospheric space between the outlet of a pipe that fills a tank and the maximum water level in the tank. The vertical distance between the pipe outlet and the water must be large enough to prevent water from backing up into the pipe.

ANSI. American National Standards Institute

contaminant. Any chemical, microbe, or other material that is not found in pure water and that can make water unsuitable for its intended use. Some contaminants only affect aesthetic qualities such as the appearance, taste, or odor of the water, while others can produce adverse health effects if present in high concentrations.

debris. A contaminant that you can see. Debris can include leaves and twigs, dust and dirt, bird and animal droppings, and insects.

drinking water. See “potable water.” (In this document, the terms “drinking water,” “potable water,” and “treated water” are used interchangeably.)

erosion chlorinator. An in-line treatment unit that contains calcium hypochlorite tablets or pellets. As water flows through an erosion chlorinator, the calcium hypochlorite slowly dissolves and releases chlorine into the water.

log removal/inactivation. A unit of measurement that expresses the percent of organisms removed or inactivated in terms of powers of 10, or “logs.” For example, a 99% reduction in the number of organisms is equivalent to a 2-log reduction, because only 1/100th (or $1/10^2$) of the original number will remain after treatment.

mg/L (milligrams per liter). A unit of measurement; the amount of a chemical found in each liter of water.

mJ/cm² (millijoules per square centimeter). A unit of measurement; the amount of ultraviolet light energy applied to each square centimeter of a surface.

NSF. National Sanitation Foundation

nonpathogenic microbe. A bacteria, parasite, or virus that does not cause an infection or disease in humans.

nonpotable water. Water that may have received some treatment but not enough to make it safe for potable use. Nonpotable water can be used for watering lawns and gardens, washing clothes, or flushing toilets, but should not be used for any purpose that might result in the ingestion of the water or its contact with the skin.

pathogenic microbe. A bacteria, parasite, and virus that can cause an infection or disease in humans.

potable water. Water that is used for preparing food or beverages for human consumption, for washing dishes and utensils that are used to prepare or consume food or beverages, for bathing, or for any other purpose that might result in the ingestion of water or its contact with the skin. It does not include water that is used only for landscape irrigation, washing clothes, or flushing toilets. (In this document, the terms “potable water,” “drinking water,” and “treated water,” are used interchangeably.)

Glossary (continued)

point of entry. The point where water enters a home's plumbing system. A point-of-entry treatment unit treats all of the water entering the home rather than treating the water at the point where it is consumed. A whole-house water softener is an example of a common point-of-entry treatment unit.

point of use. A point in a home where water is actually used. A carbon filter installed under the sink is an example of a common point-of-use treatment unit.

public water system. A public water system (PWS) is any system that serves at least 25 people per day for at least 60 days each year or that serves at least 15 service connections such as homes, apartments, or businesses.

psi (pounds per square inch). A unit of measure; the amount of pressure applied to each square inch of a surface.

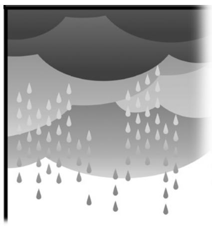
SOC (synthetic organic chemical). A type of organic molecule that is typically found in pesticides, herbicides, and similar man-made products.

treated water. Water that has been filtered and disinfected and is safe for potable use. In this guidance, the terms treated water, drinking water, and potable water are used interchangeably.

untreated water. Water that has not received enough treatment to make it safe for potable use.

VOC (volatile organic chemical). A type of organic molecule that is typically found in refined organic products such as plastics, glues, and solvents, as well as gasoline, greases, and oils.

Chapter 1
Introduction



Rainwater and snowmelt are the primary sources of all drinking water on the planet. Rainwater harvesting is the practice of collecting the water produced during rainfall events before it has a chance to run off into a river or stream or soak into the ground and become groundwater. Rainwater harvesting can be classified into two broad categories: land-based and roof-based. Land-based rainwater harvesting occurs when rainwater runoff from the land is collected in ponds and small impoundments before it has a chance to reach a river or stream. Roof-based harvesting, on the other hand, involves collecting the rainwater that falls on a roof before the water even reaches the ground.

Although roof-based systems generally produce water with lower levels of chemical and biological contaminants, the water produced by both systems is subject to contamination and must be properly treated before it can be used. The level of treatment you need to provide depends, to a great extent, on whether you will be using the water for potable purposes (such as drinking, food preparation, bathing, and dish- or hand-washing) or for nonpotable purposes (such as toilet flushing, clothes washing, and watering). Obviously, rainwater that is intended for potable purposes must receive a higher level of treatment than rainwater that is intended for irrigation purposes.

From a regulatory perspective, the Texas Commission on Environmental Quality (TCEQ) has rules that only apply to a rainwater system that supplies potable water for a public water system[1] or for any business that manufactures food or beverages. We do not set minimum treatment requirements for rainwater that will be used as a drinking water source for a single household nor do we regulate nonpotable uses of rainwater.

If you have access to a public water system, we encourage you to utilize your rainwater collection system for nonpotable use only. This approach will:

- Reduce your construction, treatment, and operational costs, because less treatment is required for nonpotable uses than for potable uses.
- Lower your monthly water bill because you will need to buy less of the public water system's drinking water for nonpotable use.
- Conserve the natural resources being developed and utilized by your public water system.

Chapter 4 contains information about how you can use a rainwater harvesting system to reduce the amount of water that you purchase from your public water system.

1. A public water system (PWS) is any system that serves at least 25 people per day for at least 60 days each year or that serves at least 15 service connections such as homes, apartments, or businesses. See 30 TAC §290.38(47) for the complete definition of a PWS.

Purpose and Organization of This Document

We created this guidance document to help you design and operate a roof-based rainwater harvesting system to supply drinking water for you and your household. It is intended to augment the information contained in *The Texas Manual on Rainwater Harvesting* and the *Rainwater Harvesting Potential and Guidelines for Texas*, which are published by the Texas Water Development Board (TWDB). Although some of the issues we discuss will help you design other types of rainwater harvesting systems, this document focuses on the information you need to make sure that your system will produce water that is chemically and biologically safe to drink.

Any domestic rainwater harvesting system you use to produce drinking water for your home will consist of the following six basic components.

1. Catchment surface: This catches the raindrops as they fall from the sky and then channels the water to a collection gutter.
2. Gutters and downspouts: These channel water from the roof to the tanks that store untreated water.
3. Leaf screens, first-flush diverters, and roof washers: These components remove debris and dust from the captured rainwater before it goes into the tank.
4. Untreated-water storage tanks, or cisterns: These are receptacles that store the harvested rainwater until you are ready to treat and use it.
5. Treatment/purification facilities: These are filters and disinfection equipment that remove contaminants from the untreated rainwater and make it safe to drink.
6. Treated water storage and distribution system: This includes storage tanks, service pumps, pressure tanks, and water lines that are used to send water to the point where it is consumed.

Summary of This Guidance Manual

Chapter 1. Introduction
Provides background information and explains why it is important to properly design and operate your rainwater harvesting system.

Chapter 2. Collection and Storage of Untreated Rainwater
Covers the first four rainwater system components and describes some of the things that you need to consider when you design your roof-based rainwater collector and the tank where you store your harvested rainwater before treating it.

Chapter 3. Treatment Units, Pumps, and Treated-Water Storage
Covers the last two rainwater system components and discusses the various technologies that you can use to filter and disinfect your rainwater prior to consumption, and covers some of the factors that will influence your design.

Chapter 4. Nonpotable Uses and Other Considerations
Discusses some of the issues you need to consider when designing a rainwater harvesting system to produce nonpotable water for indoor or outdoor use.

What Kinds of Contaminants Can Be Found in Rainwater?

Rainwater and snowfall are the ultimate sources of all drinking water on the planet. Rainwater and melted snow runs off the land and collects in lakes and rivers. They also seep through the ground and recharge the aquifers that supply drinking water wells. Regardless of where you currently obtain your drinking water, it originally fell from the sky.

The water in a raindrop is one of the cleanest sources of water available. Rainwater can absorb gases such as carbon dioxide, oxygen, nitrogen dioxide, and sulfur dioxide from the atmosphere. It can also capture soot and other microscopic particulates as it falls through the sky. Nevertheless, rainwater is almost 100% pure water before it reaches the ground.

Pure water is considered the universal solvent; it can absorb or dissolve contaminants from almost anything it comes into contact with. That is why it is especially important to design and operate your system so that the rainwater picks up as few contaminants as possible before you consume it.

Debris

We use the term "debris" to describe any contaminant that you can see. Debris includes leaves and twigs, dust and dirt, bird and animal droppings, insects, and other visible material. Although debris obviously reduces the aesthetic quality of the water, it can also pose unseen chemical and biological health threats. For example, leaves and dust can contain unseen chemical contaminants such as herbicides and pesticides. Similarly, bird and animal droppings can contain microscopic parasites, bacteria, and viruses.

Chemical Contaminants

Although rainwater can be contaminated by absorbing airborne chemicals, most of the chemicals present in harvested rainwater are introduced during collection, treatment, and distribution. By properly designing and operating your rainwater harvesting system, you can minimize your exposure to a variety of chemical contaminants that include organic chemicals, such as volatile and synthetic organics, and inorganic chemicals, such as minerals and metals.

Volatile Organic Chemicals

Volatile organic chemicals (VOCs) can be introduced when rainwater comes into contact with materials containing refined organic products. These VOC sources include plastics, glues, and solvents, as well as gasoline, greases, and oils. Most VOC contamination at rainwater systems occurs because the materials used to construct the system were not manufactured specifically for drinking water applications; these materials may not meet the standards set for potable water products and may release undesirable levels of VOCs into the water. Although most VOC contamination results from improper construction practices, VOC contamination can also occur when raindrops fall through an atmosphere containing gasoline or solvent vapors.

Synthetic Organic Chemicals

Synthetic organic chemicals (SOCs) are chemicals that are typically found in pesticides, herbicides, and similar man-made products. Since SOCs are not very volatile, these contaminants are usually introduced when debris such as dust and leaves are allowed to enter the system. However, SOC contamination can also be introduced if you install your rainwater collection and storage system in an area where aerial herbicide or pesticide application occurs. Regardless of how the chemical reaches the rainwater system, SOC contamination is usually the result of environmental exposure rather than poor construction practices.

Minerals

Minerals are inorganic materials found naturally in the environment. Most minerals are inorganic salts (such as calcium carbonate, sodium bicarbonate, magnesium sulfate, and sodium chloride) that affect the flavor of the water but generally do not pose an actual health threat. The most significant exception to this general rule of thumb is asbestos, which is a family of fibrous silica salts used to manufacture a variety of products. Under certain conditions, some of these products can release a form of asbestos that can pose a long-term health threat if ingested or inhaled.

Minerals, especially calcium and magnesium salts, are what gives water its hardness. Rainwater contains virtually no minerals before it is harvested and so it is a very soft water. It is also slightly acidic, with a pH around 5.6, due to the carbon, nitrogen, and sulfur dioxides it absorbs from the atmosphere. Because it takes time for rainwater to absorb minerals, most of the minerals present in harvested rainwater will have been leached from materials used to construct the system rather than from environmental sources.

Metals

Metals include lead, arsenic, copper, iron, and manganese. Some metals, such as lead and arsenic, can pose a long-term health threat if they are present in high enough concentrations. Other metals, such as iron and manganese, can affect the appearance and taste of the water but pose no health threat. It takes time for metal to dissolve in rainwater. Therefore, this type of contaminant is usually present only after metallic materials such as lead solder, iron and copper pipe, and brass fittings have been exposed to rainwater for several hours or longer.

Microbiological Contaminants

Rainwater seldom contains any type of microbiological contaminant until it is harvested and stored. The water in a raindrop is extremely pure, but it is virtually impossible to maintain that level of purity during the collection, treatment, and distribution processes. Rainwater can be contaminated by two major categories of microbiological agents: those that cause disease and those that do not. Microbiological contaminants that can cause a disease or infection are called pathogenic, while those that do not are called nonpathogenic.

Nonpathogenic organisms can be present in high numbers regardless of where your home is located. These nonpathogenic microbes include many kinds of protozoa, algae, bacteria, and viruses. Although they do not cause illness, nonpathogens often reduce the aesthetic quality of the water and can interfere with the operation of the rainwater harvesting and treatment facilities, increasing operational and maintenance requirements. For example, high concentrations of algae can make the water slimy, plugging the filters used to treat the water, or fungi and bacteria can colonize in the water lines in your home.

Pathogenic organisms are not normally found in rainwater. However, they can be present if the rainwater collection or storage facilities have been contaminated by fecal material such as animal or bird droppings. Pathogenic microbes pose a greater health threat to rainwater users than most chemical contaminants, for a number of reasons, including:

- Pathogens can cause disease after a single exposure, while most chemical contaminants may require months or even years of exposure before causing a health effect.
- Pathogens do not affect the taste, smell, or appearance of the water. Many chemical contaminants, on the other hand, make the water taste, smell, or look different, especially if the chemicals are present at levels that would pose a short-term risk.
- Pathogen levels can rise very quickly, while chemical levels tend to remain fairly constant. Consequently, it is relatively easy (though somewhat costly) to periodically test for chemical contaminants, while it is both difficult and costly to continuously test for most pathogens.
- A disease caused by pathogens can usually be passed from person to person, while the health effects caused by chemicals affect only those that actually consume the contaminated water.
- Waterborne illnesses caused by pathogens can be a serious health risk for the elderly, infants, chemotherapy patients, and other individuals with a delicate or weakened immune system.

Pathogenic microbiological contaminants include certain types of protozoan parasites, bacteria, and viruses. The infectivity rates (the number of microbes required to cause a disease) and the virulence (the severity of the disease) vary, depending on the type of pathogen present and the immune system of the person that is exposed. Some pathogens can cause an illness if a person with a weakened immune system is exposed to just a few organisms.

Some of the pathogens that can be introduced through improperly designed and operated rainwater systems are shown in Table 1.1.

Table 1.1. Types and Sources of Pathogens That Can Be Found in Harvested Rainwater

Type of Pathogen	Organism	Source
Parasite	*Giardia lamblia*	cats and wild animals
	Cryptosporidium parvum	cats, birds, rodents, and reptiles
	Toxoplasma gondii	cats, birds, and rodents
Bacteria	*Campylobacter spp.*	birds and rats
	Salmonella spp .	cats, birds, rodents, and reptiles
	Leptospira spp.	mammals
	Escherichia coli	birds and mammals
Virus	*Hantavirus spp.*	rodents

Product Certifications

To ensure that your rainwater system will provide you with safe drinking water, the American National Standards Institute (ANSI) has coordinated the development of various standards for products that are used to construct rainwater harvesting systems for potable water. To identify products that meet these standards, ANSI also accredits organizations that conduct certification tests. You can find out more about the ANSI organization and its accreditation program on the ANSI web site.

American National Standards Institute
www.ansi.org

The ANSI web site also provides a list of accredited testers and the types of products they certify, as well as links to their respective web sites. The address for this web page is: <www.ansi.org/conformity_assessment/accreditation_programs/product_certifiers.aspx>.

Whenever possible, you should use products that have been independently tested and certified in accordance with nationally-recognized standards. Although there are other accredited testing organizations, the two that we are most familiar with are the National Sanitation Foundation (NSF) and Underwriters Laboratories (UL). You can obtain a list of all of the drinking water products that they have certified by checking their respective web sites.

National Sanitation Foundation
http://nsf.org/consumer/drinking_water

Underwriters Laboratories, Inc.
www.ul.com/water/prodcert/waterqry.html

Products that have been tested and certified in accordance with ANSI/NSF standards will bear the seal of the organization that tested the product, and usually identify the standard or protocol that was used. Some examples of the seals are shown below.

LISTED EPH

CLASSIFIED IN ACCORDANCE WITH ANSI/NSF 61

CLASSIFIED WATER QUALITY

Certified to NSF/ANSI 60

NSF/ANSI 55 CLASS A CERTIFIED

Although we will focus on the health-related standards, you also need to consider other UL safety standards that apply when you select pumps, switches, and other electrical components.

Technical and Professional Assistance

Designing and installing an effective rainwater collection and treatment system can be a complicated, challenging task, requiring a wide range of knowledge and expertise. Although there is a variety of information available to help you meet your objective, you will probably need to hire a plumber, an electrician, a rainwater expert, and maybe even a professional engineer or architect to help you wade through your options and design and install your system. Manufacturers, suppliers, retailers, and local agencies such as the Better Business Bureau can help you select experienced, reputable contractors.

Droughts

Rainwater systems typically have a limited storage capacity. As a result, they tend to be less reliable than most other sources of water during periods of prolonged drought. If you live in a drought-prone area (like Texas), we encourage you to identify alternate sources of potable water that you can use to supplement your rainwater supply.

Chapter 2

Collection and Storage of Untreated Rainwater

As you plan your rainwater collection and storage facilities, you need to keep two things in mind.

1. The catchment and storage facilities must be designed so that they reduce potential sources of contamination.
2. The catchment surface and storage tanks must be large enough to capture and store enough rainwater to last you until the next time it rains. Otherwise, you will need to identify a supplemental source of water.

This chapter provides you with the basic information that you need to achieve these two objectives.

Roof-Based Rainwater Collection Systems

As we mentioned in Chapter 1, rainwater collection systems for potable water can be land-based or roof-based. Land-based collectors, however, are much more susceptible to chemical and biological contamination than roof-based systems. Therefore, you should not use a land-based system to provide untreated water for a potable water system, unless you are willing to design and operate a sophisticated treatment system and routinely monitor the chemical and microbiological quality of your treated water. It is preferable to use a roof-based collection system. A simple schematic of a roof-based rainwater collection system is shown at the end of this document (Appendix 1).

The Roof

The roof you use to collect the rainwater can be constructed using a variety of materials. Chapter 2 in the TWDB Manual and Section 1 in the Hawaii Guidelines contain good discussions of your options. We recommend that you use a smooth, nonporous material because it improves the efficiency of your system by absorbing less water and reducing the chance that microbes and debris will collect in the pores and seams of the roof. Although we don't know of any roofing material that has been designed specifically for potable water catchment, you should probably avoid using composite, asphalt, or asbestos shingles when you construct your roof. It is also extremely important that you NOT use any roofing material that contains fungicides, algaecides, or any other biocide compound. As these products age and decay, they release a variety of organic and inorganic chemicals that can pose a health threat if consumed. Although there are some treatment technology combinations, such as activated carbon filters followed by reverse osmosis, that can remove these contaminants, you should not risk exposing yourself and your family to these health threats.

If possible, your roof should have a steep slope. During the periods between rainfall events, dust and debris can accumulate on the roof. It is much easier to rinse the debris from a well-pitched roof than it is from a roof that is level or that only has a slight incline. As the TWDB Manual indicates, it also takes a much heavier rainfall event to rinse a level roof than an inclined one.

If you are going to coat your roof with a sealant or paint, we recommend that you use one that has been certified under NSF Protocol P151 or ANSI/NSF Standard 61. NSF Protocol P151 was developed specifically for testing rainwater harvesting and collection systems while ANSI/NSF Standard 61 is a more general standard that applies to all materials that come into contact with potable water. Products certified under either of these requirements are approved for potable water applications and are unlikely to contaminate your water if properly applied. As we discussed in Chapter 1, materials that have been certified in accordance with ANSI/NSF requirements bear the label of the organization that tested the product.

Gutters and Downspouts

Gutters, downspouts, and piping are used to collect the water harvested from your roof and convey it to the tanks that will store it prior to treatment. Chapter 2 in the TWDB Manual and Section 1 in the Hawaii Guidelines contain several illustrations that will help you design a safe and effective conveyance system.

We recommend that you install a seamless aluminum gutter or construct your gutter using a plastic pipe that meets the requirements of ANSI/NSF Standard 14 or Standard 61. We do not know of any aluminum gutter that has been certified under either NSF Protocol P151 or ANSI/NSF Standard 61. However, aluminum is a relatively inert material that oxidizes very slowly. Seamless aluminum, therefore, should be relatively safe to use and allows you to avoid joint seams, which can harbor bacteria and algal growths. PVC pipe that meets ANSI/NSF requirements is readily available and will bear an ANSI/NSF label along the length of the pipe. However, PVC gutters will probably not last as long as seamless aluminum gutters, because plastics are more vulnerable to sunlight damage and decay than aluminum.

You will need to consider several other factors as you design your gutters, downspouts, and piping.

- Your gutter should gradually (but continuously) slope toward the downspout. If you do not properly slope the gutter, it will not drain completely and algae and bacteria will begin to grow in the water that remains after the rainfall event. For best efficiency, the gutter should have about a 1% slope (in other words, the bottom of the gutter should drop 1 inch for every 8 feet of gutter length).
- If your roof tends to capture leaves, twigs, or other large debris, you should install a leaf guard, gutter screen, or other similar material on the top of your gutter. The leaf guard that you select should be self-cleaning—that is, it should flush the debris away from the gutter rather than trapping the material directly above it. If you do not have much trouble with leaves and twigs, you will probably find that a basket screen or funnel screen located at each gullet downspout provides adequate protection without obstructing water flow. Although we know of no leaf guard or screen that has been certified under Protocol P151 or Standard 61, it is probably better to prevent large debris from entering the system than to avoid the use of unapproved materials.
- Your conveyance system should prevent water from pooling at any point between the roof and your untreated-water storage tank. If you cannot design the piping system so that it drains completely between rainfall events, you must incorporate additional equipment to ensure that stagnant water is flushed from the piping before it enters the storage tank.

First-Flush Diverters

As discussed previously, roof-based collectors are much less susceptible to chemical and biological contamination than land-based collectors. Nevertheless, even well-designed roofs will collect some contaminants during the periods between rainfall events. Although a leaf guard or gutter screen can keep large debris out of your system, you will need to use a first-flush diverter to keep most of the dust, dirt, chemical contaminants, or animal and bird droppings out of the untreated-water storage tank. Most of these contaminants will be rinsed off the roof during the first few minutes of a major rainfall event. In order to prevent them from reaching your storage tank, you need to install a first-flush diverter on each downspout that discharges to the tank.

As Chapter 2 in the TWDB Manual indicates, the amount of water needed to rinse the roof depends on a number of factors, including:

- Slope of the roof. Steeply inclined roofs will rinse more quickly than roofs that only have a slight incline.

- Porosity of the roofing material. Nonporous materials (such as metal) will clean more quickly than porous materials.
- Amount and type of contaminant present. Although the concentration of all contaminants tend to increase as time passes between rainfall events, dust and small debris are much easier to remove than fecal matter.
- Rainfall rate. Long, slow drizzles will flush fewer contaminants than brief heavy rainfall.

There are two types of first-flush diverters. One type diverts a fixed volume of water before the tank begins to fill and the other begins filling the tank only after the rainfall rate reaches a certain level. Experts have not reached a consensus on which type of diverter is better. You may want to consider the following two issues when selecting the type and size of diverter you will use.

- Rainfall events typically begin with a slow drizzle and then increase in intensity. If you use a “fixed volume” diverter, you may not be able to completely flush contaminants from the roof before the diverter is filled and water begins flowing to the untreated-water storage tank.
- If rainfall intensity doesn’t increase significantly over the course of the rainfall event, some contaminants may remain on the roof. In this case, a “fixed rate” diverter may waste a lot of water that doesn’t contain many contaminants.

Chapter 2 of the TWDB Manual describes a couple of first-flush diverters and discusses the factors that can influence their performance. If you use a “fixed volume” diverter, we recommend that you size it so that it will flush at least 1 to 2 gallons of water for every 100 square feet of roof surface. For example, if your roof is 30 feet wide and 80 feet long, you would want to size your device to divert about 25 to 50 gallons of water.

100 square feet will divert 1 to 2 gallons of water

30 feet × 80 feet = 2,400 square feet (total roof area)

2,400 square feet ÷ 100 square feet = 24 units of 100 square feet

24 × 1 to 2 gallons = 24 to 48 gallons

Piping

We recommend that you use a plastic pipe that has been certified to meet ANSI/NSF Standard 14 or Standard 61 requirements. Although other piping materials are available, plastics are probably your best choice. Rainwater is very soft and somewhat acidic, so it tends to be more corrosive that most other sources of drinking water. Since plastic pipe is less susceptible to corrosion, it is more suitable for this application. However, as noted previously, plastic pipe is more susceptible to UV damage than metal pipe. You may want to paint the outside of the piping that is exposed to sunlight in order to protect it from UV rays. If you decide to use another piping material, be sure that it has been certified under Standard 14 or Standard 61. Without the ANSI/NSF certification, you have no way to know whether the pipe has been tested and whether it is acceptable for potable water use. Due to the corrosive tendencies of rainwater, you should NOT use thin-wall copper pipe or tubing, even if it is ANSI/NSF certified, because of its potential to develop pinhole leaks.

Untreated-Water Storage Systems

The untreated-rainwater storage facilities will probably be the most costly part of your system. You can use a variety of materials and types of design in constructing a tank to store your harvested rainwater prior to treatment. There are several issues that you should consider in constructing your tank.

To ensure that your untreated-water storage facilities are structurally sound, these facilities need to be designed by individuals that are familiar with the structural properties of the materials that you select and the soil characteristics at the installation site. A gallon of water weighs 8.34 pounds, so a tank that holds 5,000 gallons of water will weigh more than 41,500 pounds when it is full.

The tank must be structurally sound. Chapter 2 of the TWDB Manual and Section 2 of the Hawaii Guidelines discuss the various materials that have been used to build rainwater storage tanks and describe some of the advantages and disadvantages of each material. The materials you select must be strong enough to withstand any internal pressure generated by the water and any external pressure generated by the surrounding environment. We recommend that you hire a licensed professional engineer or other experienced professional to design your storage facilities, especially if you are installing a tank below ground level or an above-ground tank with a capacity of 10,000 gallons or more.

If you install an above-ground storage tank, your contractor will help you design a pad that will assure that the tank remains level as the soil shrinks and swells. If you install a subsurface tank, your contractor will make sure that the tank is properly bedded so that it will be protected from soil movement, is constructed of material that is very corrosion-resistant, and is not installed in an area with a high water table. You should not install your tank below the water table because it can shift or even float when it is empty.

We suggest that you use an above ground tank if possible because they are more accessible and can be easily inspected, cleaned, and repaired. However, above ground tanks are usually more susceptible to impact damage and may need to be fenced or otherwise protected. Also, remember that above ground tanks are exposed to sunlight and need to be protected from UV degradation, especially if you use plastic or other UV-sensitive materials.

All the openings in your tank need to be sealed, screened, or covered, in order to prevent insects, lizards, birds, and rodents from getting into your tank. You should seal all unnecessary openings with a bolted, gasketed cover. You must also make sure that the open end of all vents and overflows face downward and are covered with a corrosion-resistant window-screen material. In order to prevent flies and mosquitoes from using your tank as a breeding ground, there must be no gap larger than 1/16th of an inch at any opening into the tank. Painting the inside of the vents black may also help because insects will perceive the opening as a solid surface. Since the gutter and downspout are open to the atmosphere, you should probably install an insect screen or a prefilter (such as the one shown in Figure 2-4 of the TWDB Manual) at the inlet to the storage tank.

The surfaces that come into direct contact with the water must be nonporous and suitable for potable water applications. If you construct the tank out of materials that have not been certified in accordance with NSF Protocol P151 or ANSI/NSF Standard 61, you will need to coat the inside surfaces with a certified coating material or use a certified liner or bladder.

Sizing the Collection and Storage Facilities

The proper sizes for your catchment surface and your water storage tank depends on how often and how hard it rains at your home, as well as on how much water you and your family use. Chapter 4 in the TWDB Manual explains how this information is used to calculate the sizes of your collection and storage facilities.

Step 1. Determine Your Annual Water Demand

The first thing that you need to do is to figure out how much potable water you and your family need each day. Your water demand depends on how many people are in your household and what you use the water for. As a general rule, we recommend that you design your system so that it can provide at least 50 gallons of water per day for each person in your family.

However, your family may need more or less water, depending upon your water-use patterns and the type of plumbing fixtures you have. For example, you do not need to provide water for doing laundry if your family takes its clothes to a laundromat rather than washing them at home. On the other hand, you may use more water than average if your family likes to take baths instead of short showers with a water-conserving shower head. Chapter 4 in the TWDB Manual provides a handy table that you can use to estimate your actual daily water needs. Once you determine your daily water needs, you can determine your annual demand, by multiplying your daily water needs by 365. Here's an example of this calculation for a family of four:

4 people × 50 gallons = 200 gallons of water used per day

200 gallons × 365 days = 73,000 gallons of water used per year

Step 2. Determine the Amount of Rainfall You Can Capture

As discussed previously, the shape of the roof and the material you use to construct it do affect the efficiency of your system. However, the factor that has the greatest impact is the amount of area that is covered by the roof, or its footprint. Unless your roof and gutter system is extremely efficient, each inch of rain will produce approximately ½ gallon of water for every square foot of area covered by the roof. Figure 4-2 in the TWDB Manual is a map showing the average rainfall across Texas. To determine the amount of water you will capture, you need to multiply the annual inches of rainfall you get at your home by 0.5, which will give you the annual number of gallons of water you will collect per square foot of collection area. Then multiply that number by the square footage of the area cover by your roof (footprint). For example, if your footprint is 2,500 square feet, and your annual rainfall is 40 inches:

40 inches (of rain per year) × 0.5 gallons (per inch of rain) = 20 gallons (per square foot)

20 gallons × 2,500 square feet = 50,000 gallons per year

In this example, the footprint of your roof and the location of your home will not allow you to collect enough water to meet all the water needs of your family of four, even on an average year. Now you have two choices; you must either reduce your annual use, or you must increase your supply. You can increase your supply in one of two ways; you can supplement your rainwater supply with water from another source (such as potable water supplied by a water hauler or public water system) or you can increase the size of your collection system so that it can capture enough water.

Step 3. Determine How Big Your Storage Tank Needs to Be

Your untreated-water storage tank must be able to store enough water to meet or exceed the amount of water your household will use during periods of little or no rainfall. Figure 4-3 in the TWDB Manual shows the maximum number of continuous dry days that you can expect to have based on where you live. To determine how much storage you need, you must multiply your daily use by the number of continuous dry days you can expect in one year. For example,

4 people × 50 gallons = 200 gallons per day

200 gallons × 50 dry days = 10,000 gallons

You might be able to get by with a smaller untreated-water storage tank if you are going to use a supplemental drinking water supply to meet part of your family's needs.

Supplemental Sources of Supply

If you are going to connect your tank to a supply line from a public water system, the connection must be made through an air gap and must be inspected and approved by the public water system's personnel.

If you are going to obtain a supplemental supply from a water hauler, you need to make sure that:

- Your tank is equipped with a roof hatch or has a covered fill box.
- The tanker truck and hoses that the supplier uses are only used to transport potable water.
- The supplier obtains your water from a public water system.
- The ends of the fill line and hoses are capped or otherwise protected from contamination during transport.
- The supplier does not drop the end of the hose into the tank (because the outside of the hose is often much less sanitary than the inside of the hose).
- The supplier closes the hatch or fill box when they finish filling your tank.

Sizing Your Water Conveyances

Gutters, downspouts, first-flush diverters, and piping are used to transport, or convey, water from the roof to your untreated-water storage tank. To maximize the efficiency of your rainwater harvesting system, you have to design these conveyances so that they can handle all of the water that is captured on the roof during each rainfall. The size of these components depends on a number of factors, including the maximum rainfall rate, the footprint and shape of the roof, and the number of points where water is diverted to the storage tank. Chapter 2 of the TWDB Manual discusses many of the issues you will need to consider.

In most cases, a 4-inch gutter and piping system will be adequate to meet your needs. However, you should consider gutters and piping that are 6 inches or larger if your roof has a large footprint or numerous ridges and valleys, or if there is more than 80 feet or so to the nearest downspout. The best thing to do when sizing your conveyances is to consult with a reputable gutter supplier.

Operation and Maintenance of Your Rainwater Collection System

Rainwater collection and storage facilities require a variety of routine maintenance. Some of the routine maintenance activities that you will need to periodically complete are:

- Removing debris from the roof, leaf guard, gutter, gutter screen, and first-flush diverter.
- Inspecting and repairing vent screens.
- Siphoning sediment from the tank.
- Testing the coliform bacteria levels in your untreated-water storage tank.
- Disinfecting the untreated-water storage tank if total coliform levels reach 500 colony-forming units per 100 milliliters (500 CFU/100 mL) or if fecal coliform levels reach 100 CFU/100 mL.

Untreated water with total coliform levels above 500 CFU/100 mL or fecal coliform levels rise above 100 CFU/100 mL should not even be used for nonpotable purposes until it has been disinfected. Disinfection can also help prevent heavy biological growths that can foul your treatment system and contaminate your plumbing system. The most convenient way for you to control biological growths in your storage tank is to add a small amount of chlorine bleach periodically. The amount of bleach you will need to add depends on how concentrated the bleach is, how big the storage tank is, and whether you are trying to prevent biological growths or eliminate an existing problem. Table 2.1 lists the amount of bleach needed to achieve chlorine levels under varying conditions.

Table 2.1. Amount of Liquid Bleach Needed to Disinfect a Storage Tank

Desired Chlorine Level	Bleach Concentration (per bottle label)	Storage Tank Volume	Approximate Amount of Bleach Needed
0.5 mg/L (prevention)	5 %	1,000 gal	2 ½ Tablespoons
		5,000 gal	¾ cup
	10 %	1,000 gal	1 ½ Tablespoons
		5,000 gal	⅓ cup
5 mg/L (elimination)	5 %	1,000 gal	1 ½ cups
		5,000 gal	7 ¾ cups
	10 %	1,000 gal	1 ½ cups
		5,000 gal	3 ¾ cups

You should only use chlorine compounds that are certified in accordance with ANSI/NSF Standard 60 requirements. This standard, which also applies to all chemicals added to potable water, assures that the product will not pose any chemical or biological threat to you or your family when applied in accordance with manufacturer recommendations. Unfortunately, few if any of the liquid bleaches sold in grocery stores or pool-supply companies carry an NSF label. Although you can find a list of approved liquid bleaches on the NSF web site, most of these manufacturers do not produce small containers of bleach. We try to maintain a list of unlabeled bleaches that meet NSF requirements. We post this list on our web site, at <www.tceq.state.tx.us/goto/bleach>.

If you cannot find any of the bleach solutions from our list or the NSF's list, at least avoid the ones that contain fragrances or UV stabilizers: none of these bleaches are NSF certified**. And do not use products designed for use in swimming pools. These products often contain cyanide-based UV stabilizers.**

Chapter 3

Treatment Units, Pumps, and Treated-Water Storage

As you design your rainwater treatment and treated-water storage facilities, you need to keep a few things in mind.

1. The harvested water must be treated before it reaches the points in your home where it is consumed.
2. The treatment system must be able to protect you and your family from a variety of chemical and microbiological contaminants.
3. The treated-water storage tanks must prevent the treated water from being recontaminated.
4. The treatment and storage facilities must supply enough water to meet your family's needs at the instant that they need it.

This chapter provides you with the basic information that you need to achieve these objectives. Simple schematics for treatment, storage, and pumping facilities are shown at the end of this document (Appendixes 2 and 3).

Point-of-Entry vs. Point-of-Use Treatment

Treatment units can be categorized in a variety of ways. For example, some treatment processes are designed to improve the safety of the water, while others are designed to improve its aesthetic qualities (such as taste and odor). Another way to categorize a treatment unit is by the location in your home where the treatment occurs. Treatment units that treat all of the water as it enters you home's plumbing system are called "Point-of-Entry," or POE, units while the units that treat the water at the point where it is actually consumed are called "Point-of-Use," or POU, units.

Although the POE and POU approaches can both provide adequate protection if properly installed, we recommend that you install a POE treatment system when treating for contaminants that pose a potential health threat. Using a POE system for this application helps to ensure that all the water entering your home is safe to use, simplifies your operational and maintenance requirements, and may even reduce your installation costs. We recommend that you only use POU systems to improve the aesthetic quality of your water.

Treating for Microbiological Contaminants

As we discussed in Chapter 1, harvested rainwater can contain a variety of pathogenic (disease-causing) microbes. Although the water harvested from a roof-based collection system will usually contain few of these microbiological contaminants, you still need to treat the water as though it were highly contaminated. Providing this level of treatment ensures that your family is constantly protected from a waterborne disease.

The threat posed by microbiological contaminants is controlled by physically removing the contaminants with a filter, or by inactivating them with a disinfectant. State and federal regulations establish minimum treatment requirements for public water systems that use rainwater systems and other water sources that are susceptible to microbiological contamination. Although there are no similar mandatory requirements for individual domestic rainwater harvesting systems, we recommend that you use a treatment system that provides the same level of protection as one that would be used by a public water system. Table 3.1 lists the minimum treatment requirements of the current surface water treatment rules for public water systems.

Table 3.1. Microbiological Removal/Inactivation Requirements for Public Water Systems Using Rainwater

Contaminant	Log Removal / Inactivation	Equivalent Percent Removal / Inactivation
Cryptosporidium	2	99
Giardia	3	99.9
Viruses	4	99.99

It is difficult to design a single treatment process that provides complete protection against all pathogens. Although it is possible that a filtration system or a disinfection system could each achieve adequate levels of protection by themselves, we recommend that you use a combination of filters and disinfectants to provide multiple barriers and increase your protection from waterborne disease. Regardless of which technology or combination of technologies you select, you should only use equipment that has been certified in accordance with applicable ANSI/NSF requirements. This will ensure that your treatment system will offer adequate protection. A properly designed treatment system will provide you and your family with a safe, sanitary supply of drinking water. On the other hand, improperly treated rainwater will, at some point, make you, your family, or your guests very sick.

Filtration Technologies

You can use a variety of technologies to remove microbial pathogens from your harvested rainwater. Some of these filters can only remove relatively large particles, such as parasites, while other technologies can remove extremely minute particles, such as viruses. Table 3.2 lists some of the filtration technologies that you may want to consider and their relative effectiveness for removing the microbes that could be present in harvested rainwater.

Table 3.2. Filter Technologies and the Type of Microbes They Can Remove

Filtration System	Types of Pathogens Removed
Some Types of Bag Filters	Parasites (*Cryptosporidium, Giardia, Toxoplasma*)
Some Types of Cartridge Filters	Parasites
Microfiltration Membranes	Parasites, most bacteria
Ultrafiltration Membranes	Parasites, bacteria, some viruses
Nanofiltration Membranes	Parasites, bacteria, viruses

You need to consider several issues when selecting the filtration technology that you want to use.

For example:

- The gutter screens and prefilters we discussed in Chapter 2 can only remove large particles. They are completely ineffective against pathogenic microbes (parasites, bacteria, viruses).
- Not all bag and cartridge filters will remove *Cryptosporidium* and *Giardia*. You need to select a unit that is specifically designed to remove these parasitic pathogens.
- Since bag and cartridge filters do not remove bacteria or viruses, you will need to rely entirely on a disinfectant to kill or inactive these pathogens.
- Some bag filters can be cleaned and reused, while others must be replaced when they get full.
- Cartridge filters are usually less expensive than bag filters but the cartridges usually cannot be cleaned and must be replaced periodically.
- Some membrane materials, such as cellulose acetate, are extremely susceptible to damage by chlorine and other disinfectants. If you select a unit that uses one of these susceptible membranes, you need to install an activated carbon filter upstream of your membrane filter to remove any disinfectant that might be present in the water. This activated carbon filter is especially important if you are going to supplement your rainwater supply with hauled water or water from a public water system because we require these water suppliers to maintain a disinfectant residual in the water they deliver to you.
- Nanofiltration and reverse osmosis membranes usually require a higher operating pressure than microfiltration and ultrafiltration membranes.
- Membrane filters can be plugged by larger-size particles. Therefore, you will probably need to install a cartridge or bag prefilter to make sure that large particles do not enter the membrane unit.

- You must flush and backwash membrane filters periodically to remove the particles that have been trapped on the membrane surface. Therefore, not all of the water you treat can be consumed. Depending on the design, the membrane system may only be able to deliver 85 to 95% of the water you harvest.
- **Be sure that you read and follow the manufacturer's instructions.** Filtration systems are usually quite reliable pieces of equipment. However, they can be easily damaged if you don't follow the manufacturer's recommendations.

Unless you are going to disinfect with a high dose of ultraviolet light, we recommend that you use filters that have been certified for the removal of parasitic cysts in accordance with ANSI/NSF Standard 53 requirements. Filters that have been certified to meet this requirement have been proven safe for drinking water applications and will remove 99.95% of *Cryptosporidium*-size particles. Since the other parasites are larger than *Cryptosporidium*, these filters will protect you and your family from all of the parasitic pathogens that might be present in harvested rainwater.

Some filtration technologies, especially bag and cartridge filters, are unable to meet the stringent performance standards established by ANSI/NSF Standard 53. Although some of these units can reduce *Cryptosporidium* levels significantly, you need to make sure that an uncertified unit has been tested in accordance with the United States Environmental Protection Agency (EPA) requirements by an independent third party. Please feel free to call us if you are interested in using a bag, cartridge, or membrane filter that has not been certified under ANSI/NSF Standard 53.

If you are going to disinfect with a high dose of ultraviolet light, it is not absolutely essential for you to use a filter that is certified to meet ANSI/NSF Standard 53 requirements. However, you must use a filter that removes most particulate matter, because the UV light cannot disinfect pathogens that are shaded by other particles. In order to maximize the efficiency of your UV disinfection process, we recommend that you install one of the membrane filter technologies or a cartridge filter that has a pore size of 3 to 5 microns or smaller. In order to assure that the filter does not leach undesirable contaminants into the water, you should only use filtration systems that that have been certified to meet ANSI/NSF Standard 61 requirements.

Disinfection Technologies

Although there are numerous disinfection technologies, some of them are more appropriate for home use than others. We recommend that you consider using a combination of ultraviolet light and chlorine for the following reasons.

- Ultraviolet light (UV) is extremely effective against *Cryptosporidium*, but high doses are required to inactivate some viral pathogens. In addition, UV systems do not maintain a disinfectant residual in your plumbing system.
- Free chlorine is very effective against viruses but is virtually ineffective against *Cryptosporidium*. In addition, it is easy to maintain and measure a free chlorine residual in your plumbing system.

If you do not want to maintain a disinfectant residual in your plumbing system, you may want to consider using ozone as an alternative to UV. Like UV, ozone does not produce a long-lasting residual and will not provide any protection against bacterial regrowth in your plumbing. However, it is effective against both parasites and viruses. The major reason that we are not recommending ozone is that there is no ANSI/NSF standard for evaluating the safety of ozone generators used for potable water applications. If you do decide to use ozone as your disinfectant, be sure to use an ozone contact vessel that is certified in accordance with ANSI/NSF Standard 61 requirements.

Ultraviolet Light

As we just discussed, some disinfectants are more effective against certain pathogens than others. Ultraviolet light provides an excellent example of this limitation since it is much more effective against parasites than it is against certain viruses. Table 3.3 shows the UV dose that must be applied to achieve certain levels of disinfection.

Table 3.3. UV Dose Requirements for *Cryptosporidium*, *Giardia*, and Virus Inactivation

To achieve this level of Inactivation		This UV dose (mJ/cm²) is required for this Pathogen		
Log	**Percent**	***Cryptosporidium***	***Giardia***	**Virus**
0.5	67 %	1.6	1.5	39
1.0	90	2.5	2.1	58
1.5	96.7	3.9	3.0	79
2.0	99	5.8	5.2	100
2.5	99.67	8.5	7.7	121
3.0	99.9	12	11	143
3.5	99.97	15	15	163
4.0	99.99	22	22	186

As Table 3.3 indicates, the UV dose needed to achieve a 4-log (99.99%) inactivation of viruses is more than eight times greater than the dose needed to achieve an equivalent inactivation of parasites. ANSI/NSF Standard 55 establishes testing requirements for UV water treatment systems. UV systems that meet the Class A requirements of Standard 55 are capable of producing an UV dose of 400 mJ/cm^2 at their rated capacity and are equipped with a sensor to alert you if the UV system needs to be cleaned or has begun to fail due to lamp age. UV systems that meet the Class B requirements of Standard 55 are not required to have a sensor and have not been certified for pathogen control, although they can be used to provide additional treatment on water that has already been properly disinfected. Consequently, if you are going to install a UV system to control pathogens, you need to choose a unit that is certified as Class A under ANSI/NSF Standard 55.

It is important to remember that UV can only inactivate a pathogen if the microbe has actually been exposed to the UV light. In order for the UV system to work, the water passing though it must be relatively clear and free of particles. Consequently, you need to install a filter upstream of your UV unit. (This filter should be one of the filters discussed in the previous section.)

Chlorine

Chlorine is one of a group of non-metallic elements know as halogens. Chlorine, like UV, is more effective against some pathogens than it is against others. However, there are several important differences between UV and chlorine, including:

- Chlorine is more effective against viruses than it is against parasites, while UV is more effective against parasites than against viruses.
- UV light can inactivate pathogens in a few tenths of a second, while chlorine requires several minutes to work.
- UV disinfection only works on water that is relatively clear, while chlorine can be used to disinfect water that is relatively cloudy.
- The effectiveness of UV disinfection is unaffected by the pH and temperature of the water, while the effectiveness of chlorine is affected by pH, temperature, and the chlorine concentration in the water.

Table 3.4 shows how long it takes chlorine to achieve a desired level of disinfection under a specific set of conditions. Table 3.5 shows how the effectiveness of chlorine can be affected by pH, temperature, and concentration.

Table 3.4. An Example of the Chlorine Contact Time Requirements for *Cryptosporidium*, *Giardia*, and Virus Inactivation†

To achieve this level of Inactivation		This much contact time (minutes) is required for this Pathogen		
Log	**Percent**	***Cryptosporidium***	***Giardia***	**Virus**
0.5	67 %	Ineffective	9	0.25 (15 sec)
1.0	90	Ineffective	19	0.5 (30 sec)
1.5	96.7	Ineffective	28	0.75 (45 sec)
2.0	99	Ineffective	37	1
2.5	99.67	Ineffective	47	1.5
3.0	99.9	Ineffective	56	2
3.5	99.97	Ineffective	65	2.5
4.0	99.99	Ineffective	75	3

† Under the following conditions: Free chlorine residual = 1.0 mg/L (milligrams per liter), pH = 7.0, and temperature = 20°C (68°F).

Table 3.5. An Example of the Effect that pH, Temperature, and Chlorine Concentration Has on *Giardia* Inactivation†

At this water temperature	And this pH	This much contact time (minutes) is requred if the free chlorine residual is:	
		1.0 mg/L	2.0 mg/L
25° C (77° F)	6.5	31	17.5
	8.0	54	30.5
5° C (41° F)	6.5	125	69
	8.0	216	121.5

† Based on a 3-log (99.9%) *Giardia* inactivation

The data presented in Tables 3.4 and 3.5 indicate that you should not rely on chlorine as your primary disinfectant unless you have used a filtration system that has been certified in accordance with ANSI/NSF Standard 53 requirements. On the other hand, chlorine is an extremely attractive alternative if you have installed such a filtration system because chlorine is extremely effective against viral contaminants.

Chlorine is available in gaseous, solid, and liquid forms. We recommend that you avoid using gas chlorine because it is much more corrosive and much more hazardous than the solid (calcium hypochlorite) or liquid (sodium hypochlorite bleach) forms. Chlorine gas is extremely hazardous and has been used as a chemical warfare agent. You should not use chlorine gas unless you have OSHA-approved safety equipment on hand and are extremely familiar with its use.

Many homeowners and public water systems prefer using calcium hypochlorite because, in its solid form, it is more stable than liquid bleach and is available in higher concentrations. Solid calcium hypochlorite is produced in tablet, pellet, and granular forms. Tablets and pellets are frequently used in in-line erosion chlorinators. The calcium hypochlorite tablets or pellets are placed inside the erosion chlorinator; as water flows through the unit, the calcium hypochlorite slowly dissolves and releases chlorine into the water. Granular products are often mixed with water to form a liquid bleach solution that is fed with a metering pump. Due to its high chlorine content, calcium hypochlorite containers should be kept tightly closed and stored away from combustible materials such as oils, fuels, and greases.

You can also use sodium hypochlorite (liquid bleach) as your chlorine source. Liquid bleach is arguably the safest of the chlorine compounds because it is not as concentrated as the other materials and is less likely to release high concentrations of chlorine gas. However, it is much more susceptible to thermal decay and you should probably not keep more than a 30- to 60-day supply on hand. Sodium hypochlorite solutions, like solutions of dissolved calcium hypochlorite, are fed with a small metering pump.

You should only use chlorine compounds that are certified in accordance with ANSI/NSF Standard 60 requirements. This standard, which also applies to any other chemical used to treat potable water, assures that your chemical will not pose any chemical or biological threat to you or your family when applied in accordance with manufacturer recommendations. Unfortunately, few if any of the liquid bleaches sold in grocery stores or pool-supply companies carry an NSF label. Although you can find a list of approved liquid bleaches on the NSF web site, most of these manufacturers do not produce small containers of bleach. We try to maintain a list of unlabeled bleaches that meet NSF requirements. We post this list on our web site, at <www.tceq.state.tx.us/goto/bleach>.

If you cannot find any of the bleach solutions from our list or the NSF's list, at least avoid the ones that contain fragrances or UV stablizers: none of these bleaches are NSF certified. **And do not use products designed for use in swimming pools. These products often contain cyanide-based UV stabilizers.**

As stated previously, chlorine is only one of a chemical group known as halogens. The other halogens are bromine, iodine, fluorine, and astatine. Although the other halogens are probably effective viral disinfectants, we recommend that you stick with chlorine because:

1. There is only limited data on the effectiveness of the other halogens. We don't know what level is needed to kill most pathogens under various conditions or how long it takes for the other halogens to work.
2. We have not been able to find any other halogen disinfectant that has been certified in accordance with ANSI/NSF Standard 60 requirements.

Other Treatment Processes

There are other treatment processes that you may want to consider using to improve the chemical or aesthetic quality of the water in your home. Some of these (like corrosion control) are more important than others (like supplemental demineralization).

Corrosion Control

Corrosion control treatment can be very beneficial because rainwater is slightly acidic, contains very few dissolved minerals, and can be very corrosive. Since plastic pipe is not subject to corrosion, you do not need to consider installing corrosion control treatment if your home is totally plumbed with plastic pipe. On the other hand, corrosion control treatment is especially important if your household plumbing was constructed out of thin-walled copper tubing because this material is particularly susceptible to pinhole leaks. There are several approaches that you can use to control corrosion.

The simplest method for controlling corrosion is to reduce the corrosivity of the untreated water by periodically adding sodium bicarbonate (baking soda) to your untreated water storage tank. The bicarbonate will increase the alkalinity level (buffering capacity) in the water significantly and raise the pH of the water slightly. One benefit of this approach is that, unlike the other alternatives, it will help prevent corrosion in your home's plumbing as well as in your untreated water storage tank. Another benefit is that it does not require any special equipment. If you use this approach, we recommend that you apply the following procedure about every three months:

1. Measure the pH of the water in the storage tank.
2. If the pH is 7.4 or higher, you're done.
3. If the pH is between 7.0 and 7.4, add 1 pound of baking soda for every 10,000 gallons of water for each 0.1 pH unit below 7.4. For example, a tank that contains about 10,000 gallons of water with a pH of 7.1 would require about 3 pounds of baking soda to get the pH up to about 7.4, while a 5,000-gallon tank would require about 1.5 pounds.
4. If the pH is less than 7.0, add 2 pounds of baking soda for every 10,000 gallons of water, wait a couple of days for the pH to equalize, and then repeat the procedure.

As with any chemical, be sure to use a product that has been certified in accordance with NSF Standard 60. Fortunately, one of the certified products is the Arm & Hammer baking soda you find at your local grocery store.

To use this approach you need to be able to measure the pH of the untreated water. You can find pH test kits at almost any store that sells swimming-pool supplies. We recommend that you select a test kit that will measure both pH and alkalinity. If you use this corrosion control approach, your goal is to keep the pH between 7.0 and 7.5, with an alkalinity level of at least 20 mg/L but not more than about 80 mg/L.

If you are supplementing your rainwater system with water from a public water system, it is important to avoid raising the pH above 7.7 or so. At higher pH levels, the calcium carbonate that is usually present in the water that you get from a water hauler or public water system might precipitate. While this precipitate is not harmful, it may cause the water to be slightly cloudy until the next time it rains. You may also be able to eliminate the cloudiness by adding a little acid to the water to drop the pH back down below 7.7. While we recommend using a product that is certified under NSF Standard 60, you can also use acetic acid (white vinegar) from the grocery store, if the product label says that it is safe for ingestion.

Another way to control corrosion is to pass the rainwater through an in-line filter that contains a bed of calcium carbonate (limestone) pellets, calcium oxide (lime) pellets, or sodium carbonate (soda ash) pellets. As the rainwater passes through the filter bed, it dissolves some of the limestone. The dissolved calcium increases the hardness slightly, which may reduce the likelihood that your rainwater will corrode your pipes. If you decide to use one of these in-line calcium carbonate filters in conjunction with a UV disinfection unit, be sure to install the filter downstream of (after) the UV unit to help prevent the formation of scale in the UV reactor. The UV lamp can get rather warm and cause minerals, such as calcium, to form scale deposits on the reactor lens.

Yet another way to reduce corrosion rates involves using a metering pump to feed a liquid chemical called zinc orthophosphate. The zinc orthophosphate coats the interior of your pipes and prevents the soft rainwater from actually reaching the pipe wall.

As we discussed previously, you should only use chemicals and drinking water additives that are certified in accordance with ANSI/NSF Standard 60 requirements.

VOC/SOC Adsorption

If you have followed our advice, it is very unlikely that your rainwater will contain any significant amount of volatile organic chemicals (VOCs) or synthetic organic chemicals (SOCs). However, you may want to install an activated carbon filter to provide an additional level of protection. If you are going to install an activated carbon filter, be sure to select one that has been certified for VOC/SOC removal in accordance with ANSI/NSF Standard 53 and to install it upstream of your chlorinator. Activated carbon adsorbs chlorine, so installing your carbon filter downstream of your chlorinator will not only remove the chlorine you add, it will reduce the useful life of the carbon.

Point-of-Use Treatment

Unless something has gone terribly wrong during the primary treatment process, you probably will not benefit much from installing a point-of-use system (such as a reverse osmosis filter or an activated carbon filter) at each sink and shower in your home. The only time when you should seriously consider using a point-of-use device in a rainwater system is when your home's plumbing system was constructed using pipe, faucets, or fittings that contain more than 8.0% lead, or solders and fluxes that contain more than 0.2% lead. Because rainwater is slightly acidic and very soft, it will easily leach the lead from these materials. Excessive lead levels should not be a problem if your home was constructed after 1988, because materials produced since that time were required to meet this low-lead standard. If you do decide to install point-of-use treatment, make sure that it is certified under ANSI/NSF Standard 53 to reduce the contaminants that you are targeting.

Treated-Water Storage Tanks

Treated-water storage tanks can be either pressurized or unpressurized vessels. The primary role of a pressurized (pressure) tank is to provide treated water during periods when your pump is not running. However, pressure tanks also help prevent pressure surges that can occur at the beginning and end of each production run. The primary purpose of an unpressurized (storage) tank is to store large volumes of treated water so that you can install smaller treatment units.

If your treatment system is not large enough to treat all of the water that your family needs at the instant that they need it, you will need to install a storage or pressure tank that is large enough to meet your needs during periods when the treatment units cannot keep up with demand.

We recommend that you use the following guidelines when designing your water storage and pressure tanks.

1. Never install a treated-water storage tank or pressure tank below ground.
2. Install the tanks inside of a building if possible, to protect them from contamination and inclement weather.
3. Make sure that the tank or its internal coating materials have been certified in accordance with ANSI/NSF Standard 14 or Standard 61.
4. Unless you need a very large storage tank, use a tank constructed of polypropylene, high density polyethylene, or a similar corrosion-resistant material. Regardless of the material you select, the tank needs to be opaque to prevent or reduce the growth of algae. Opaque tanks are particularly important if you are not constantly maintaining a chlorine residual in the treated water storage tank.
5. Make sure that any vents on your storage tank face downward and are covered by 16-mesh corrosion-resistant material (such as nylon window screen), and that other openings are protected with a gasketed cover. Painting the inside surface of the vent with a flat black paint may also help, because insects will perceive the opening as a solid surface.
6. Install a bladder-type pressure tank because they are less susceptible to corrosion than galvanized-steel pressure tanks and provide more water per gallon of capacity.
7. Be sure to install a pressure-relief, or pop-off, valve on the fill line to your pressure tank to protect it from excessive pressures and pressure surges.

Supplemental Sources of Supply

If you are going to connect your tank to a supply line from a public water system, the connection must be made through an air gap and must be inspected and approved by the public water system's personnel.

If you are going to obtain a supplemental supply from a water hauler, you need to make sure that:

- Your tank is equipped with a roof hatch or has a covered fill box.
- The tanker truck and hoses that the supplier uses are only used to transport potable water.

- The supplier obtains your water from a public water system.
- The ends of the fill line and hoses are capped or otherwise protected from contamination during transport.
- The supplier does not drop the end of the hose into the tank (because the outside of the hose is often much less sanitary than the inside of the hose).
- The supplier closes the hatch or fill box when they finish filling your tank.

Water Pumps

You will need to use at least one pump to move water from your untreated-water storage tank, through the treatment process, and into the treated-water storage tank. If you install an unpressurized storage tank, you will also need a second pump to repressurize the treated water as it enters your plumbing system. The type of pump you will need will depend on whether you installed your untreated-water storage tank above ground or below ground, what pressure your treatment systems requires, and the water pressure that you want to maintain in your home. We recommend that you only use pumps that are designed for potable water applications and certified in accordance with ANSI/NSF Standard 61 requirements.

Piping

As discussed in Chapter 2, we recommend that you use plastic pipe that has been certified to meet ANSI/NSF Standard 14 or Standard 61 requirements. Rainwater is very soft and somewhat acidic, so it tends to be more corrosive than most other sources of drinking water. Since plastic pipe is less susceptible to corrosion, it is more suitable for this particular application. If you decide to use another piping material, be sure that it has been certified under NSF Standard 14 or Standard 61. Due to the corrosive tendencies of rainwater, you should NOT use thin-wall copper pipe or tubing, even if it is ANSI/NSF certified, because of the potential to develop pinhole leaks.

In order to help you distinguish between pipes that contain untreated water and those that contain treated water, we recommend that you label the untreated-rainwater pipe. Using black lettering, print "**UNTREATED RAINWATER – DO NOT DRINK**" on a bright orange background. The lettering should be in bold and clearly visible. The label should be painted at two-foot intervals on all piping located between the untreated-water storage tank and the last treatment unit.

Sizing the Treatment and Treated-Water Storage Facilities

There are two major issues you need to evaluate when designing the capacity of your treatment and treated-water storage system: how fast you are going to use the water and how fast you are able to supply it.

Step 1. Determining Your Maximum (Instantaneous) Consumption Rate

To a great extent, your maximum consumption rate depends on your family's lifestyle. If you all bathe at the same time that you are doing laundry and running the dishwasher, your consumption rate will be much higher than if your family spreads its usage out over a two-hour period. Let's consider the hypothetical family that we discussed in Chapter 2. This family of four uses about 200 gallons of treated water each day. If they use most of those 200 gallons within 10 minutes or so, they will be consuming water at a rate of about 20 gallons per minute (gpm). However, if they spread their usage out over a two hour period, they will be consuming water at a rate of less than 2 gpm.

We recommend that you assume that your family will have a maximum consumption rate of between 5 and 10 gpm. However, you can calculate your family's maximum consumption rate by adding the flow rate though each plumbing fixture you might be using simultaneously. For example,

4 gpm	+	2 gpm	+	2.2 gpm	=	8.2 gpm
(2 faucets)		(2 toilets)		(1 shower head)		

Step 2. Designing Your Treated-Water Supply Facilities

Your treated-water supply system will include pumps, treatment units, pressure tanks, and, perhaps, treated-water storage tanks. There is a relationship between the capacities of your treatment, pumping, and storage units. For example, if your treatment rate is greater than or equal to your consumption rate, you will only need a small pressure tank or, if you select an appropriate pump, you may even be able to operate a "tankless" system. On the other hand, you will require a larger pressure tank if you consume water faster than you can treat it. If the difference between the treatment and consumption rates is great enough, you will need to add an unpressurized treated-water storage tank and a high-service pump to repressurize the water.

There are several good reasons to include a storage tank and second pump even if your treatment facilities have enough capacity to meet your peak momentary demands. For example, having a storage tank can allow you to operate (although in a strict water conservation mode) for two or three days while you repair or maintain your upstream equipment. However, this capability can add significantly to the complexity and cost of your system.

An individual needs to understand a variety of complex subjects to properly design the treatment, pumping, and storage facilities. For example, system design involves selecting a pump that will operate properly at your home, ensuring that your electrical system will handle the additional load, choosing an appropriate system to control the pump, and matching the capacity of the pump with that of the treatment units and storage tanks. Due to the complex nature of this task and the level of expertise required to complete it properly, we recommend that you hire an engineer or other experienced professional to design this part of your system.

If you are NOT going to install a treated-water storage tank, we have the following recommendations:

- Make sure your pumps and treatment units have sufficient capacity to meet your peak momentary demands (usually, 5 to 10 gpm or more, depending on your lifestyle).
- Install a 40- to 80-gallon or larger bladder-type pressure tank to reduce pressure surges and provide additional water during periods of unexpected demands, such as when you have guests.
- Select treatment units and pressure tanks that can operate at pressures of at least 60 psi, so that you can set your pump to maintain a minimum pressure of 35 to 40 psi in your home.
- Install a pressure reducer at an appropriate location to protect your plumbing system from pressure surges if you are using a treatment process—such as nanofiltration or reverse osmosis—that must operate at pressures significantly above 60 psi.
- Consider installing an erosion chlorinator even if you are using UV as your primary disinfectant, so that you can periodically disinfect your plumbing system.

If you ARE going to install a treated-water storage tank, we have the following recommendations:

- Install a tank with a capacity of 300 to 400 gallons or more.
- Make sure your treatment units (and the pump that supplies them) have a capacity that is at least 35% of your peak momentary demands, in other words, 2 to 4 gpm.
- Operate your treatment system based on the water level in your storage tank.
- Install a service pump that has a sufficient capacity to meet your peak instantaneous demand, and a 20- to 40-gallon bladder-type pressure tank.
- Set your service pump to maintain a pressure of 40 to 60 psi in your home.

Operation and Maintenance of Your Rainwater Treatment System

It is extremely important for you to follow the manufacturer's maintenance recommendations in order to maximize the reliability of your treatment and storage facilities. For example, filters and UV lamps will need to be replaced on schedule, pumps may need to be lubricated, and chemical feeders will need to be checked and periodically refilled.

We also recommend that you run bacteriological tests on the treated water entering your home every 3 to 6 months. Bacteriological testing is especially important if you have decided not to continuously maintain a chlorine residual in your plumbing system. These tests are extremely sensitive; you must use the sterile containers supplied by a laboratory and return the samples as they direct or you *could* get "false positive" results. You should disinfect your facilities if the laboratory report indicates that your treated water:

- has a heterotrophic plate count (HPC) above 500 colony-forming units per 100 milliliters (CFU/100 mL), or
- contains any coliform organisms.

If you are feeding chlorine continuously, you can increase the effectiveness of your disinfection process by increasing the chlorine residual slightly for a few days. If you are not chlorinating continuously, you can "batch chlorinate" your system as we described in Chapter 2.

Your local or county health department can probably provide you with a list of local laboratories that can test the bacteriological quality of your water. We inspect some of the drinking water laboratories in Texas and other laboratories participate in the National Environmental Laboratory Accreditation Program (NELAP). Laboratories are not required to participate in these quality-control programs unless they run tests for public water systems. Although some of the other local laboratories may also give you accurate results, we recommend that you use a certified or accredited laboratory. You can obtain laboratory contact information for the labs we regulate from the web page <www.tceq.state.tx.us/goto/lab_list>.

Chapter 4

Nonpotable Use and Other Considerations

If you are going to rely on other sources—such as a public water system or private well—to meet your potable water needs, you can still use rainwater for nonpotable purposes like doing laundry or flushing toilets. Rainwater harvesting systems that are used only for nonpotable purposes do not need to meet the demanding standards that apply to systems used to supply potable water. Nevertheless, the system must still be able to provide relatively clean water that is suitable for its intended use. Furthermore, you need to take special precautions to ensure that your potable and nonpotable systems are isolated from one another so that you do not accidentally consume nonpotable water. This chapter provides you with some basic information that you need to achieve these objectives.

There are other documents, however, that provide more extensive information on nonpotable rainwater systems. Two of these documents are *The Texas Manual on Rainwater Harvesting* (referred to here as the "TWDB Manual") and the *Rainwater Harvesting Potential and Guidelines for Texas* (referred to here as the "Committee Report"). Copies of these two documents can be downloaded from the web page <www.twdb.state.tx.us/iwt/rainwater/docs.html>.

Nonpotable Harvesting, Storage, and Treatment

Chapters 3 and 4 of the Committee Report do an excellent job of comparing and contrasting the different design practices, treatment options, and water quality standards that apply to systems using rainwater for potable and nonpotable applications. The differences are summarized in Table 4.1.

Table 4.1. Comparison of Nonpotable and Potable Rainwater Systems

Issue	Nonpotable System	Potable System
Materials of Construction	Potable water certification not needed. Thin-wall copper tubing should not be used.	Materials used should be (when available) certified for potable water applications under ANSI/NSF Std 61. Thin-wall copper tubing and materials containing lead or biocides should not be used.
Treatment Technology	*Pre-treatment* First-flush, roof washer, or other appropriate pre-filtration method. *Treatment* Bag or cartridge filtration with a 5-micron sediment filter and periodic chlorination with household bleach.	*Pre-treatment* First-flush, roof washer, or other appropriate pre-filtration method. *Treatment* Filtration with an ANSI/NSF Std 53 filter followed by disinfection with ANSI/NSF Std 60 chlorine or an ANSI/NSF Std 55, Class A UV unit. ***OR*** Filtration with a 3- to 5-micron ANSI/NSF Std 61 sediment filter and disinfection with an ANSI/NSF Std 55, Class A UV unit.
Treatment Goals	Total Coliform: < 500 CFU/100 mL Fecal Coliform: < 100 CFU/100 mL Turbidity: < 10 NTU Water should be tested annually.	Total Coliform: 0 Fecal Coliform: 0 Protozoan Cysts: 0 Viruses: 0 Turbidity: < 0.3 NTU Water should be tested every 3 months.

Dual Distribution Systems

In a dual distribution design, one plumbing system is used to supply treated water to all the connections—such as sinks, showers, and dishwashers—where your family might be using the water for a potable purpose. And another, completely separate, plumbing system is used to carry untreated rainwater to one or more nonpotable outlets—such as your washing machine or toilets. Chapter 5 in the Committee Report does an excellent job of describing how a dual distribution system operates and the amount of potable water that can be saved by using rainwater for nonpotable applications. Little can be added to the Committee Report except to emphasize how important it is to completely protect your potable system from cross-connections.

Cross-connection Control

To protect your family from cross-connections, you must be able to distinguish between the pipes that contain potable (treated) water and those that contain nonpotable (untreated or partially treated) water and you must prevent nonpotable water from entering the potable system. We support the Texas Rainwater Harvesting Evaluation Committee's recommendation that you label all piping that contains nonpotable water and install air gaps or reduced-pressure principle backflow assemblies to protect the potable water system.

Piping Labels

We recommend that you label all untreated-rainwater pipe installed downstream (or after) your untreated-water storage tank. With black lettering, on a bright orange background, the pipe should be labeled "**UNTREATED RAINWATER – DO NOT DRINK.**" The lettering should be in bold and clearly visible. The label should be repeated at two-foot intervals on all piping located between the untreated-water storage tank and every point where nonpotable water is used. We also recommend that you label any faucet or water tap that supplies nonpotable water, especially those—such as the washing machine faucet—that are located inside your home.

Air Gaps

We recommend that you use an air gap to maintain a physical separation between the potable and nonpotable systems whenever possible. For example, if you are going to install a line so that your untreated-water storage tank can be refilled using potable water, you need to install the water line so that it discharges above the overflow elevation, which is the maximum water level that you can get in the tank. Most plumbing codes require that the distance from the outlet of the fill pipe and the maximum water level be at least 1½ times the diameter of the fill line. So, for example, if you have a 2-inch fill line, the bottom of the pipe outlet should be at least 3 inches above the overflow level in the tank. We recommend that you comply with this design standard.

The air gap is the safest method of preventing the potable water line from getting contaminated by nonpotable water. However, because all of the water pressure is lost when the water enters the air, you must repressurize the water after it passes through the air gap.

Reduced-Pressure Principle Backflow Assemblies

Many sources, including the Texas Rainwater Harvesting Evaluation Committee, refer to the reduced-pressure principle backflow assembly (RPBA) as a reduced-pressure-zone backflow preventor (RPZ). The RPBA is a mechanical device that contains two check valves on opposite sides of a central chamber. If the pressure on the potable-water (inlet) side of the RPBA drops below the pressure on the nonpotable-water (outlet) side, the two valves close and the chamber between them drains to establish an air gap between the potable and nonpotable systems.

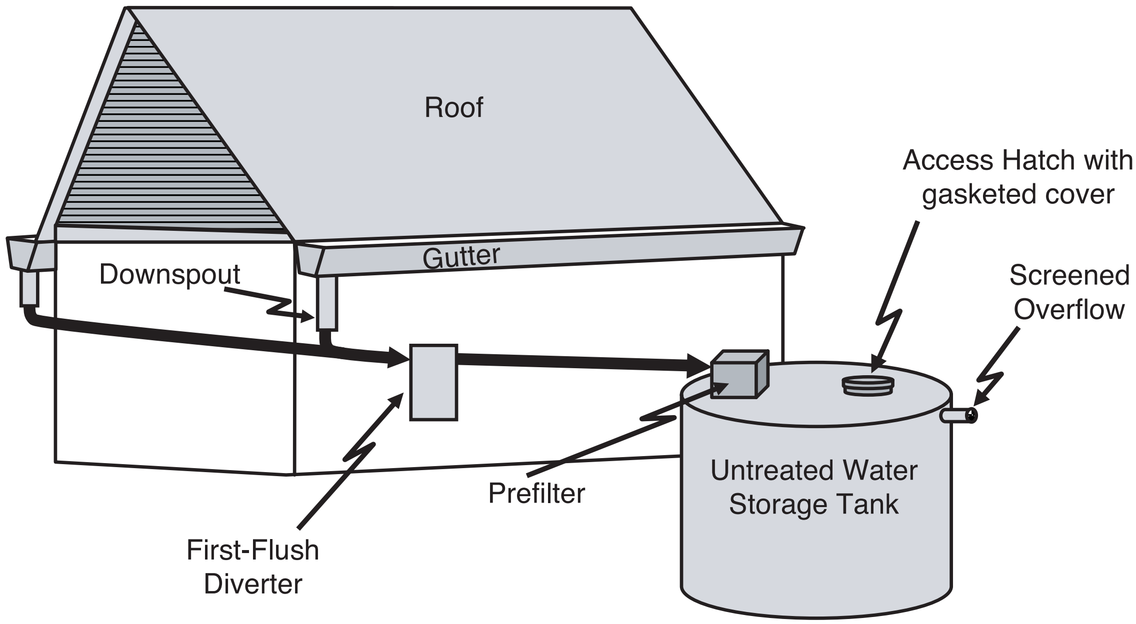
Although the RPBA is not as reliable as an air gap, the RPBA allows you to connect the potable and nonpotable systems without having to repressurize the water. If you properly install (and maintain) an RPBA, you can connect a pressurized potable line to a pressurized nonpotable line relatively safely. One of the biggest disadvantages of the RPBA is that the device must be tested by a Certified Backflow Assembly Tester when it is installed and annually thereafter.

Public Water System Inspection

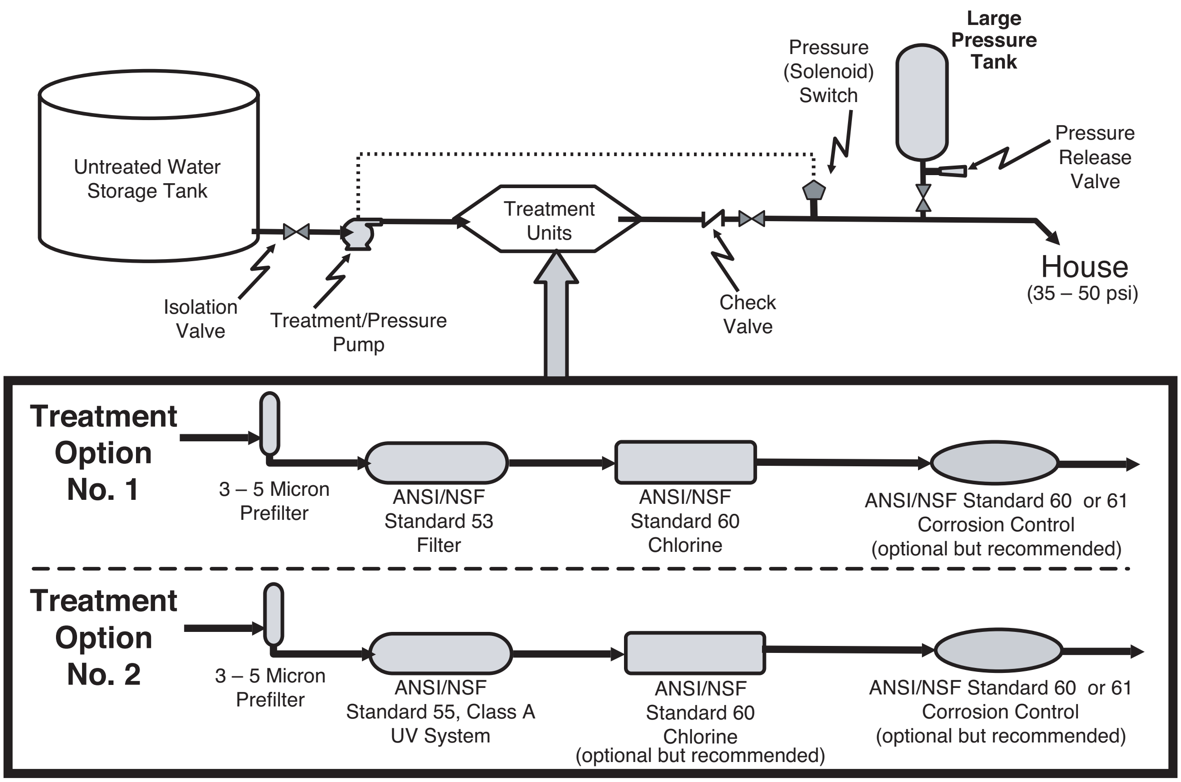
As noted in Chapter 5 of the Committee Report, we require public water systems to isolate their system from sources of contamination at all times. If you are going to design your rainwater system so that it can be refilled or repressurized from a public water system, the connection must be inspected and approved by the public water system's personnel. The public water system may require you to install an RPBA at your water meter even if you have installed air gaps and RPBAs within your property. We allow public water systems to exercise this option because they must be absolutely sure that there are no undetected cross-connections within your property and that their other customers are protected in the event that the water system loses water pressure.

Appendixes

Appendix 1. Rainwater Collection and Untreated Water Storage



Appendix 2. Treatment System without a Treated-Water Storage Tank



Appendix 3. Treatment System with a Treated-Water Storage Tank