Roof-Reliant Landscaping™

Rainwater Harvesting with Cistern Systems in New Mexico




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New Mexico Office of the State Engineer
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Preface

The term “rainwater harvesting” is used primarily to describe a landscaping strategy designed to capture rooftop precipitation for irrigation of the landscape, reducing the need for supplemental potable water. As the agency charged with administering the state's water supply, the New Mexico Office of the State Engineer (NMOSE) promotes a variety of water conservation strategies[1]. One strategy with excellent potential for significant water conservation is the Roof-Reliant Landscaping™ method presented in this manual[2].

Because New Mexico is an arid state with significant water challenges, there is a renewed interest statewide in the concept of rainwater harvesting and cisterns. During the hottest summer months in New Mexico, more than half of the total metropolitan water use in residential neighborhoods in Albuquerque goes toward landscape irrigation. Rooftop rainwater harvesting, along with other outdoor water reuse practices, can reduce the demands on municipal water systems and our aquifers.

As increased cycles of drought coupled with population growth strain our limited water resources, not only does it make sense to explore ways to get the most use of rainwater, it is also wise to design and create landscapes that need little or no supplemental water to thrive. The Roof-Reliant Landscaping™ method detailed in this manual begins by emphasizing the need to adhere to xeriscape principles (waterwise landscaping techniques).

New Mexico receives 12 inches of precipitation per year on average. The Office of the State Engineer continues to respond to the public’s need for new and progressive ways to conserve New Mexico’s limited water supply. In the near future, look for a recommended list of “Waterwise Plants of New Mexico” with a column dedicated to “precipitation only plants.” NMOSE will also be developing an Irrigation Calculator, which will help users to determine the appropriate amount of water to use for their landscapes.

Water is a precious resource in New Mexico, and it is in our best interest to be good stewards of this life-giving resource. Committed water conservation efforts will result not only in significant water savings, but also in appropriate public spaces and beautiful and responsible landscapes.

We ask the readers of this manual to visit the Water Use and Conservation section of our website www.ose.state.nm.us.

NEW MEXICO OFFICE OF THE STATE ENGINEER
Rainwater/Snowmelt Harvesting Policy

The New Mexico Office of the State Engineer supports the wise and efficient use of the state’s water resources and, therefore, encourages the harvesting, collection and use of rainwater from residential and commercial roof surfaces for on-site landscape irrigation and other on-site domestic uses.

The collection of water harvested in this manner should not reduce the amount of runoff that would have occurred from the site in its natural, pre-development state. Harvested rainwater may not be appropriated for any other uses.

For additional information visit http://www.ose.state.nm.us and click on Water Use and Conservation.

[1] For more information, please contact the OSE's Water Use and Conservation Bureau's toll free phone number 1-800-WATER-NM or visit www.ose.state.nm.us

[2] This manual applies to landscape uses of harvested rooftop water only. The use of rainwater for drinking purposes is beyond the scope of this publication.

Introduction

***Make you every man a cistern in his house.* –King Mesha of Moab, 850 B.C.**

Cistern systems date back several thousand years. In its simplest form, a cistern system collects rainwater that falls on a roof so that the collected water can be used at a later time. Unfortunately, when the industrial age brought the ability to pump water from distant places at a relatively low cost, modern society forgot that roofs could be efficient and convenient water collection surfaces.

In a dry state such as New Mexico, it makes sense to explore ways to get the maximum use of natural precipitation. It is also wise to design and create landscapes that need little or no supplemental water to thrive. Roof-reliant landscaping™ combines these two ideas in a waterwise landscaping strategy.

A roof-reliant landscape is designed to survive on the natural precipitation that falls on the plant material—plus the water that can be harvested from the roofs of onsite buildings and stored in a cistern for later distribution. "Totally" roof-reliant landscapes need no supplemental water (such as surface water or groundwater) to maintain the health of the plants. Plants that require no supplemental water are often called "precipitation-only" plants. Landscapes are defined as "primarily" roof-reliant when the associated plants get over 75% of their water from natural precipitation off a nearby roof during the first five years after the plants have been installed.

Establishing a roof-reliant landscape—or any landscape that is designed to thrive in a local climate with low water-use requirements and low maintenance—takes careful planning. In addition, site design, plant knowledge, an ability to work within a budget and patience are all important characteristics of a roof-reliant landscaper.

Because the goal of a roof-reliant landscaper is to reduce or eliminate the dependency on supplemental sources of water, knowledge of appropriate native and adapted plant material and water-conserving landscaping techniques is crucial. Although each landscape is different and presents specific onsite conditions and challenges, understanding the relationship between the variables of your landscaped area, the plants you select and your cistern's storage capacity is vital to the successful implementation of a roof-reliant landscape.

A Long-Term View

A roof-reliant landscape is not a short-term project that can be quickly accomplished in a weekend. Rather, it takes careful planning and patience to establish such a landscape. By definition, roof-reliant landscaping uses plants that (1) can establish themselves within three to five years and (2) can, once established, bounce back quickly after a period of drought.

In an ideal roof-reliant landscape, plant material is phased in over the course of several years so that the landscape can fit within a strict water budget[3]. One example of such a schedule might be:

- **Year 1:** Develop the landscape plan and design the cistern system in the winter. Install the cistern system in the spring. Harvest water during the summer monsoon season. Plant trees in the fall. (Xeric trees generally need 6-8 weeks for root growth before the first hard freeze.)

- **Year 2:** Install hardscape areas (including shade structures) and any important landscape features that do not require water throughout the year. If enough water is stored in the cistern and enough money exists in the budget, plant xeric shrubs in late summer or early fall.

- **Year 3:** Harvest precipitation throughout the winter, spring and summer. If enough water is stored in the cistern and enough money exists in the budget, plant heat-loving xeric perennials and shrubs during warm weather and cold-adapted plants in the early fall.

- **Year 4:** Harvest precipitation throughout the year and continue to establish plants.

- **Year 5:** Given normal years of precipitation, much of the landscape could be established at this time. Attempt to keep at least 67% of the cistern filled in order to be prepared for drought.

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[3] See Chapter 6 for more information on water budgets

Figure A-1: A healthy waterwise landscape can take several years to establish. This landscape in northern New Mexico is irrigated with rooftop harvested water using a drip system.

This schedule is not *required* for a landscape to become totally roof reliant, but it is *highly recommended* that plants be gradually established over a period of years so that more plant material can be planted over a longer time frame. An alternative schedule might divide a landscape into distinct areas for development beginning with those areas that are the most visible. For example, you might choose to install your front-yard plants in the first year, the backyard plants in the second year and the side-yard plants in the third year.

Please note that although this manual is focused on the roof-reliant landscaper who is installing a new landscape, much of the information contained here is also helpful for those who would like to incorporate a cistern into an existing landscape. This manual would be helpful as well for anyone who would like to gradually make the shift from using potable water for landscape irrigation to using rooftop harvested rainwater. In fact, those who already have an established landscape may be able to make the switch from potable water to harvested rainwater fairly quickly. Even if you're not ready to make the commitment to total roof-reliant landscaping, rainbarrels and cisterns can reduce the amount of supplemental (potable) water needed by your landscape. It makes sense for property owners in New Mexico to understand and install rainwater harvesting systems whenever possible.

A Brief Overview of This Manual

This manual is designed to introduce the concept of roof-reliant landscaping in a logical manner that begins with a basic introduction to xeriscaping (waterwise landscaping techniques) and continues through a detailed "how-to" discussion of cistern system design, construction and maintenance. Here's a quick summary of each chapter:

Chapter 1: The Fundamentals of Waterwise Landscaping

Understanding the basics of waterwise landscaping is crucial to the success of any roof-reliant landscape. Although this might be a "refresher course" for many who read this manual, applying the principles of xeriscaping and selecting appropriate plants must be considered baseline knowledge before any waterwise landscape can be designed and any cistern system planned.

Chapter 2: The Basics of Cistern Systems

Water collection can be as simple as catching rainwater from a downspout and storing it in a rainbarrel. More elaborate systems are described and depicted to introduce the terminology that will be used throughout this manual.

Chapter 3: Sizing Your Cistern

An equation for predicting potential rainwater harvests uses simple arithmetic to approximate how much water can be collected from your roof in a normal year. With this figure, you can determine an appropriate size for your property's cistern.

Chapter 4: Landscape Planning and Design

Thorough landscape planning can save money, time and water, so it is an essential element of every roof-reliant landscape. A landscape plan determines the size and location of your cistern system, a significant step undertaken before designing any cistern system.

Chapter 5: Cost Estimating

Cistern systems, particularly underground cistern systems, can be expensive to install. The materials are often heavy, delivery can be expensive, a surprisingly large number of subcontractors can sometimes be involved and the sheer size of the excavation for an underground tank is substantial. This means that a thorough cost estimating process is essential.

Chapter 6: Water Budgeting
This manual takes a seasonal approach to water budgeting, by creating a working water budget that accurately predicts harvested inflows to the cistern and potential outflows to landscape plants. With this budget approach, water can be more efficiently allocated to the appropriate plants as needed.

Chapter 7: Water Collection
The fundamentals of how to collect rooftop rainwater are covered in this chapter. The impact of flat roofs versus pitched roofs on water collection is discussed, as is the effect of roofing materials on water collection.

Chapter 8: Water Conveyance
Once the water has been collected off the roof, it has to be conveyed to a storage tank. How the water is conveyed and how it is filtered has to be carefully planned for a water system to be successful.

Chapter 9: Water Storage
Cisterns (or water storage tanks) are the heart of roof-reliant landscaping. Cistern components and materials are discussed in detail. The advantages and disadvantages of aboveground and underground cisterns are presented along with information about cistern placement.

Figure A-2: A water storage tank is the heart of a roof-reliant landscaping system. Shown here is a 10,000 gallon aboveground corrugated metal tank.

Chapter 10: Water Distribution
The distribution of cistern water to the root zones of plants is the final step in the rainwater harvesting cycle. There are many techniques that can be employed to distribute harvested rainwater—ranging from a simple garden hose to an elaborate drip irrigation system. The greatest potential for water waste occurs during the distribution process, so careful planning and regular monitoring of the manner of distribution is vital.

Chapter 11: Maintenance
After the design, installation and successful use of a rainwater harvesting system, the roof-reliant landscaper's work isn't over. In order to keep the system functioning efficiently, routine inspections and maintenance are required on a regular basis.

To make this manual as user-friendly as possible, following the body of the text are various appendices, a bibliography, a list of helpful websites and resources and a glossary of terms. In addition, worksheets are provided to assist in the development of a roof-reliant landscape. Additional copies of these worksheets are available at http://www.ose.state.nm.us (click on Water Use and Conservation).

Call Before You Dig
Call 1-800-321-2537 before beginning any excavation.

Please note that nothing in this manual should be construed as an endorsement of any product, person, or corporation. Any and all references to products, persons, and corporations herein are intended merely to provide a brief and general sketch of the ever-expanding field of cistern technology. Since new advances in cistern technology are being made constantly, the Office of the State Engineer strongly encourages you to complete your own due diligence when it comes to choosing the cistern system's material that is best suited for your particular situation.

Chapter 1: The Fundamentals of Waterwise Landscaping

A manual about rainwater harvesting in New Mexico would not be complete without a discussion of the basic principles and techniques of waterwise landscaping (also known as dryland landscaping or xeriscaping). By applying waterwise principles to your landscape, you will not only get the most out of the available water supply, you will also enjoy the beauty and diversity of native and other low-water-use plants.

The term *xeriscape* is derived from the Greek word *xeros*, meaning "dry." The goal of xeriscaping is to create a visually attractive landscape that uses plants selected for their ability to thrive in local climates. In New Mexico, this means using plants that can grow with very little (or no) water, other than what nature provides.

There are seven basic principles of xeriscaping and dryland gardening:

Planning and Design

1. Planning and Design. A beautiful xeriscape starts with a good design. The physical characteristics of the site must be considered, as should your needs and aesthetic preferences. The design of a landscape, especially a roof-reliant landscape that includes a cistern system, is such an important topic that Chapter 4 delves into it in detail.

Soil Improvements

2. Soil Improvements. New Mexico's soils typically lack the organic matter necessary to provide sufficient plant nutrients and water retention. Native plants tend to need less organic matter than adapted plants, but most plants benefit from the addition of some organic matter, such as compost, into the soil.

Compost helps sandy soils retain water and helps clay-dominated soils drain faster. When water mixes with compost in soil, the resultant carbonic acid dissolves the 18 essential elements typically found in compost so that plant roots can more easily take up these nutrients. Compost also aerates the soil so that plant roots can maintain their optimal moisture content. In these improved conditions, the insects, microorganisms and mycelium found in healthy soil can thrive, so plants can establish themselves quickly in the landscape.

Perhaps you have already been diligently making compost with your kitchen scraps and yard waste in a convenient, shaded and wind-protected corner of your garden. Maybe you've even added rabbit, chicken or horse manure, or some other source of nitrogen to your compost pile. Chances are, however, that you may need to either import compost (to mix into your existing soil) or bring in some premixed topsoil.

But don't give plants (especially native plants and other plants that like "lean" soil) too much of a good thing. Roots pampered by too-rich soil are likely to be stunted when they grow to the outer edges of the imported soil and hit the hard edge of existing native soil. Those pampered plants will not be as hardy, particularly in drought or precipitation-only conditions.

Smart roof-reliant landscapers understand that the best time to complete the soil-building part of the project occurs when cistern excavation equipment is onsite, particularly when installing a new landscape. With impressive efficiency, a backhoe can often handle much of the excavation, importation and mixing processes of soil improvement. Heavy equipment can also efficiently remove layers of cement-like caliche, which sometimes plague New Mexico's soil.

If it is not practical to use heavy excavation equipment to mix compost into your soil, consider renting a jackhammer to loosen up hard soil. Rototillers are also helpful when mixing compost and other organic matter into the soil.

Appropriate Turf Areas

3. Appropriate Turf Areas. Xeriscapes in New Mexico tend to minimize turf areas because traditional Kentucky bluegrass lawns are not native to our desert and dry mountain climates, and they use prodigious amounts of water. Small turf areas, particularly those using drought-tolerant grasses such as buffalograss and blue grama, can provide appropriate play areas for outdoor activities. However, it is not recommended to use cistern-based systems to irrigate turf areas, so this roof-reliant landscaping manual does not deal with lawn applications.

Low-Water-Use Plants

4. Low-Water-Use Plants. Choosing appropriate plants for your local area and for the specific conditions on your property is a key element in creating a roof-reliant landscape. For example, the range of waterwise plant options near Red Bluff Reservoir (elevation just under 3,000 feet) in southern New Mexico is very different from the plant palette for the village of Truchas (elevation just over 8,000 feet) in northern New Mexico. Local plant nurseries, landscape designers and other landscape professionals, horticulturists, native plant societies, local master gardeners and county extension agents can be invaluable resources for information about the types of plants that are appropriate for your landscape.

To conserve water, choose native and low-water-use plants whenever possible. Understanding the particular needs of your plants is also crucial. Soil conditions, sunlight requirements, water and spatial needs (i.e., the sizes and shape of root zones and branching habits) will all affect the long-term success of your roof-reliant landscape.

Xeriscaping uses the concept of plant "zoning" or grouping. By grouping plants with similar water needs together in specific "zones," the landscape can use water more efficiently. Low-water-use plants should be grouped together, away from the high-water-use plants. (See page 41 for a complete description of plant zoning.) Also, take advantage of warm or cool "microclimates" (the small areas of different climatic conditions around a property that typically occur near walls, shade trees, etc.).

Using microclimates as places to group plants with similar needs is a great way to create areas of interest and diversity in the landscape. (See Figure 1-1.)

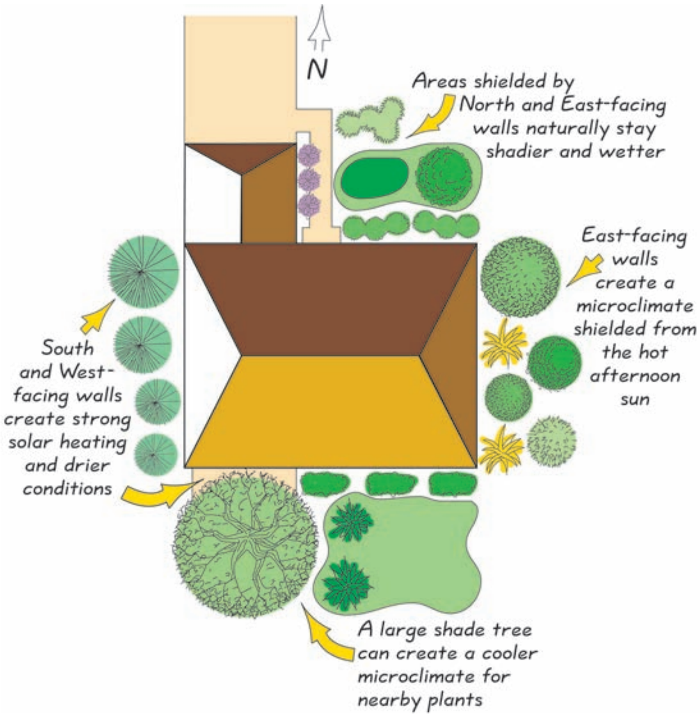


Figure 1-1: Microclimates are small areas in a landscape that typically occur near walls, underneath shade trees or by another landscape feature.

From a plant-choice standpoint, other kinds of useful information come into play, too. Is a particular tree species a shade tree or an ornamental tree? Does a species of flowering perennial bloom in spring, summer or fall? Will this shrub grow tall enough and densely enough to block the wind when you are sitting at a table on your patio? Will this flower's fragrance make you smile or sneeze?

A roof-reliant landscaper must also consider these additional plant characteristics: (1) whether a species can be established in three to five years, (2) whether a species will typically, once established, bounce back from drought and (3) whether a particular species can survive with precipitation water only. The Office of the State Engineer is developing a statewide xeric plant list, Waterwise Plants of New Mexico, that will be helpful in this regard. Email waternm@state.nm.us or visit http://www.ose.state.nm.us (click on Water Use and Conservation).

Efficient Irrigation

5. Efficient Irrigation. It doesn't make sense to design a roof-reliant landscape that uses water inefficiently. A well-planned and well-maintained irrigation system significantly reduces a landscape's water use, which is especially important when relying on rainwater harvesting for most or all of its irrigation water. For the most efficient use of water, irrigation zones should be designed so that low-water-use plants receive only the water they require. Low-volume drip emitters are the most effective mechanism to deliver water to the root zones of most trees, shrubs and perennials. Chapter 10 covers the distribution of water to the landscape in detail, including drip irrigation, the most efficient watering method.

Mulch

6. Mulch. After building healthy soil by adding compost and planting water-thrifty plants in the appropriate locations, you will want to further conserve water and promote plant health by spreading a thick layer of mulch over your improved soil. Mulch does five critical things for soil: it shades, insulates, prevents erosion, adds nutrients (especially if fibrous mulch such as shredded bark is used) and obstructs weed growth.

Shading the soil with mulch prevents water loss due to evaporation and also provides habitat for important microorganisms.

Insulating the soil from ambient air temperatures prevents plant stress caused by the rapid temperature changes that can occur in the high deserts of New Mexico. Soils and plant roots do not respond well to intense heat or cold, so having a blanket of insulation in the form of a thick layer of mulch keeps soil at a more constant temperature. This is equally important in winter and summer.

From a soil-erosion standpoint, mulch can help prevent wind from blowing the soil away. Mulch can also help prevent erosion caused by major storm events. Even though its effects are usually less visible than those from storm-water-induced erosion, wind-induced erosion can have a larger negative impact on our fragile soils because of the frequent (sometimes daily!) blowing that unprotected, exposed soil receives.

Simply by creating a microclimate suitable for microorganisms, even inert mulches such as gravel will help to increase the nutrient level in soil. While organic mulches (such as bark, straw and pecan shells) will provide more nutrients than inert mulches, they tend to need replenishing on an annual or biannual basis. By contrast, inert mulches can sometimes last years before needing to be replenished.

Typically, the thicker the mulch, the more effective it will be as a weed barrier. Smaller and low spreading plants may be mulched two inches deep until they grow larger, while larger trees and open areas (including pathways) should have a minimum mulch depth of four inches.

If perennial weeds are a problem, a water-permeable commercial-grade weed barrier, such as landscape fabric, can be placed underneath any type of mulch. (Remember, do not use nonpermeable plastic as a weed barrier.) Weeds that grow out of any mulch can sometimes be difficult to control, but weeds that grow out of gravel mulches can be extremely difficult to extract. Rock and gravel mulches should be weeded often, before weeds can establish large root systems.

Gravel and stone mulches have many benefits, but they can reflect light in a manner that is often too bright, and these mulches can create “heat islands” if overused. Breaking up stone-mulched areas with one or two organic mulches can improve the aesthetics of your roof-reliant landscape. The most interesting and perhaps most important waterwise aspect of stone mulch is that it can create moisture; condensation collects underneath the rocks when there is a change in ambient air temperature in a short period of time.

The smallest form of stone mulch is called crusher fines, which are extremely small pieces of commercially available gravel. They are often not much bigger than grains of sand and are typically rolled or tamped into place. They provide a clean, relatively natural look since their color often resembles the ochre tones that we recognize in our native soils.

Other common mulch materials include bark, wood chips and pecan shells. A less commonly used mulch, straw, is one of the more effective mulches for retaining moisture and providing nutrients for your soil. Contrary to popular belief, straw will almost never blow away if properly laid, and the aesthetics of straw are quite natural because the sun quickly bleaches out the bright yellow hue of a newly opened straw bale.

Bark mulch and pecan shells help soil retain moisture, and they add nutrients to the soil as they decompose. Compared to gravel, these mulches are lightweight and easy to install. However, in areas with strong winds these lighter-weight materials will be the most likely to blow away.

The types of plants selected for the landscape can help you determine what kinds of mulch to use. Less heat-tolerant, more moisture-loving plants prefer fibrous mulches, while xeric (sun- and heat-loving plants) prefer gravel and stone mulches. For example, many desert wildflowers grow much more vigorously and live longer when mulched with crusher fines or small pebbles.

Proper Maintenance

7. Proper Maintenance. Although xeriscapes and dryland gardens are low maintenance, they are not no maintenance. Keeping your roof-reliant landscape healthy through a well-timed program of pruning, fertilizing, weeding and pest control will ensure that your landscape develops beautifully and keeps growing for many years to come.

The Importance of Erosion Control

If you go through the steps of creating a roof-reliant landscape using the seven basic xeriscaping principles highlighted above, it is important to take the necessary precautions to prevent your precious soil from eroding away during heavy storm events. Grade your garden in such a way that moisture can percolate into the soil, preventing the soil from migrating downhill.

Unless your property is completely level (and very few properties maintain a consistent elevation from one end to the other), you will want to grade your planting areas so the velocity of the storm water that flows during a high storm event is significantly reduced. One way to do this is to form "plant pockets," as opposed to "tree wells," around your plants. As shown in Figure 1-2, tree wells are completely circular, while the plant pockets, or "mini-swales," are designed to accept storm water.

The small berm making up the pocket is placed on the downhill side of the plant or tree such that no part of the berm blocks nearby storm water runoff. Conventional tree wells divert this runoff away from plants while simultaneously increasing the velocity and mass of the storm water, which can quickly create serious erosion problems. Properly placed plant pockets slow the water down, minimize erosion and allow time for infiltration to take place at the plant's root zone.

Ideally, plant pockets should be situated in a fish-scale pattern (depicted in Figure 1-2 below) so that none of the soil near your plants erodes during large storm events. Consider using the spoils from your native soil excavation for building your plant pockets. Just be sure not to allow moisture to back up against any structures.

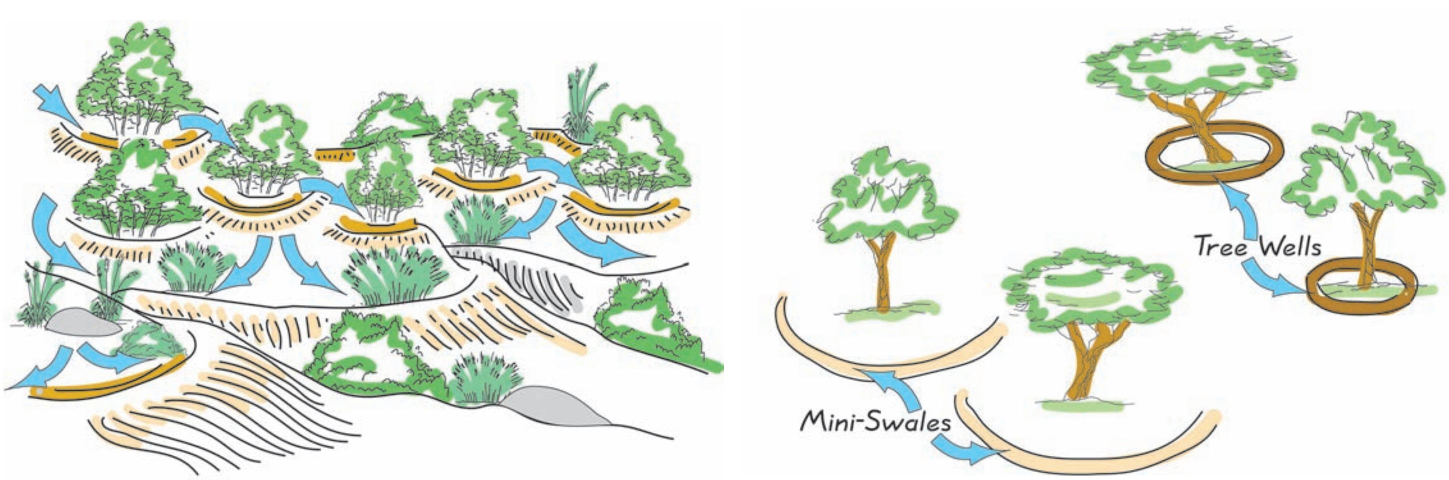


Figure 1-2: Mini-swales or plant pockets (left) are designed to hold some storm water near plants. Tree wells (right) completely circle the root area and can be filled with irrigation water.

Figure 1-3: Retaining walls are an effective way to create terraces to control erosion and create spaces for plants.

If your property is steep enough and your finances allow, you can also build retaining walls to hold back some of the soil that you excavated to make room for compost and mulch. The resulting terraces will control erosion and serve as more highly engineered planting pockets. If terraces do not fit within your budget but your erosion potential is significant, on-contour earthen swales and straw bale swales can be used in some cases.

An on-contour earthen swale is a ditch dug along points on a slope that are all at the same elevation above sea level. Points on the same contour line can be determined by using one of a number of simple devices, including laser levels, tripod levels, water levels or A-frame levels. The dirt from your ditch is then placed on the downhill side of the ditch in the form of an on-contour berm. On either end of their berms, swales turn upslope in order to control the runoff that causes erosion.

In the event that your site is too steep for earthen swales, you can install straw bales and other permeable barriers that can reduce soil erosion on a slope. As you establish plant material next to these barriers, the root systems of your plants strengthen the soil in the vicinity of the barriers. Over time, all of these barriers disappear, leaving healthy plants and soil behind.

NOTE: The above information about xeriscaping is not intended to be a comprehensive resource. For more about dryland gardening and the traditions of land use in desert environments, see Appendix 8.

Figure 1-4: Workers install a straw bale swale.

Chapter 2: The Basics of Cistern Systems

Every roof-reliant landscaper needs to have an understanding of how to collect water from a roof and how to divert this water to landscape plants or to a cistern for storage. This chapter provides an introduction to rooftop rainwater harvesting and gives an overview of both types of cistern systems—aboveground (the water tank sits at ground level) and below-ground (the water tank is buried underground). The terms and cistern system components introduced in this chapter are further described in detail in Chapter 8, Water Conveyance, and Chapter 9, Water Storage.

Rainwater harvesting systems are usually divided into two main types: simple (also commonly known as "passive") and complex (also known as "active"). In a simple rooftop rainwater harvesting system, precipitation is captured from a roof and diverted directly to plants in the landscape. (Figure 2-1 shows an example of this simple approach.) Note that in this simple system, rainwater hits the surface of a roof and is gravity-fed downward. The water collected off the roof is diverted by gutters and downspouts, which then deliver the water to the area of landscape plants. Except for some land contouring to direct the flow of water on the ground and encourage the water to settle near the planted vegetation, no attempt is made to store the rainwater for future use.

A complex rainwater harvesting system includes a storage tank for some or all of the water collected. Therefore, a true roof-reliant system as defined in this manual is a complex rainwater harvesting system because it requires a storage tank so that the water can be used at a later time. The ability to store water greatly increases the number and variety of plants that can be grown in a roof-reliant landscape because it provides a water source between natural rainfall events. When widely installed and used throughout New Mexico, rooftop water harvesting systems that include cisterns have the potential to significantly reduce the use of potable water for landscape irrigation.

An Introduction to Water Storage

Although it is accurate to say that a cistern is a water storage tank, the term cistern, as used in this manual, is much more than a container. In roof-reliant landscaping, a cistern denotes a functioning water-storage system, not simply the shape and the material that make up the water tank's walls. A cistern system includes the storage tank and its relationship and connection to each of its constituent parts.

The complexity of cistern systems vary widely from aboveground systems that distribute collected water via standard, manually operated garden hoses to underground systems that use the latest technology to automatically distribute water to

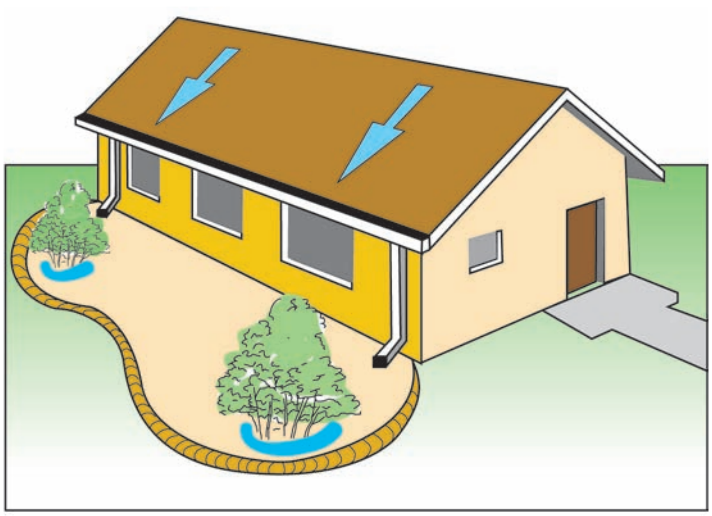


Figure 2-1: A simple ("passive") rainwater harvesting system, with no water storage.

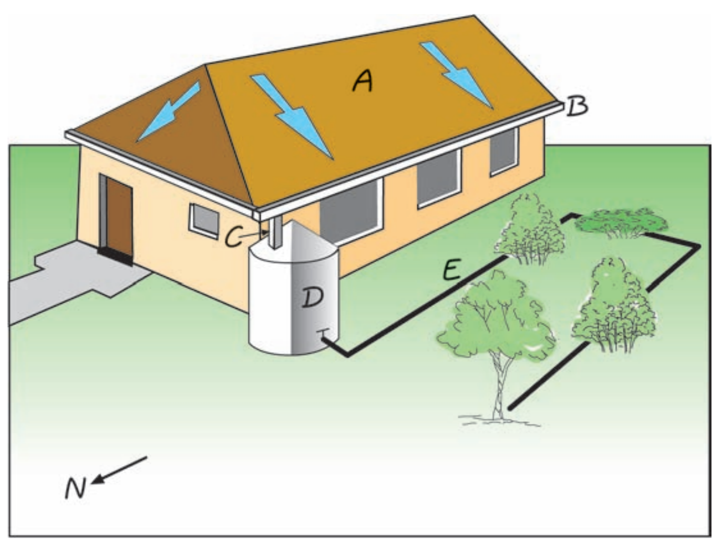


Figure 2-2: A complex ("active") rainwater harvesting system includes water storage. Shown here are: collection (A), conveyance (B and C), storage (D) and distribution (E).

landscape plants using an intricate network of drip irrigation components. Regardless of the precise form of your system's anatomy, your roof-reliant cistern system will perform four basic functions: collection, conveyance, storage and distribution. (See Figure 2-2 on page 14).

Roofs are particularly well suited as water collection surfaces. The sloped surfaces of roofs efficiently use the force of gravity to direct rainwater downward. (Even so-called flat roofs are slightly sloped.) Water collected off a roof is relatively clean and healthy when used for **irrigation purposes only**.

In roof-reliant landscaping, conveyance systems move roof water from precipitation collection surfaces to cisterns. In a basic water collection system, a downspout or canale funnels water directly into an aboveground rainbarrel or cistern for storage. In the more complicated system presented in Figure 2-4a and 2-4b on pages 16 and 17, the water in the conveyance system must pass through gutters, downspouts, a leaf screen, a first-flush device, a sediment trap and conveyance piping before it is delivered to the cistern.
The distribution of cistern water to the root zones of plants is the final act of water harvesting. Although collecting, conveying and storing roof water is often referred to as rainwater harvesting, the entire function of harvesting is not completed until the water has been effectively distributed.

From Rainbarrels to Cisterns

As the storage capacity of rainwater harvesting systems grows, their complexity and cost also grow. In modest systems, storage tanks can consist of rainbarrels that can be purchased at retail stores and landscape supply outlets. When simple rainbarrels do not provide adequate water storage, rainbarrels can be connected together with pipes to provide more storage capacity. In more ambitious systems, larger tanks designed for water storage can be purchased and delivered onsite. Sometimes storage tanks are built onsite to precise specifications.

For the most part, this manual concentrates on larger rainwater harvesting systems that include large aboveground or below-ground cisterns. Because of their size and scope, these larger cistern systems require detailed planning, careful design of the cistern system as well as the finished landscape, skilled labor to assist with installation, and

(continued on page 18)

Figure 2-3: An example of an aboveground cistern system storage tank with a solar-powered pump.

A Sample Below-Ground Cistern System (Part 1), Figure 2-4a

An underground cistern system is much more than a buried water tank. In order to function properly, a rainwater harvesting system with an underground cistern must efficiently collect water from a roof, filter dirt and debris from the water, and convey clean water to the cistern for storage. The stored water will then be available for landscape use when needed.

Together, Figures 2-4a and 2-4b depict the first three functions of a rainwater harvesting system-collection, conveyance and storage. The roof of the house depicted in Figure 2-4a is the collection surface, from which rainwater flows into the gutter that runs along the roofline. This illustration depicts four types of filtering devices. A gutter guard (1) is a simple device that is placed in, or sometimes over, a gutter that filters out large debris such as leaves. A leaf screen (2) is similar to a gutter guard in that it filters out leaves and large debris. A first-flush diverter (3) is a length of capped pipe that captures the first water that is conveyed off the roof. This first-flush of water typically contains the most debris. After the first-flush pipe fills up with water, debris and sediment, any additional water flows through the connected pipe and downward toward the cistern. A sediment trap with a removable filter (4) is a device that separates sediment from water. The sediment settles at the bottom of the trap, allowing clean water to flow through.

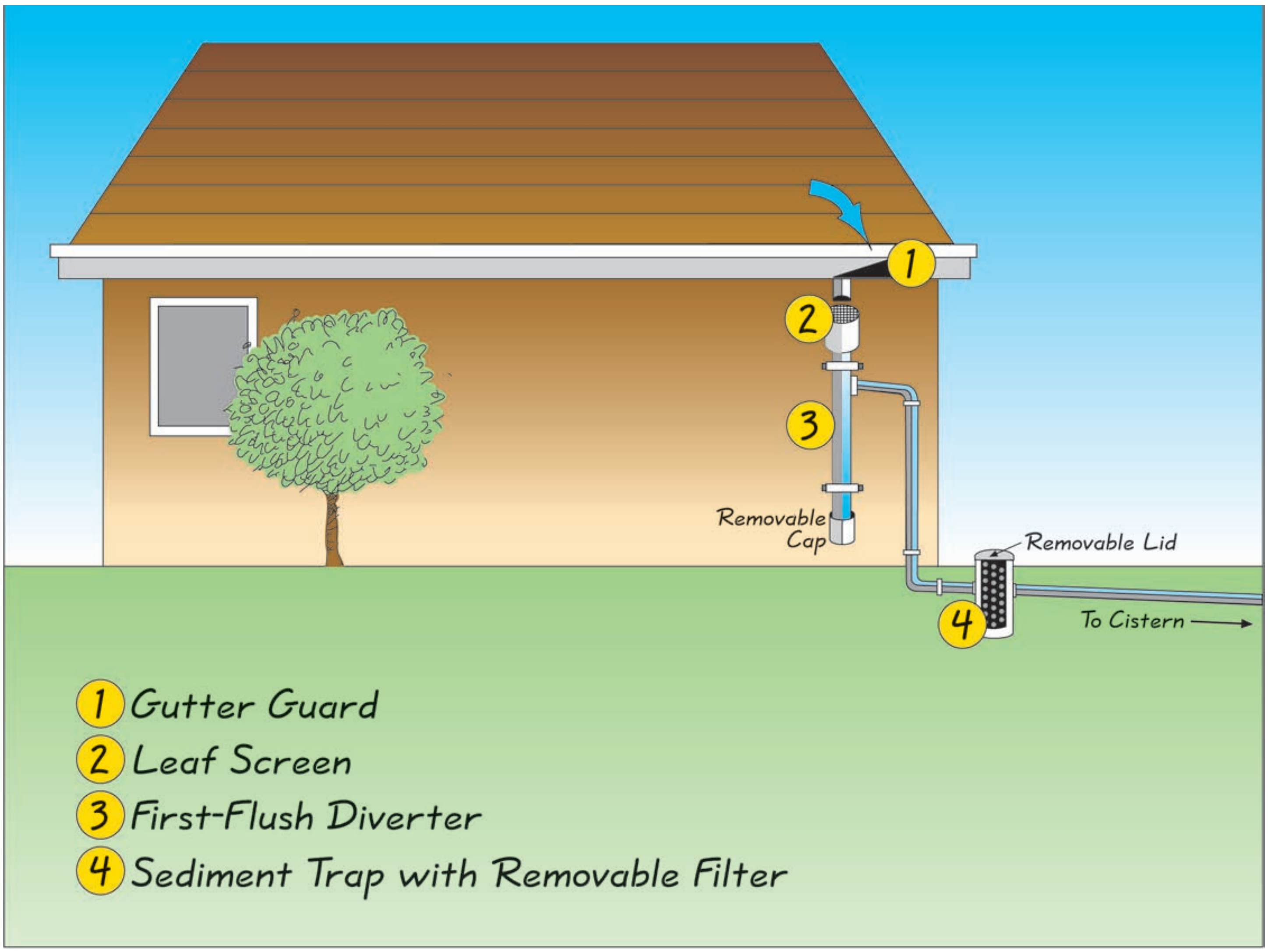


Figure 2-4a: A complex conveyance system moves water from a roof through water filtering devices.

NOTE: A typical rainwater harvesting system would not have all four of the filters depicted in this illustration. A common approach would be to have either a gutter guard or a leaf screen and either a first-flush diverter or a sediment trap.

A Sample Below-Ground Cistern System (Part 2), Figure 2-4b

After passing through the filters, water flows through underground conveyance pipe to the cistern. The cistern depicted in Figure 2-4b is a commonly available unit made of molded plastic. An underground cistern tank has a serviceway that allows access to the inside of the cistern and its associated components. (These components will be covered in detail in Chapter 9.)

An important feature of every cistern tank is an overflow pipe. Even in arid climates such as those found in New Mexico, large storm events can result in a volume of harvested rainwater beyond that which the storage tank can hold. The overflow pipe directs excess water away from structures and toward landscape plants, a swale or a French drain. With careful planning, even the water harvested from an unusually large storm can be safely and effectively managed.

Not depicted in this illustration is the final stage of rainwater harvesting, distribution. See Chapter 10 for a complete discussion of distributing water to the landscape.

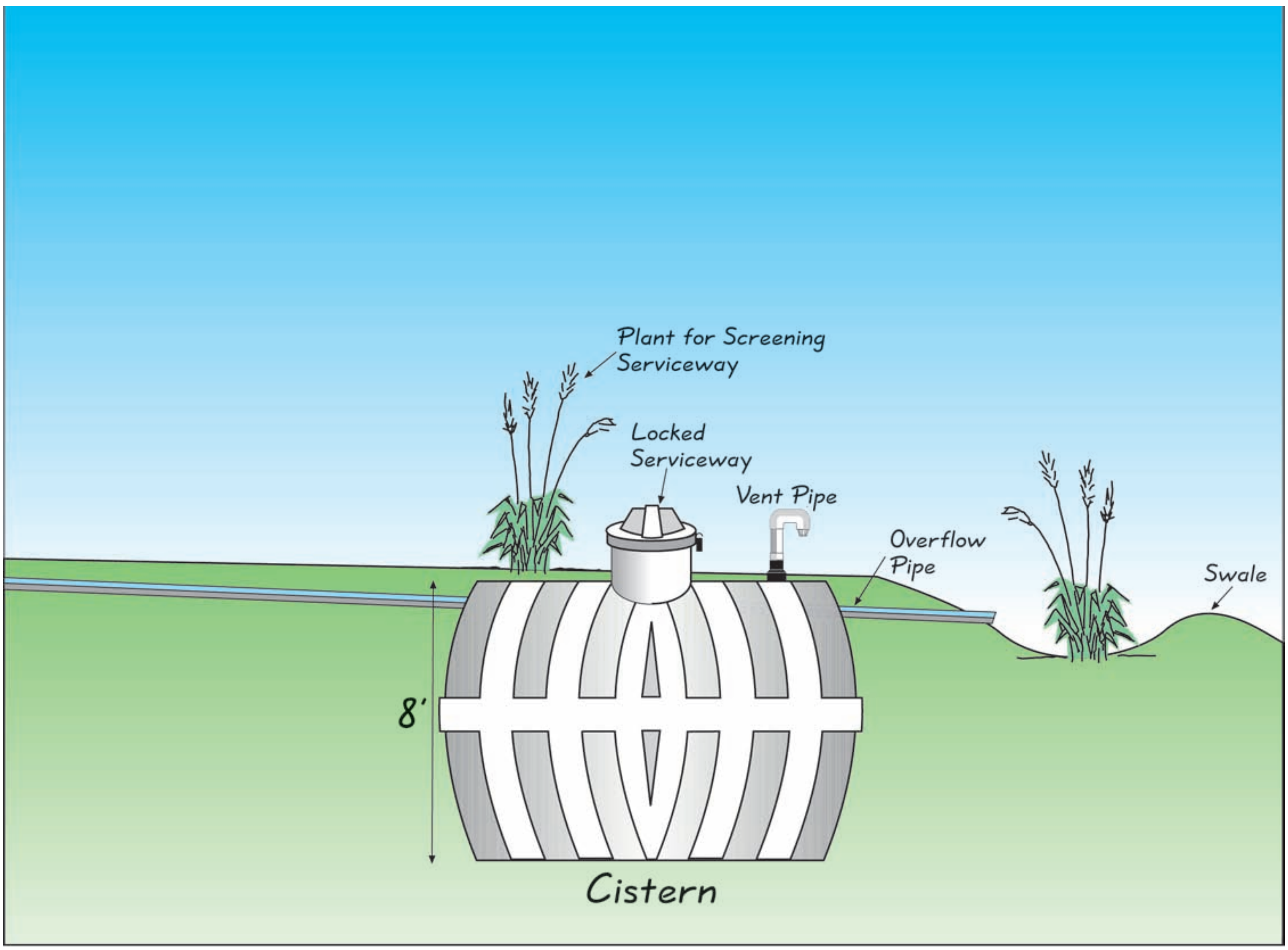


Figure 2-4b: After passing through filters (as shown on previous page), water is conveyed to an underground cistern for storage.

compliance with any local building codes and applicable regulations. All of these steps must proceed in a logical order to ensure the success and the cost-efficiency of the project. Mistakes can be costly, dangerous and wasteful, but the benefits of a well-designed system are enormous.

Figure 2-5 shows a design overview of a large roof-reliant underground cistern system. Water is harvested off of the roof via canales, which feed water into inground drain boxes. Branching off and away from the house is the underground conveyance piping leading to an underground cistern. Also shown are a sediment trap, pumphouse, a buried conduit line running electricity for the cistern system and an overflow pipe[4].

In roof-reliant landscaping, water travels through the cistern system, and given a thoughtful plan, a successful installation and occasional maintenance, this water can help establish an oasis in any desert.

---

[4] "Overflow" refers to the discharge of water that pours out of a cistern whenever the tank is full and a precipitation event is occurring. Legally, every cistern system needs to control this kind of runoff, such that the overflow pipe never increases the level of water and/or sediment that runs off of your property. This runoff, if properly controlled, provides an additional benefit due to an increased quantity of water directed toward newly planted, recently established, or existing native plant material.

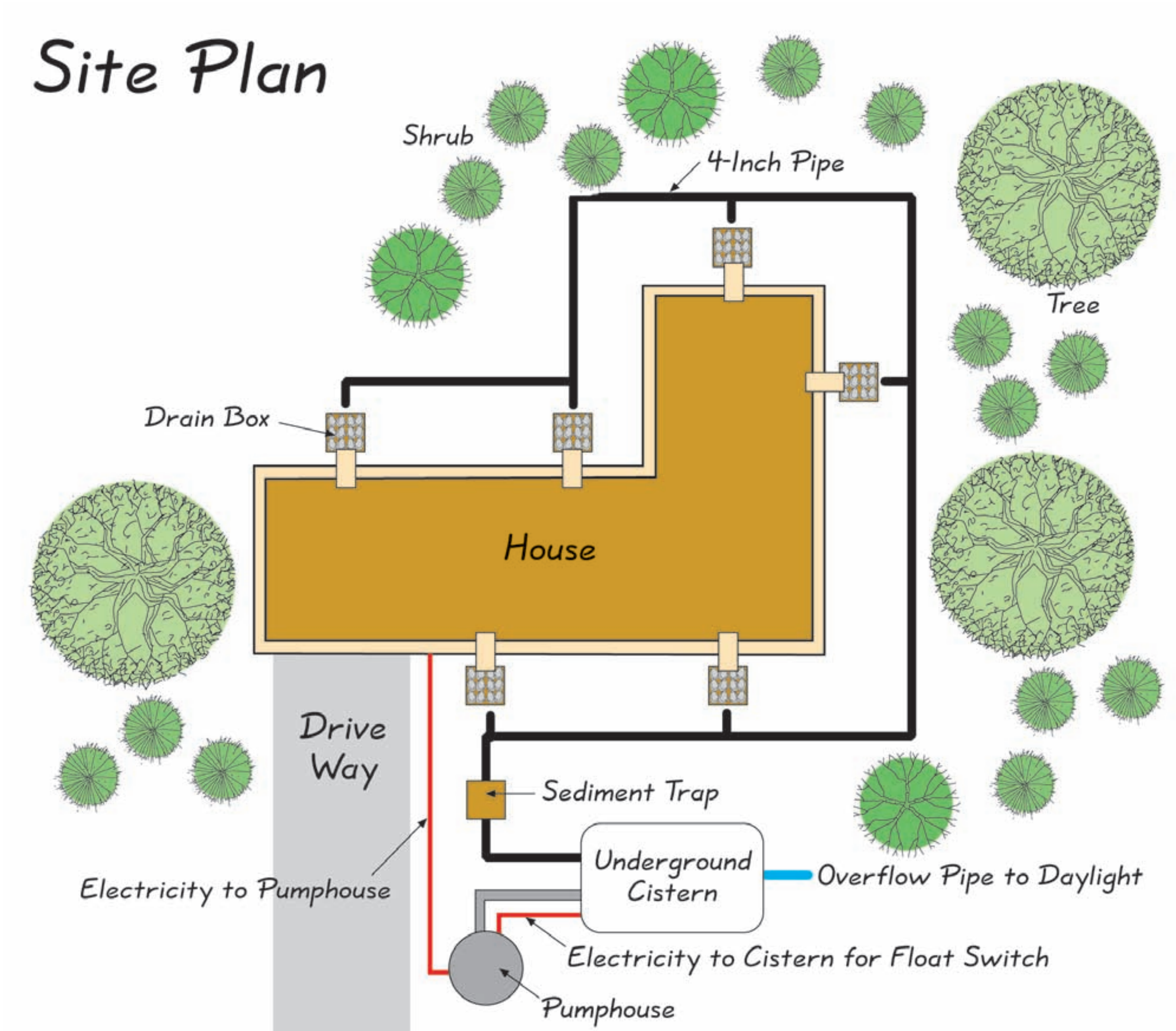


Figure 2-5: An overview of a roof-reliant rainwater harvesting system (water distribution not shown). Conveyance pipes and electrical conduit lines are buried, according to code.

Chapter 3: Sizing Your Cistern

One of the first steps in any roof-reliant landscaping project is estimating the appropriate size of your water storage tank. This estimate will be required as you begin to design your landscape, estimate its cost, create your water budget and schedule the installation of your project. Knowing the exact size of your system will, of course, be of critical importance when you actually design your cistern system.

You can determine the appropriate size of your cistern by taking the following simple steps:

- Calculate the catchment area of your roof
- Estimate your "normal" rainwater harvest
- Apply the One-Third Rule

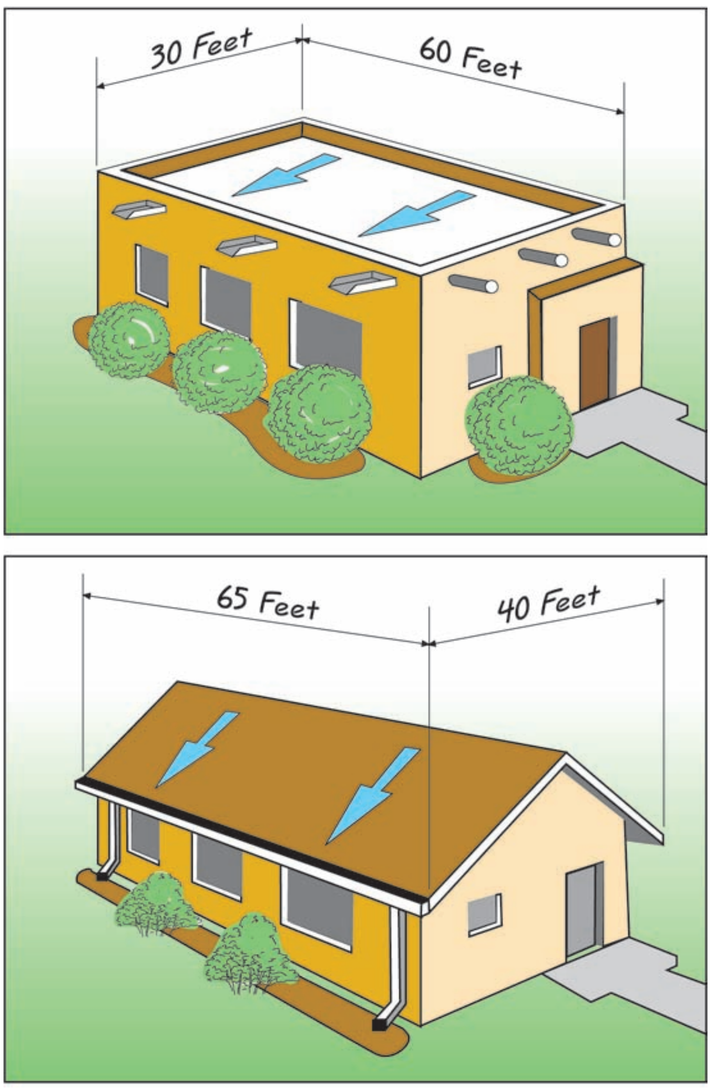


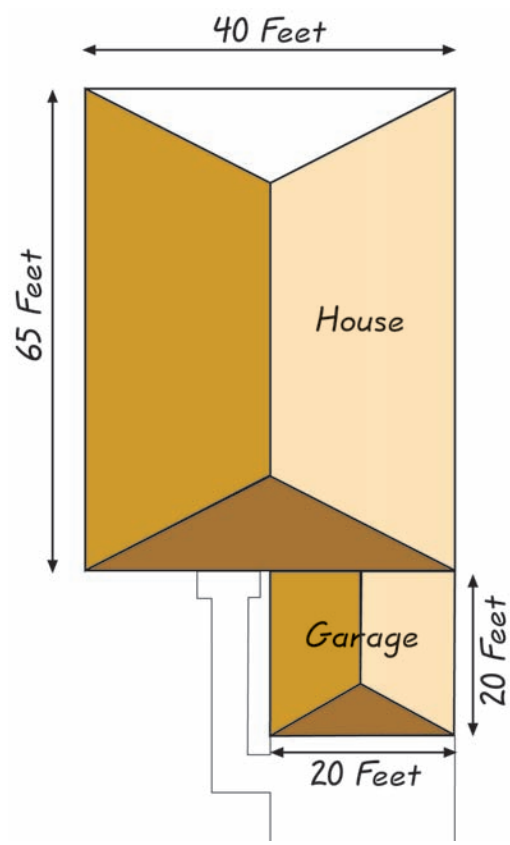
Figure 3-1: Calculating the square footage of roof or catchment area

Calculate the Catchment Area of Your Roof

The amount of water that can be harvested is determined by the size of the catchment area and the amount of rain that falls on that catchment area. Start by determining the size of your roof in square feet. Figure 3-1 shows that the square footage of a rectilinear roof can be easily calculated by multiplying the length of the roof by its width.

Length (in feet) x width (in feet) = square feet

However, it is not uncommon for a roof to be affected by other factors that can slightly complicate this simple calculation. The most common of these factors occurs when two roof surfaces need to be added together, as in Figure 3-2. The house shown below has a garage, which should be included in the total roof square footage. Buildings such as portals, sheds, shade structures and other roof surfaces that can serve as collection areas also need to be included in your calculations.



(65 ft. x 40 ft.) + (20 ft. x 20 ft.) = Total square feet

Figure 3-2: How to calculate the square footage of a complex roof to determine the catchment area.

Note that the increased angle of a pitched roof does not increase your catchment area. While it is true that more materials are needed to cover a house with a pitched roof than a flat roof, a pitched roof still covers the same amount of ground surface as a flat roof (of the same length and width measured at the given buildings' ceilings).

One advantage that pitched-roof structures do have over flat-roof structures is that pitched roofs often have large overhangs. Given the same building footprint, a pitched-roof house will typically have larger roof dimensions than a flat-roof house. In Figure 3-3, we see how a two-foot overhang can significantly increase a roof's catchment area.

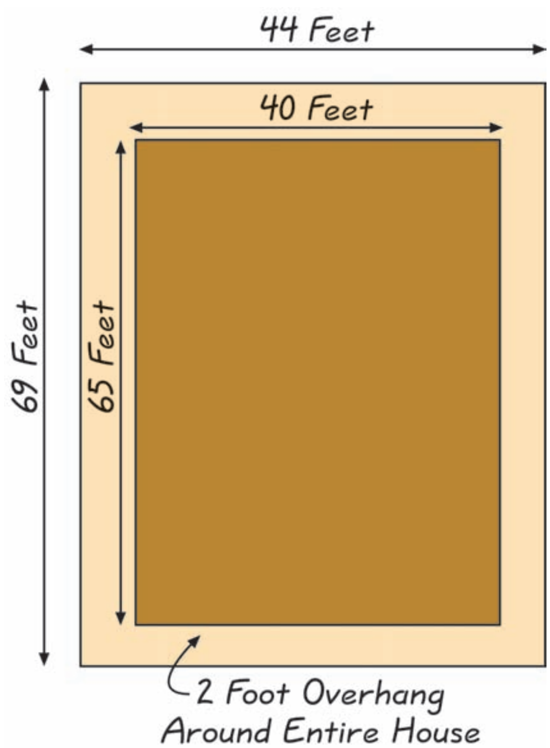


Figure 3-3: Calculating the catchment area including roof overhang

Other minor mathematical complications occur when roof lines are not rectilinear. Typically, such roofs can be reduced to either triangular or curvilinear shapes. In the case of triangular shapes in which one of the angles is 90 degrees, simply multiply the length of the roof by the width of the roof, then divide this product by two:

Length x width / 2 = area of a triangle

Curvilinear shapes are rare, but most of them can be reduced to circular shapes, the areas of which are determined by multiplying the square of the radius of the circle by pi (3.14).

Radius x radius x 3.14 = area of a circle

It is imperative that your square-footage calculation is accurate. The proper sizing of your cistern, the total cost of your project and perhaps even the success of your project will depend on your precision here.

Estimate Your "Normal" Harvest

Now that you have determined the square footage of your collection area, the next step in sizing your cistern is to estimate the amount of precipitation that you might collect in a given time period. It is important to note that there is a significant distinction between "average" and "normal" when discussing the amount of precipitation your location receives in a year.

Although average annual precipitation data is easy to find for most municipalities and counties throughout the state[5], the concept of average precipitation is misleading in New Mexico. It is actually normal for a location to get 20 percent less precipitation than the average annual precipitation figure. This is because occasional wet years skew the average.

Take the example of Albuquerque from 1996 through 2005. Table 3-1 on the following page shows that Albuquerque received an average of 9.09 inches of precipitation during this 10-year period (which is 0.43 inches more than its historic average of 8.66 inches). Albuquerque received less than the average annual rainfall during five years of this period, and during three of those years it received only about 70 percent of the 10-year average.

[5] See Appendix 1, which contains average monthly and annual precipitation figures for municipalities in New Mexico.

TABLE 3-1: Precipitation in Albuquerque from 1996-2005

YEAR	PRECIPITATION
1996	9.75”
1997	12.36”
1998	9.83”
1999	8.29”
2000	8.24”
2001	6.50”
2002	6.39”
2003	6.35”
2004	11.80”
2005	11.42”
Total inches for 10 year period =	90.93”
Average (90.93/10) =	9.09” per year

Historical weather data shows that a normal year receives about 80% of the precipitation that an average year receives. The equation below describes this concept in simple arithmetic terms. Here, average precipitation is multiplied by 80% in order to determine the most likely amount of precipitation for a location in a given year.

Average precipitation x 0.80 = “Normal” precipitation

For Albuquerque, using the historic average of 8.66 inches of average precipitation results in this equation:

8.66 inches x 0.80 = 6.93 inches

Table 3-2 shows how to convert inches of rainfall into gallons per square foot. For every inch of rainfall, 0.62 gallons of water can be harvested from every square foot of roof surface. Rounding the “normal” year in Albuquerque to 7.0 inches reveals that every square foot of roof catchment surface will predictably result in 4.34 gallons of collected rainwater.

TABLE 3-2: Approximate Annual Supply from Roof Catchment

Inches of Rainfall	Gallons/Square Foot
0	0.00
1	0.62
2	1.24
3	1.86
4	2.48
5	3.10
6	3.72
7	4.34
8	4.96
9	5.58
10	6.20
11	6.82
12	7.44
13	8.06
14	8.68
15	9.30
16	9.92
17	10.54
18	11.16

Finally, in order to finally estimate the amount of precipitation that can potentially be collected from a roof in a normal year, multiply the total square footage by the number of gallons per square foot. For a 1,800-square-foot roof in Albuquerque, this translates into less than 8,000 gallons of water. The calculation looks like this:

1,800 (square feet of catchment area) x 4.34 gallons = 7,812 gallons

In summary, your catchment area multiplied by the number of gallons per square foot in a normal year equals the total number of gallons you can expect to collect off of your roof during a normal year.

Catchment Area
x Gallons per square foot
= Total Gallons

Apply the One-Third Rule*

Precipitation can come at any time of year in New Mexico, and you can expect to distribute some portion of your rainwater harvest in between storm events. Therefore, it is unnecessary to have a cistern large enough to store an entire year's worth of precipitation.

For this reason, the recommended cistern size is approximately one-third of the amount that can be collected in a normal year. Therefore, the owners of the 1,800-square-foot roof in the Albuquerque example on the previous page should consider a cistern in the 2,000 to 3,000 gallon range.

If cost is a major factor, it may be wise to consider a storage tank on the smaller side of the containment spectrum. If finances allow, consider a tank on the larger side of the spectrum. Please note that the “One-Third Rule” is meant only as a helpful tool for getting you started. While developing your plans and designs, you can always modify this calculation depending on your needs, desires and finances.

The last step in sizing your cistern is simply to convert gallons into cubic feet so that you can get a sense of what size tank you will need. One way to determine the approximate dimensions of your storage tank is to ask potential cistern suppliers what size tanks are available in the number of gallons you require. Or, to manually calculate the volume of your tank, use this simple conversion equation:

1 cu. ft. water = 7.48 gallons of water

A 1,000-gallon cistern, then, equals 133.69 cubic feet of volume, which is about the size of a compact car. A 2,000-gallon cistern is approximately the size of a minivan, and the volume of 5,000-gallon tank is the equivalent of a large van or small school bus. A 10,000-gallon cistern can fit snugly on a large flatbed trailer.

Detailed information on different types of cisterns and on cistern-system components appears in Chapter 9, Water Storage.

*The Case for the “One-Half Rule” (or even more)

Some landscape professionals have been known to say that the only cistern that is too large is the one you cannot afford. That’s because in New Mexico, we tend to get infrequent rainfall events. A typical “good” monsoon season consists of a handful of rainfall events that deliver quite a lot of rain (1/2 to 2 inches of rain) at a time. For example, it is not uncommon for areas in New Mexico to receive 1.5 inches of rain within a 24-hour period every two or three years. This would produce almost 1,700 gallons of water from a 1,800 square foot roof. If your water storage tank holds 2,000 gallons and you've already “banked” 500 gallons, then almost 200 gallons of water would overflow out of your cistern.

So, if the budget allows for a larger tank—and there is space on the property for a larger tank—consider applying the One-Half Rule (or even more) if you want to minimize the rainfall events that produce more water than your cistern can hold.

Use Worksheet 1 on the next page to perform the calculations described in this chapter.

Figure 3-4: A 10,000 gallon tank like the one shown above must be delivered to the site on a flatbed trailer.

WORKSHEET 1

Use this worksheet to perform the calculations described in this chapter.

1. Determine the square footage of your rectilinear areas by multiplying the length by the width

Main House

Length of catchment area (linear feet)	
Width of catchment area (linear feet)	
Multiply the two numbers above	x
Total square footage =	

Garage

Length of catchment area (linear feet)	
Width of catchment area (linear feet)	
Multiply the two numbers above	x
Total square footage =	

Other

Length of catchment area (linear feet)	
Width of catchment area (linear feet)	
Multiply the two numbers above	x
Total square footage =	

2. Add up your various catchment areas

Square footage of main house	
Square footage of garage	
Square footage of storage shed(s)	
Square footage of portals and covered porches	
Square footage of all other roof surfaces	
Add up all of the numbers above	+
Total square footage of catchment area =	

3. Estimate your "normal" harvest

Total square footage of catchment area	
Average annual rainfall x .80 x value in Table 3-2	
Multiply the two numbers above	x
Total normal annual precipitation in gallons =	

4. Apply the One-Third Rule

Total normal annual precipitation in gallons	
One third	0.333
Multiply the two numbers above	x
An appropriate size of cistern in gallons	

Chapter 4: Landscape Planning and Design

After determining the approximate size of your water storage tank, the next step is to start the landscape planning process. However, it should be noted that a landscape plan (especially a roof-reliant plan) does not always develop in a linear fashion. Because the components of a landscape plan are so directly related to each other, these components often evolve simultaneously. And as landscape components change during the planning process, other components are also affected and often further adjustments must be made.

With that caveat in mind, a roof-reliant landscaping project should be undertaken only if thorough landscape planning is completed before the installation begins. Not only is a cistern system a significant financial investment, serious safety concerns must be addressed. In addition, permits may be required.[6]

Whether you use pen and paper, computer assisted design, three-dimensional modeling or any other design method, a landscape design provides the size and precise location of both existing and proposed landscape features. At a minimum, a roof-reliant landscape design typically indicates the specific location of structures, utility lines, the four components of your cistern system (collection, conveyance, storage and distribution), plant material, pathways, roads, patios, property lines and easements.

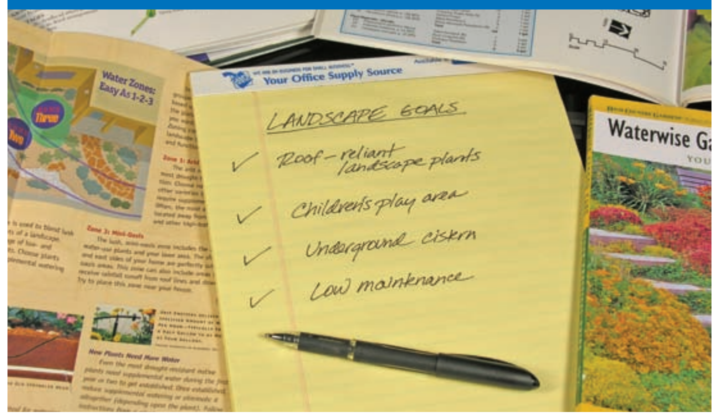
Whether you are providing multiple sets of plans for various people or you just want to make sure you install your own system properly, it is extremely useful to have a clear, visual representation of the landscape design. Installing a complete cistern system typically necessitates a scaled drawing so that the backhoe operator, the cistern installation crew, the irrigation contractor, the landscaper, the electrician and the homeowner can all ensure that their respective jobs are performed correctly. Expensive mistakes can be avoided with an accurate landscape design. In addition, you may be violating state laws and local ordinances if you fail to submit a scaled drawing of your proposed work and do not obtain any necessary permits.

[6] Always check with appropriate regulating entities before starting a roof water harvesting project.

A Five-Phase Landscape Design Process

To help in the landscape design process, a detailed five-step process is presented in this manual. Proceeding slowly and carefully with your landscape design will save time, money, aggravation and, quite possibly, significant quantities of water.

Clarify the Scope of Your Project



PHASE 1: Clarify the Scope of Your Project

The first phase in designing your landscape should be to establish goals and objectives that help clarify the scope of your project. These goals will help set the course for your design and ensure that you create a roof-reliant landscape that is compatible with your lifestyle.

To help you get started, here is an important list of planning and design questions:

- Will your landscape consist of only roof-reliant plants?
- Do you plan on installing your landscape in phases? If so, over how many years?
- What have you determined is the appropriate size of your cistern?
- Do you have a strong preference for an aboveground cistern or a below-ground cistern?

The answers to these questions may help you to answer the basic design considerations that follow.

Preliminary Budget
Unless you are already familiar with the costs of

landscaping and cistern systems, your preliminary cost estimates will probably have less to do with the actual costs of roof-reliant landscaping and cistern systems than it will be based on how much money you think you will have available for your project. This is the most realistic starting point available to you at this stage in the process. Knowing that you can adjust your budget as you receive more information, you can now begin making decisions about your roof-reliant landscape.

Your Commitment to Maintenance
Before designing a landscape, it is important to consider how much time you are willing to spend on landscape and cistern system maintenance. Many people find that the best landscape maintenance plan consists of a combination of do-it-yourself time and some occasional unskilled labor and/or professional assistance.

Outdoor Living Areas
Sometimes an excellent place for an underground cistern is under an outdoor living area—a place where people can relax, read, play games and/or have a meal. Such a location depends on two factors: (1) how often the system will need maintenance and (2) how expensive is it to remove and replace the surface of the outdoor room. For example, it would be a mistake to install a cistern system that needs regular maintenance under an expensive flagstone patio, but installing a cistern under an easily removable shredded-bark surface would be appropriate.

Children's Play Areas
Cisterns can be situated appropriately under temporary play structures, such as a lightweight swing set, a trampoline or a playhouse. However, placing such an item so close to where children play requires extra diligence about ensuring that your cistern's serviceway remains locked and inaccessible (except when being serviced).

Handicap Access
Handicap access (if needed) should be taken into consideration at the outset of the design process. Retrofitting a landscape to offer such access can be an expensive proposition.

Domestic Animals
Domestic animals can have a profound effect on any landscape. When establishing your water distribution lines (especially drip irrigation lines and other components that will be aboveground), take into account the possible effects that domestic animals might have on them.

Storage
The landscape is often a place where certain large items need to be stored, including firewood, compost piles, toolsheds and recreational vehicles. Aboveground cisterns can sometimes hide these eyesores, while an underground cistern can sometimes be buried underneath them.

Use Worksheet 2 (on the next page) to help record and clarify the goals for your new landscape.

Figure 4-1: A successful landscape begins with careful planning and design.

WORKSHEET 2:
SETTING GOALS FOR YOUR LANDSCAPE (Circle all that apply)

1. Preliminary budget (first year)

< $5,000	$5,000 -15,000	$15,000-30,000	> $30,000

2. Maintenance

< 1 hr./month	1-3 hrs./month	3-6 hrs./month	> 6 hrs./month

3. Outdoor living areas

< 4 people	4-8 people	8-12 people	> 12 people

4. Children's play areas

Yes	No	Specify__________________

5. Handicap access

Yes	No	Specify_________________

6. Domestic animals

Dog (dog run OK?)	Cat (indoor OK?)	Other ________

7. Storage

Firewood	Storage/Toolshed	Compost Pile	RV	Other ________

8. Projected time before the sale of your property

< 3 years	3-5 years	5-10 years	> 10 years

9. Other____

____

Evaluating the Site

PHASE 2: Evaluating the Site

The second step in the landscape design process is site evaluation. This consists primarily of observation and research.

Observation

Below is a list of environmental factors that are important in landscape site evaluation. Take this list out on your property at different times of day and during different seasons of the year to observe and take notes about these items. Many of these factors combine to create microclimates, the small areas in your landscape that have different growing conditions than those that exist on your property as a whole.

- Moisture. Where does the water fall from your roof? Where does moisture remain after a heavy rain?
- Wind exposure. What direction do winds typically come from? Is there a time of day and/or a time of year when the winds are extremely strong and persistent?
- Temperatures. Where are the hottest and coolest spots on your property? Determining the location of hot and cool temperatures on your land will help when it is time to decide which plants should be placed where.
- Shade and light. How far does your house cast its shadow on the north side of your house during the winter solstice (December 21st)? How does that shadow differ from that of the summer solstice (June 21st)?
- Slope. How will the slope of your property affect where a cistern might be located?
- Vegetative cover. How can you use the existing vegetation on your property for the benefit of your future landscape? What plants might need to be transplanted to another part of the property?
- Wildlife habitat. Which aspects of natural wildlife do you want to encourage and/or discourage in your landscape?
- Use and traffic patterns. Observe and predict the human activity that is likely to occur on your property.
- Views and privacy. What views do you want to protect? Landscaping can be very effective at enhancing beautiful vistas and hiding ugly views, and it can also be critical in creating privacy.

Research

Studying your site also requires gathering public information about your specific region and your particular property. Your research should include information provided by landscape professionals, surveyors and government agencies; it can also include many other sources of information such as family, friends and neighbors, especially those who have lived in your community for many years.

Topics to be included in your research at this point in your design process include:

- Locations of utility lines
- Property lines and easements
- Restrictions on development
- Permits
- Soil types
- Frost dates
- Frost depth
- Flood potential
- Wildfire potential
- Local plant palette

Develop a Conceptual Plan

PHASE 3: Develop a Conceptual Plan

The third phase of landscape design is the development of a conceptual plan. Here, you integrate the scope and goals of your design with your site observations and evaluation. A conceptual plan provides the basic form of your landscape design, which includes the most important requirements of the plan with few details.

Every conceptual plan shows three types of features: fixed, variable and natural. Fixed features include property lines, easements, utility lines and exterior walls of permanent structures. Fixed features also include existing hardscaped areas, parking areas, driveways and pathways.

Variable features are those that could work in more than one place in your landscape. These can include cisterns, entertainment areas, play areas and planting beds.

Your conceptual plan should also reflect the information about the natural features of your landscape that you gathered from your observations and research in the site evaluation phase of the landscape design process. You should indicate where moisture collects, where prevailing winds come through, where temperatures differ, where you'll have summer shade and winter sun, where wildlife corridors and habitat exist, and so forth.

It is important to place your cistern system somewhere on your conceptual plan, knowing that at any time during the design process you can always change its location, its relationship to grade and its size.

Figure 4-2 (a finished conceptual plan) and Figure 4-3 (a filled out Worksheet 2) show how the conceptual plan and the worksheet can work together.

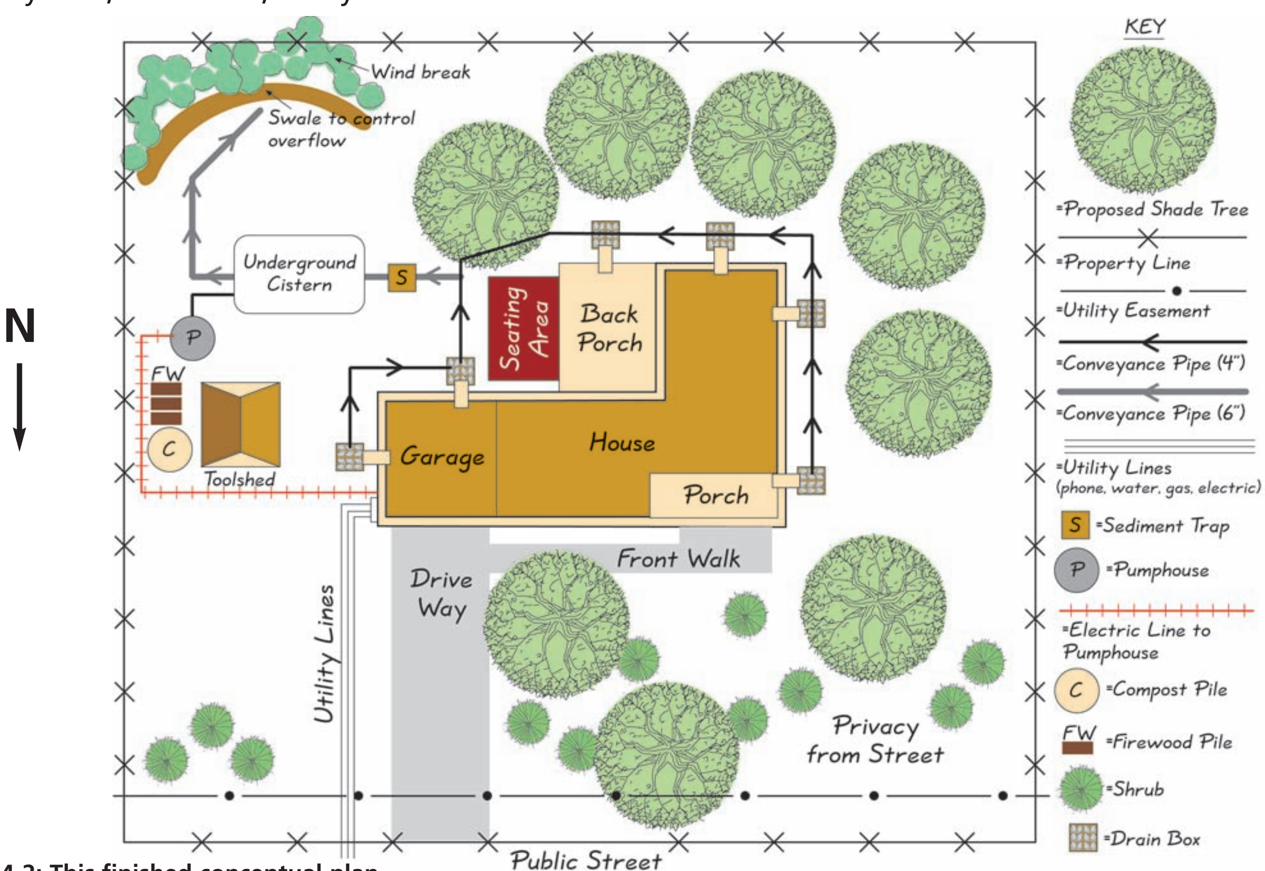


Figure 4-2: This finished conceptual plan shows the buried components for the entire site.

WORKSHEET 2:
SETTING GOALS FOR YOUR LANDSCAPE (Circle all that apply)

1. Preliminary budget

<$5,000 $5,000 - $15,000 $15,000 - $30,000 >$30,000

2. Maintenance

<1 hr./month 1-3 hrs./month 3-6 hrs./month >6 hrs./month

3. Outdoor living areas

<4 people 4-8 people 8-12 people >12 people

4. Children's play areas

Yes No Specify ____________________

5. Handicap access

Yes No Specify ____________________

6. Domestic animals

Dog (dog run OK?) Cat (indoor OK?) Other Not Applicable

7. Storage

Firewood Storage/Toolshed Compost Pile RV Other ________

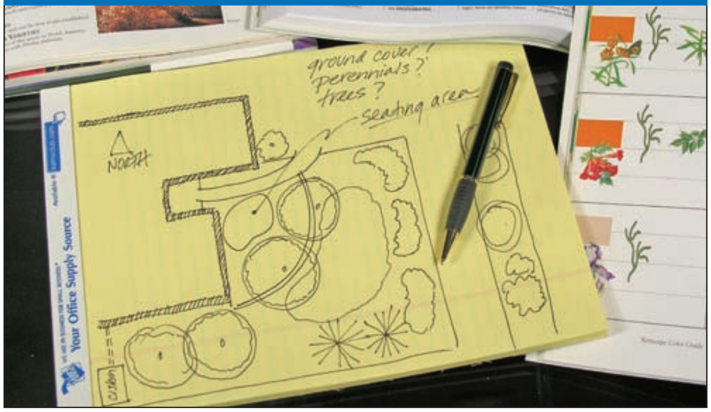
8. Projected time before the sale of your property

<3 years 3-5 years 5-10 years >10 years

9. Other Windbreak needed on Southeast side of property

Figure 4-3: A filled-out worksheet shows the goals for the landscape.

Generate Various Options



PHASE 4: Generate Various Options

Now it is time to determine options for the landscape features you will have on your property and where they will be placed in relationship to each other. Based on your conceptual design, start to determine the places where the various features of your landscape might best be located.

In order to provide you with some basic knowledge about important landscape features that are of particular interest to the roof-reliant landscaper, we have developed a list of common roof-reliant landscape features. It is not necessary to include all of these features in your landscape design.

The common roof-reliant landscape features are:

- Cistern system
- Erosion and drainage control
- Plant material
- Hardscape
- Fences and walls
- Recreation areas
- Lighting

Choose a Design

PHASE 5: Choose a Design

Choosing a design for your final roof-reliant system is a very personal decision. It involves your particular sense of aesthetics, your level of desire for being outdoors, your finances, your level of commitment to roof reliance and many other factors.

For many homeowners, the selection process begins with a narrowing down of choices. If financial factors are of primary importance, some of the more expensive options may be rejected at this point. If aesthetics are your number one concern, then perhaps aboveground tanks can be ruled out.

At this stage in the process, define and locate the set of rooftop water harvesting options that you will work with as you proceed with your project. This design is not necessarily the only or best final option; it is simply a draft to work with during the rest of the planning process.

Locate and define walkways, patios, walls and other hard surfaces that may contribute to the water available to plants. Place the largest plants—the shade trees, vines and shrubs needed for privacy and/or wind screening. Then overlay the accent plants, groundcovers and other smaller plants you are considering for seasonal color and texture so that you begin to have a sense of how much total surface area will be planted.

At this point, you do not need to decide what each specific plant will be, but do think about which areas will be the most xeric and which will act as "oases." You may want to note favorite plants so that they get first consideration when you begin matching the planting plan to the water budget.

Chapter 5: Cost Estimating

Now that you have chosen a workable landscape design option, you can estimate the cost of your landscape installation project. The cost-estimating procedure presented in this manual is based on the categories of common roof-reliant landscape features that were outlined in the previous chapter, and it will enable you to calculate a reasonably accurate financial picture of your project.

Worksheet 3 is provided at the end of this chapter for you to enter your cost estimates for the many aspects of your project. This worksheet was designed to be as inclusive as possible, so you may not need to fill in every box on Worksheet 3. Worksheet 4 is also provided to give you a less-detailed overview of your anticipated project costs. The additional information about some key categories provided in this chapter should assist you in filling out the worksheets.

Landscape Planning Costs

Landscape Planning Costs

It is possible to design your own landscape and cistern system, particularly if they are relatively simple. However, most large-scale or complex systems and landscapes are best designed by professionals who know the details of project planning and design.

On-site consultations for landscape evaluation are sometimes provided free of charge. Even if you plan the entire project by yourself, it often makes sense to get some professional advice and feedback concerning design and implementation.

Surveying and other forms of land measurement are often necessary in order to be certain of the locations of property boundaries, easements, utility lines, etc. More precise measurements of existing vegetation, pathways, play structures and any other items that typically do not appear on professional surveys will need to be taken in the field. A detailed and comprehensive scaled drawing or blueprint of your landscape design can often save significant time and money in the long run and help prevent costly mistakes.

Since the permitting process can often consume significant time and require qualified, professional expertise, the cost of getting all of the permits for your project must be figured into the estimate.

Cistern System Expenditures

Cistern System Expenditures

Although it is helpful to be familiar with every feature of your cistern system during the cost-estimating process, this knowledge is not required to arrive at an accurate estimate. Obvious costs include the tank(s), delivery system, pump, pipe connections, excavation and backfilling. Less obvious cistern system expenditures include a pumphouse, a sediment trap, a vent, overflow piping (and associated erosion control structure[s]), a pressure tank, a level reader, at least two 110-volt (minimum) electrical circuits, a float switch and the cost of removing (or using) excess dirt from the excavation process.

Cistern tank delivery can be a sizable installation cost. Most tanks are not put together on-site. Consequently, the cost of shipping a tank that ranges in size from a small car to an 18-wheeler truck is given a separate line item on Worksheet 3. Delivery may also include renting a crane large enough to lift a steel tank over your house.

Especially for underground and partially buried cisterns, excavation can be costly. Aboveground tanks typically do not require a line item for excavating around the tank, but some excavation is often necessary for at least some piping and the pumphouse. When excavation costs are low, you should expect to spend a little more money on landscape features that lessen the tank's visual impact, and additional costs could involve securing aboveground tanks (when empty) from high winds or pouring a concrete slab under an aboveground pumphouse. In addition, don't forget the costs of backfilling (and proper tamping) dirt back on top of all of the subsurface work.

Pipe connections include roof gutters, downspouts, drains, conveyance piping, first-flush devices, vent piping, electrical conduit, pump-related piping and pipes that connect cisterns together. These are described in greater detail in Chapter 8, but it is important here to recognize the materials and labor costs involved in this complicated matrix.

Sediment traps and first-flush devices are relatively inexpensive items that act as filtration mechanisms for all of your roof water. For ease of maintenance, these are usually conveniently located in your system's conveyance piping (which directs water from your roof to your tanks). This is a highly recommended item because it prevents significant future expense when too much solid matter collects at the bottom of your cistern.
The water pump and associated parts and labor certainly need a line item on your spreadsheet. Submersible pumps, which are installed at or near the bottom of the cistern, propel water out of the cistern, while in-line pumps, which are typically installed in a separate pumphouse, draw water out of the cistern via a pipe through the pump and run toward the distribution system. Note that an in-line pumphouse system, although it has some advantages, usually requires a greater initial investment.

Every cistern needs a vent so that air can enter the tank when water is pumped out. (Underground tanks typically have a vent pipe that protrudes from the ground.) Vents are also important during flood events because they provide space for air to escape, and this allows your overflow pipe to work more effectively. The cost of venting a cistern is often very low, but this does not mean venting is less important than other items. Remember also to consider the cost of creating a view screen for your vent if needed.

Overflow piping is essential for times when the cistern is full and precipitation is occurring. On relatively flat, level sites, this can become a significant cost because overflow pipes need to reach a daylight point in order to be effective. A daylight point is the place at which overflow water can become surface runoff. The cost of this piping is usually very little, but the cost of controlling erosion from the large flows of water that periodically pass through such pipes should not be underestimated.

(NOTE: Make sure that the ends of all vent pipes and overflow pipes have a screen covering of small enough mesh to keep mosquitoes from entering.)

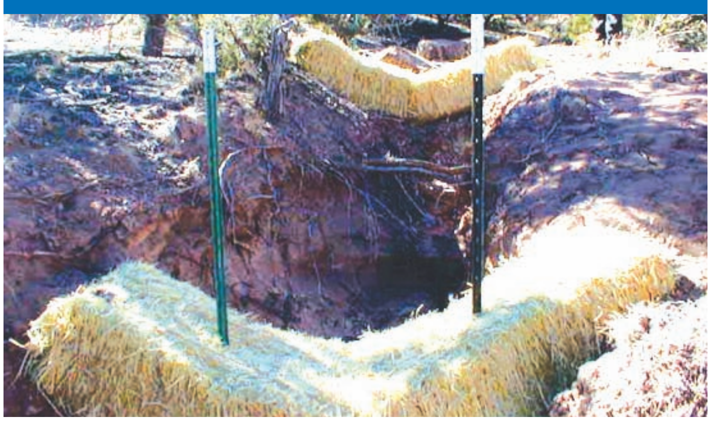
Many systems have a number of accessories including pressure tanks, level readers, float switches, heating mechanisms and others that will be discussed in greater detail in Chapter 9, Water Storage. Keep in mind that the cost of getting professionals—such as licensed electricians, plumbers, irrigators and cistern systems installers—involved early in your design project is almost always worth the effort. For example, your pump will need electrical power, and many of the accessories often require dedicated low-volt, 110-

volt or 220-volt circuits. Be sure to outline the work order for each professional up front in order to prevent costly change orders.

One potentially significant cost is that of dirt removal. For now, suffice it to say that not only are there often expenses associated with a pile of dirt the size of a school bus, serious fines can be levied on those who dump dirt illegally. In a best-case scenario, your extra dirt will become a resource (for use in terraced beds, for example). But in other cases, you might have to pay a surprisingly high price for the removal of the dirt leftover from an underground cistern installation.

In the simplest cistern system, water distribution components may consist of only a valve, a garden hose and a spray nozzle. However, many distribution systems include an automated drip irrigation system connected to a pump and a pressure tank. The associated parts for water distribution range from expensive computerized valve controllers to plastic emitters and couplings that cost pennies apiece.

Errosion Control Expenses



Erosion Control Expenses

The costs of controlling erosion and properly handling any drainage issues on your property are extremely variable. In most cases, all that is needed is a large French drain and a small swale located below a cistern's overflow pipe. With a shovel and some extra rocks or gravel, this work can take less than an hour and cost virtually nothing. In extreme cases where, for example, a cistern must be sited near the unstable bank of an arroyo, it might cost thousands of dollars for proper erosion control. Be sure to manage water appropriately, as neighbors will not appreciate your overflow, and in most cases it is required by law.

Plant Material

Plant Material

In general, the larger the plant material, the greater the price tag. It is usually most cost effective to invest in larger sizes of slower-growing plants and smaller sizes of plants that will grow quickly, even with modest watering. To accurately predict the costs of plants, contact a local plant nursery or landscape professional. From a water budgeting perspective, also keep in mind that larger plants require more water to get established than smaller plants of the same species.

Hardscape

Hardscape

For the purposes of this manual, hardscape refers to any surface on which people walk. Typically, hardscapes also provide space for other activities such as dining and relaxing. Hardscapes enable people to enjoy being in the midst of the landscape.

Concrete and gravel provide cost-effective hardscape surfaces. Wooden decks, brick, pavers and widely spaced flagstones set in sand can fit within many mid-range budgets. Flagstone (especially that which is set in concrete with tight joints and broad, finely chiseled stones) is one of the most expensive hardscape surfaces commonly available in New Mexico.

Fences and Walls

Fences and Walls

A fence can be a cost-effective alternative to plants when privacy, wind and water consumption are issues. Free-standing walls can also provide privacy and wind protection, but walls are usually more expensive than fences. Keep in mind that a permeable windbreak, such as a fence with space between the slats, is better at reducing the negative effects of wind than an impervious windbreak, such as a solid wall.

Retaining walls can quickly increase the cost of the project. If money is an issue, good alternatives include on-contour swales and/or decorative boulders associated with appropriate grading. If a wall is designed to retain the earth surrounding a cistern, include the cost of having a licensed engineer approve the design.

Other Costs

Birdbaths, shade houses and tool sheds are examples of items that do not fit into a predetemined category. These other costs should still be accounted for in the cost estimating worksheets.

Now, let’s assume that you are ready to begin filling out your cost estimating worksheet. From the time you begin meeting with professionals on your property and continuing through the creation of the conceptual design, you have done the majority of the research necessary to create an itemized estimate for a particular category. At this point it makes sense to add up all of the features for each category to determine the subtotals.

Whenever you have a subtotal completed in Worksheet 3, move this figure to the corresponding category in Worksheet 4. While the more detailed version of Worksheet 3 is essential, it is also helpful to get a quick overview at the major expense categories provided in Worksheet 4.

Figure 5-1: Retaining walls can reduce soil erosion and create additional spaces for plants and recreation areas.

WORKSHEET 3 Estimating Roof-Reliant Landscape Installation Costs (Detailed Version)				
CATEGORY	**FEATURE**	**MATERIALS**	**LABOR**	**COST**
Landscape Planning				
	Design			
	Cost estimating			
	Installation scheduling			
	Water budgeting			
	Permit fees			
	Project management			
	Other			
	Landscape Planning Subtotal			
Cistern System				
	Tank(s)			
	Cistern fittings, serviceway, lid, lock, etc.			
	Delivery			
	Excavation, tank setting, extra dirt removal			
	Access issues			
	Pipe connections (conveyance and delivery)			
	Sediment trap or first-flush device			
	Backfill and tamping			
	Vent			
	Overflow piping			
	Pump			
	Pressure tank			
	Pumphouse and associated accessories			
	Level reader			
	Float switch(es)			

(continued next page)

WORKSHEET 3
Estimating Roof-Reliant Landscape Installation Costs (Detailed Version)

CATEGORY	FEATURE	MATERIALS	LABOR	COST
Cistern System				
	Electrical work (contractor)			
	Connection to supplemental water			
	Pressurized pipe			
	Winterization shutoff valves			
	Frost-free hydrant(s)			
	Landscape hose and spray nozzles			
	Backflow prevention			
	Zone valves and boxes			
	Polypropylene tubing			
	Drip emitters, couplings, etc.			
	Deep pipe irrigation			
	Electrical connections and supplies			
	Other/Miscellaneous			
	Cistern System Subtotal			
Erosion Control				
	Grading			
	French drains			
	Swales			
	Check dams, gabions, etc.			
	Other			
	Erosion Control Subtotal			

(continued next page)

WORKSHEET 3
Estimating Roof-Reliant Landscape Installation Costs (Detailed Version)

CATEGORY	FEATURE	MATERIALS	LABOR	COST
Plant Material and				
Decorative Materials				
	Soil building and amendments			
	Large trees			
	Small trees / large shrubs			
	5-gallon vines			
	5-gallon shrubs			
	1-gallon shrubs and perennials			
	4” perennials			
	2” perennials			
	Annuals			
	Seeding			
	Boulders			
	Decorative accents			
	Other			
	Plants Material and Decorative Materials			
	Subtotal			
Mulch and				
Weed Barrier				
	Gravel			
	Crusher fines			
	Shredded bark			
	Bark chips			
	Straw			
	Hay			

(continued next page)

WORKSHEET 3 **Estimating Roof-Reliant Landscape Installation Costs (Detailed Version)**				
CATEGORY	**FEATURE**	**MATERIALS**	**LABOR**	**COST**
Mulch and				
Weed Barrier				
	Pecan shells			
	Compost			
	Landscape Fabric (permeable)			
	Other			
	Mulch and Weed Barrier Subtotal			
Hardscape				
	Pathways and stepping stones			
	Patio areas			
	Stairs			
	Wooden deck			
	Other			
	Hardscape Subtotal			
Fences and Walls				
	Wood fence (coyote, split rail, etc.)			
	Metal fence			
	Concrete wall with stucco (free standing)			
	Rock wall (free standing)			
	Concrete wall with stucco (retaining)			
	Rock wall (retaining)			
	Railroad tie/treated wood wall (retaining)			
	Edging (metal, plastic, wood, rock, concrete)			
	Other			
	Fences and Walls Subtotal			
(continued next page)				

WORKSHEET 3
Estimating Roof-Reliant Landscape Installation Costs (Detailed Version)

CATEGORY	FEATURE	MATERIALS	LABOR	COST
Recreation				
	Sandbox			
	Swing set, trampoline			
	Basketball hoop			
	Other			
	Recreation Subtotal			
Lighting				
	Pathway			
	Security			
	Accent			
	Other			
	Lighting Subtotal			
Additional				
	Birdbath /small fountain			
	Garden ornaments			
	Trellis /arbor			
	Shade house /ramada /pergola			
	Additional Subtotal			
	Pre-Contingency and Pre-Tax Subtotal			
Miscellaneous				
	Add your contingency factor here.			
	(20% is recommended.)			
Tax (NM Gross				
Receipts Tax)				
	TOTAL ESTIMATE			

WORKSHEET 4 **Estimating Roof-Reliant Landscape Installation Costs (Condensed Version)**	
CATEGORY	**COST**
Landscape planning subtotal	$
Cistern system subtotal	$
Erosion control subtotal	$
Plant material and decorative materials subtotal	$
Mulch and weed barrier subtotal	$
Hardscape subtotal	$
Fences and walls subtotal	$
Recreation areas subtotal	$
Lighting subtotal	$
Additional subtotal	$
Miscellaneous	$
Subtotal	$
Contingency Factor (20%)	$
NM Gross Receipts Tax	$
TOTAL ESTIMATE	**$**

Chapter 6: Water Budgeting

A budget is a numerical estimate that describes a plan for the future use of resources. For the roof-reliant landscaper, a water budget is an accounting of the potential use of water during drier-than-normal years. Such a budget focuses on establishing the appropriate plant material that you expect to install according to your roof-reliant landscape plan.

An easy way to begin to understand water budgeting is to think of a typical household budget. In household financial planning, incomes are projected and expenses are estimated. Often, at the end of a given time period, any money left over goes into a savings account.

Similarly, in water budgeting for roof-reliant landscaping, the "income" is projected in terms of the number of gallons of precipitation that can be expected to be stored in a cistern. "Expenses" (or outlays) are estimated in terms of the gallons of water that landscape plants might need. Any water left over is banked in the cistern for future use.

There is one major difference between a typical household budget and a typical landscape water budget. While most household expenses tend to increase over time, a new landscape's water needs tend to decrease after the first year. That is because even appropriately chosen plants need supplemental water during their first growing year. But once established these plants need less irrigation.

Water-Budgeting Basics: Income and Outlays

The basics are the same for every water budget. Every time period starts with a projected quantity of water in storage, and a projected quantity of income water in the form of newly harvested precipitation. These two variables will depend on the size of your catchment area, the amount of precipitation captured in a given year and the size of your storage tank. A detailed description of how to calculate the projected quantity of storage and income water is presented in Chapter 3, Sizing Your Cistern. (Also see Appendix 1 for average precipitation by month in various New Mexico cities).

Water Outlays

Water outlays are delivered from storage to your landscape plants. There are many variables that need to be taken into account when calculating outlays, and this section is designed to estimate landscape water needs in order to determine the appropriate storage. Actual irrigation requirements will depend on several variables including age of plants, density of plantings, soil type and distribution efficiency. The irrigation requirements outlined in Appendix 4 should be used as a guideline, with appropriate adjustments for specific circumstances.

To determine how much water a given plant needs, please answer the following questions:

- Where in the state do you live?
- What is the irrigation requirement of the plant (low, medium or high)? For the purposes of this manual, low-water-use plants are called "zone 1" plants. Medium-water-use plants are "zone 2" plants and high-water-use plants are "zone 3." If you are unsure, please ask a local nursery person or county extension agent.

From a roof-reliant landscaping standpoint, the most important factor in plant irrigation is the water-use requirement of the plant. While similarly sized low-water-use (zone 1) perennials and trees do have slightly different water requirements in the landscape, these differences are not significant when compared to the differences between low-water-use plants (zone 1) and medium-water-use (zone 2) or high-water-use (zone 3) plants.

Table 6-1: Plant Water-Use Zones

Water Use Requirement	Water-Use Zones
Low	Zone 1
Medium	Zone 2
High	Zone 3

NOTE: Turfgrass, as a plant category is not covered in this manual because of the high-water-use requirements of cool season grasses and the fact that too much harvested water would be wasted due to the inefficiency of sprinkler systems.

The information found in Appendix 3, Landscape Irrigation Requirements in New Mexico, shows the amount of water required by different types of plants in different parts of the state in gallons per square foot per year. Because the root area of a large "zone 2" tree covers more square footage than the root area of a flowering "zone 2" perennial, the tree requires more supplemental water to maintain than the perennial. However, the rate of water applied per square foot is the same for both plants.

To find the estimated irrigation requirements in a normal-weather year in gallons per square foot for different water-use zones, simply find the appropriate line in Appendix 3. For example:

County	Locale	Zone 1	Zone 2	Zone 3
Bernalillo	Albuquerque	5.97	14.79	37.65

Make sure to use the irrigation requirement for your locale or the locale closest to you. For each different plant in each water-use-requirement zone, make a new entry in the worksheet in Appendix 2. The example shown below is for Albuquerque and assumes a mature landscape.

Table 6-2: Sample Water Demand Worksheet

A	B	C	D	E
Zone	Locale	Irrigation requirement in gallons per sq. ft. per year	Square footage of irrigated area	Total gallons required (C x D)
1	Albuquerque	5.97	150 sq ft	895.5 gallons
1	Albuquerque	5.97	100 sq ft	597 gallons
2	Albuquerque	14.79	50 sq ft	739.5 gallons
Total				2232 gallons

NOTE: Newly established plants need more water in order to get established in the landscape. Multiply the figures in Appendix 3 by 1.2 to determine first-year water requirements. For year two, multiply these figures by 1.1 and for year three multiply by 1.05. For all subsequent years use the figures in Appendix 3.

Other Factors to Consider

- Factor in the seasonal demand. Throughout New Mexico, the period of heaviest supplemental irrigation is typically late June through early July. Using July as the benchmark for maximum supplemental irrigation needed (100%), all other months need less irrigation. For example, in Las Cruces during the month of April, irrigation controllers should be set to deliver only 41% of the total water that is needed for the hot month of July. See Appendix 5 for a chart of monthly water-budget settings for eight New Mexico locations.
- Most drip emitters measure water delivered in gallons per hour. To convert irrigation run times to total gallons delivered, multiply the total number of hours times the flow rate of the emitter. For example, a 4-gallon-per-hour emitter that runs for 30 minutes three times a week will deliver 6 gallons of water per week (4 gallons/hour x 0.5 hours x 3 = 6 gallons).
- Location of drip emitters is important. Watering plants too closely to the middle of their root-areas does not encourage roots to expand outward. Another common mistake is locating drip irrigation emitters too close to the trunk of a tree or the stem of a plant. Emitters should be placed at the "dripline" (the edge of the leaf canopy) of shrubs and trees. As plants grow larger, the drip emitters should be moved outward toward the dripline.
- Irrigation system efficiency. No irrigation system is 100 percent efficient. Drip irrigation systems, which are recommended for all roof-reliant landscapes, are the most efficient irrigation systems. But even drip systems lose water to leaks, improperly placed drip emitters and other factors. According to irrigation industry statistics, drip irrigation systems have an efficiency rating of 85 to 90 percent. (This means that 85-90 percent of the water entering the distribution system actually makes it to plant roots. The remaining 10-15 percent is lost to leakage or does not make it to plant roots.)
- Soil types impact run times. Sandy soils quickly direct water down and away from the root zones of plants, while soils with high clay content tend to saturate quickly, sometimes choking the roots of plants. In sandy soils,

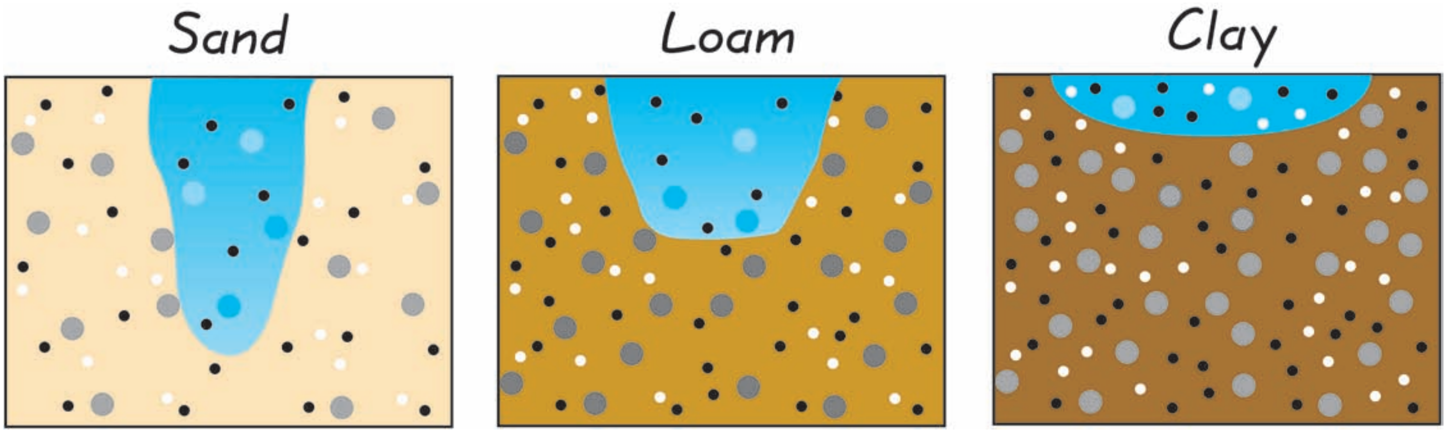


Figure 6-1: Illustration of how soil types affect how water Is dispersed into soil

shorter and more frequent run times can be more effective. Conversely, longer time periods between run times is a good watering strategy for clay-based soils. (See Figure 6-1 above for an illustration of how soil types affect the dispersal of water into the soil.)

- Regularly inspect plants. Plants that are receiving too much water often display symptoms similar to plants that are getting too little water, such as yellowing leaves. Therefore, determining the cause of plant stress early on can help reduce your water use.

The Roof-Reliant Calendar

A quarterly water budget, divided into "seasons" that coincide with the climatic and precipitation patterns in the state, is recommended for roof-reliant landscapers. The water-budget fiscal year begins on September 1 and ends on August 31.

Breaking down the year in this way also relates more precisely with the extremely variable water needs that plants have during the course of the year. Specifically, most plants typically need decreasing amounts of water in fall, little to no water in winter, increasing amounts of water in spring and the most water in summer.

Dividing the year in this manner reminds us that the beginning of summer is the most important time of the year to have water stored in your cistern (because water use will be highest in this season). This seasonal calendar can also serve to remind us that fall is an excellent time to plant the less heat- and drought-adapted plants such as fruit trees and shade trees in the high-water zones (zone 3) of the landscape. Fall is also the time to begin weaning established xeric plants off of supplemental water as days become shorter and temperatures become cooler. This allows plants to start going dormant in preparation of upcoming winter weather.

For the roof-reliant landscaper, the fiscal year should start with a full cistern system. Fall comes soon after the end of a typical "monsoon" season, so the assumption that water-storage tanks will be full at the beginning of the process of water budgeting is certainly plausible—especially if your cistern installation occurred the previous winter or fall. The first season begins after the time of greatest landscape-water need and at the beginning of the time to start saving water for the next hot season.

Each season can vary considerably depending on where you live. Table 6-3 presents a guideline to the seasons for the three climatic regions of the

Table 6-3: New Mexico's Quarterly Water-Budget Calendar by Climatic Region

	Southern	Central	Mountain
Season 1 (Fall)	Sept., Oct., Nov.	Sept., Oct., Nov.	Sept., Oct., Nov.
Season 2 (Winter)	Dec., Jan.	Dec., Jan., Feb.	Dec., Jan., Feb., Mar.
Season 3 (Spring)	Feb., Mar., April	Mar., April, May	April, May
Season 4 (Summer)	May, June, July, Aug.	June, July, Aug.	June, July, Aug.

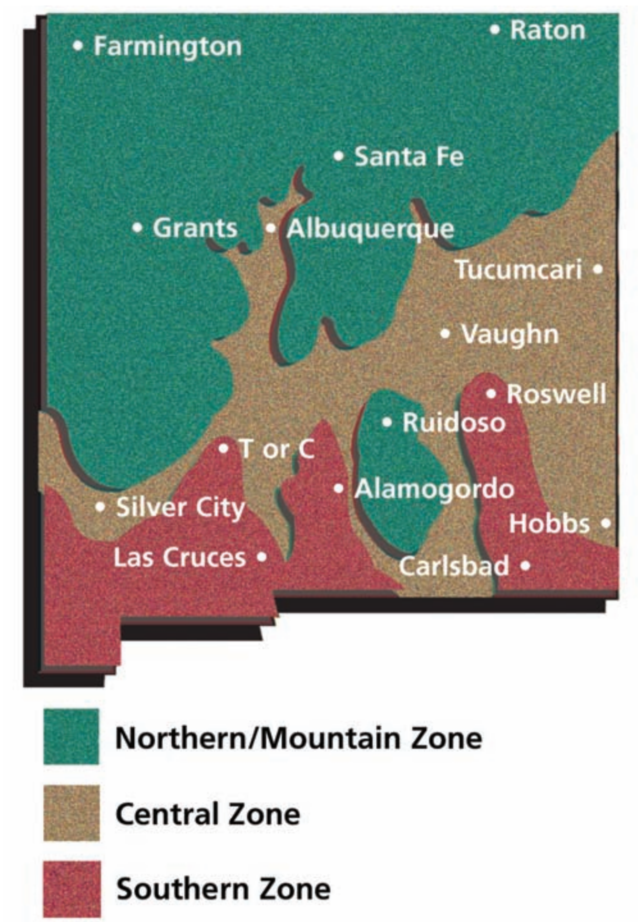


Figure 6-2: New Mexico has three major climatic regions, as depicted on this map.

state. Please contact your county extension agent for localized information.

Below is a quick summary of the watering goals and strategies for each quarter of the water-budget calendar year. Remember that precipitation not only fills up your cistern but also waters your plants, so adapt your watering schedule accordingly.

- Season 1/Fall. Water sparingly, especially as the season progresses. The exception is for new plantings, which will need extra supplemental water to get established. (Your cistern should be relatively full after the summer monsoon season.)
- Season 2/Winter. Most plants are dormant, so refrain from watering. Trees, especially evergreens, may need monthly watering during dry months with little or no precipitation.
- Season 3/Spring. A time for frugal watering that keeps plants alive but reserves as much water as possible. Watering should increase as temperatures rise with the approach of summer.
- Season 4/Summer. Plants need the most water during the hottest months of the year. Being prepared for the beginning of the hot weather with water stored in the cistern is critical. The monsoons should begin to refill your cistern and start the cycle again.

Due to its higher temperatures, Season 4 of the water budget fiscal year is often the most challenging. But given a "normal" monsoon season in New Mexico, a realistic planting plan and conscientious water saving during the three previous seasons, your landscape should have no difficulty surviving the heat of summer. In fact, the summer months are when cisterns can fill up rapidly, sometimes to capacity.

Before detailing a water budget, it is important to address weather variations. New Mexico weather varies not only by location and elevation but also from year to year. Floods, drought, late and early freezes, high temperatures and wide temperature variations are all part of our weather cycle. Prepare your landscape to survive these extreme conditions by planting appropriate drought-tolerant species, encouraging deep roots and storing water for the days without rain.

Water Income

It is also extremely helpful to know when in the year it is most likely to rain. On average, the "typical" year's rainfall in New Mexico will be delivered as follows:

- One-eighth will be harvested in Season 1 (September, October and November).
- One-quarter will fall in Season 2 (typically December, January and February).
- One-eighth will be harvested in Season 3 (March, April and May).
- One-half of the year's precipitation will come in Season 4 (June, July and August, in most parts of the state)[7].

[7] Based upon recent data, precipitation patterns may be changing and New Mexico's summer "monsoon" season may not be as predictable or consistent as in the past. Nevertheless, New Mexico continues to receive a large percentage of its annual precipitation during the warmer months.

If 12,000 gallons of water income is anticipated to be harvested per year, the first season (fall), of the water budget year will typically produce 1,500 gallons of new water. During the second season (winter), 3,000 gallons will be collected and the third season (spring) will provide 1,500 gallons. The total new-water income expected during these three seasons is 6,000 gallons.

Let's assume that your cistern holds 6,000 gallons, and that you start the water budget year (September 1) with a full cistern. In this example, the total anticipated water budget for the first three seasons of the year is 6,000 gallons of new income plus 6,000 gallons of previously stored water, or 12,000 gallons of total water income from September through May. However, since the goal is to start the fourth season of the year with a full cistern (because it is the hottest part of the year), of the 12,000 gallons only 6,000 gallons of it is useable income.

In the example above, the estimated fourth-quarter water budget would be 12,000 gallons (6,000 gallons in storage plus the anticipated 6,000 gallons in new water to be harvested during the fourth quarter). Because some years are drier than "normal," it is wise to estimate usable fourth-quarter income at approximately 80% of maximum. Consequently, you should install plant material that can survive on approximately 9,600 gallons of water during June, July and August.

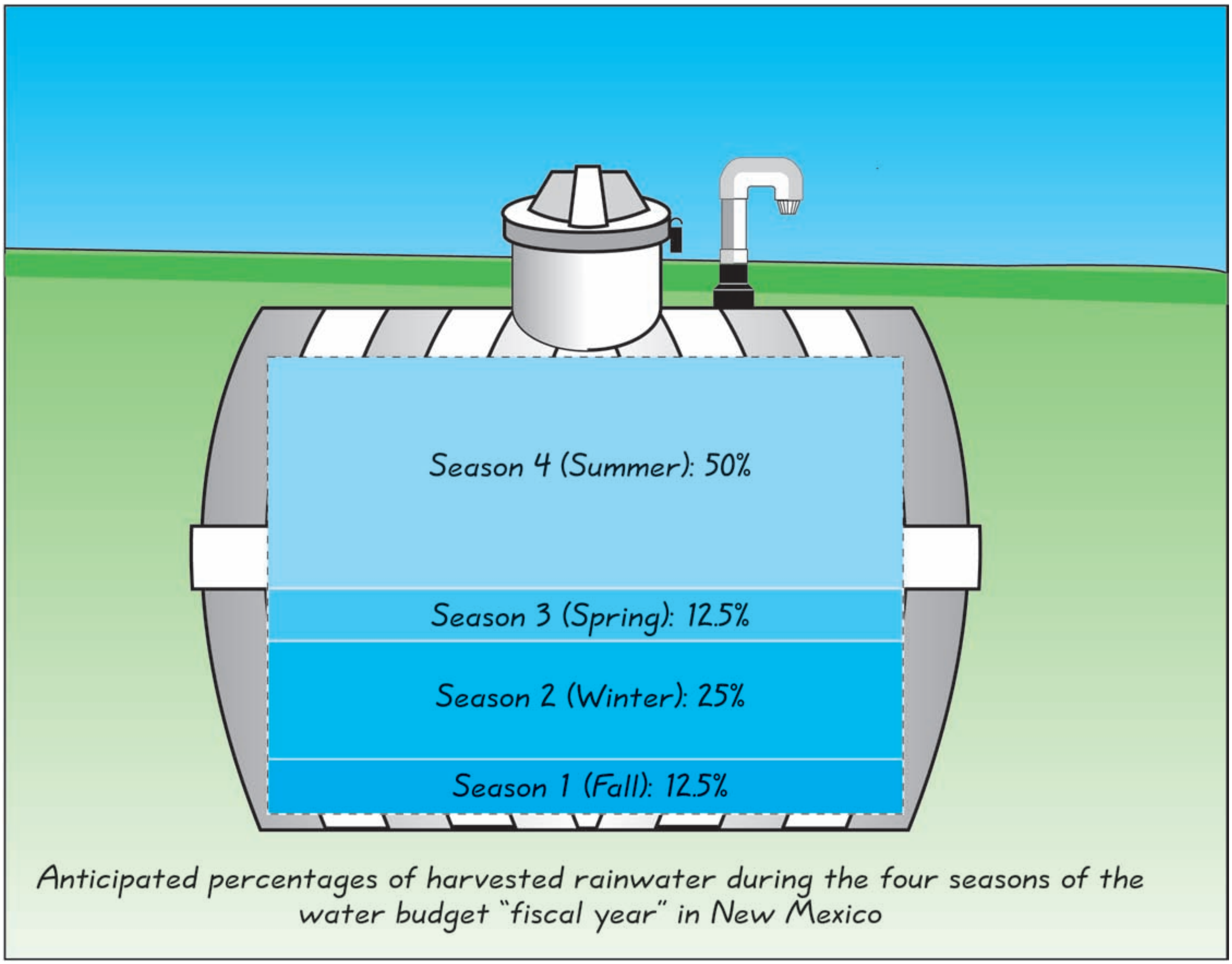


Figure 6-3: Anticipated percentages of harvested rainwater during the four seasons of the water budget year in New Mexico. One-half of the expected rainfall occurs during Season 4—New Mexico's summer "monsoon" season.

Chapter 7: Water Collection

When it comes to rainwater harvesting in New Mexico, the major question concerning your roof is whether it is pitched or flat.[8] Pitched roofs are slightly more efficient than flat roofs for water harvesting, but flat roofs are quite suitable surfaces for rainwater collection as well.

The "Pitch" for Pitched Roofs

When it comes to harvesting precipitation, pitched roofs provide a cleaner resource than flat roofs because less debris accumulates on them. Flat roofs have parapets that prevent debris from being blown or sliding off the roof. When significant storm events occur, anything on a pitched roof will quickly wash away, while at least some portion of the debris on a flat roof is left behind to slowly decompose on the water-collection surface.

Many materials used in flat roofs leach low levels of toxic chemicals, but as long as your cistern is locked and marked "nonpotable," this should not be a problem.[9] Plants should thrive as a result of being watered by your harvested precipitation.

Pitched roofs collect a greater amount of precipitation than flat roofs for the following reasons:

1. Less precipitation evaporates off of pitched roofs than off of flat roofs because the angle of a pitched roof directs precipitation more immediately to the conveyance system. Since the precipitation landing on a flat roof moves much more slowly than that landing on a pitched roof, the sun, wind and ambient air have an increased amount of time to cause evaporation.
2. The gravel that is typically part of a flat-roof system prevents rain and snow delivered from light-precipitation events from making it to the system's conveyance piping. Water is inhibited from flowing toward the initial conveyance points, and the gravel, with its multiple surfaces, causes significant evaporation, especially when conditions just prior to precipitation were hot and dry.
3. Given an identical building footprint, the square footage of a pitched roof is typically larger than that of a flat roof. This is due to the overhangs associated with pitched roofs, which add catchment area.
4. The conveyance system for a pitched roof is usually slightly less expensive to install and slightly more efficient at transporting water than that of a typical flat roof. (This will be made more apparent in Chapter 8, Water Conveyance.)

Runoff Coefficients

When calculating the amount of runoff that can be harvested from a roof, it is common to include a runoff coefficient. This coefficient accounts for the fact that some roof surfaces are more efficient than others at collecting rainwater. For example, a pitched metal roof is typically the most efficient type of roof for collecting water, delivering 95% of the water that falls on it (except for some heavy snowfalls). Conversely, a flat tar-and-gravel roof is typically the least efficient roof type, delivering 80-85% of the water that falls on it. Table 7-1 lists the runoff coefficients for common roof materials.

Table 7-1

Runoff Coefficients for Common Roof Materials	
Metal	0.95
Asphalt	0.90
Concrete	0.90
Tar and gravel	0.80-0.85

Please note that the figures in Table 7-1 are estimates. In a very light rain event, the runoff coefficient can equal 0.00, since no rainwater will flow through your catchment system into your cistern.

[8] Throughout the text, the common term "flat" is used to describe both flat and seemingly flat, low-sloped roofs.

[9] For water quality issues, contact the New Mexico Environment Department Water Quality Bureau.

In Chapter 3, Sizing Your Cistern, the runoff coefficient was not included in the calculations you made when estimating anticipated rainwater harvests. Instead, you were encouraged to use a generally cautious approach to predicting rooftop rainwater harvests. The decrease in harvested rainwater due to loss from the runoff coefficient was one of the reasons for this. If you would now like to include the runoff coefficient in your rainwater harvesting calculations, you can more accurately predict the net runoff.

Roof Materials (Pitched Roofs)

Pitched roofs are constructed using a wide variety of materials, including metal, tile, shingle, slate and treated wood. From a water harvesting perspective, metal is the preferred pitched roof material because of its high runoff coefficient and because other more-porous roof materials can leach toxins into your cistern and, ultimately, to the root zones of your plants.[10]

Metal. A pitched, sheet metal roof is the cleanest and most efficient collection surface available. It provides a smooth surface that conveys water efficiently. Sheet metal is competitively priced throughout much of New Mexico and lasts a long time under normal conditions. Metal tile is also available, but it is more expensive and less efficient at collecting water. Metal is a relatively durable and long-lasting roof material, and it is priced in the mid-range for roof materials. (See Figure 7-1.)

Asphalt. Asphalt roofs are popular because they are made from some of the least expensive roofing materials available. Asphalt shingles are typically made of either a paper-based or a fiberglass-based mesh soaked in asphalt. Due to the leaching that can occur from asphalt shingles, this is a poor roof choice from a water quality perspective.

10 More info concerning environmental issues of roof materials may be found at: http://www.austinenergy.com/energy%20efficiency/programs/green%20building/Sourcebook/roofing.htm

Figure 7-1: A pitched metal roof is the most efficient catchment surface for rainwater harvesting.

Clay. In some parts of the world, clay tile roofs are the dominant roofing material. Although clay makes a great material for water harvesting due to its smoothness, clay tile is not especially popular in New Mexico because it is usually more expensive than metal roofing and the tiles need to be replaced more often because they crack easily in our freeze-thaw climate.

Slate. Slate is a very smooth and exceptionally durable surface, which makes it excellent for water harvesting. However, slate roofs are not common in New Mexico because slate is expensive to import from the few eastern states that quarry it. Slate typically comes in small rectangular tiles (also called shingles), but it is a relatively heavy material, which further increases the high cost of shipping.

Concrete. Concrete tile can be a good roof choice in New Mexico due to its ability to insulate the building it covers. A small portion of each storm's water will be absorbed due to the natural porosity of concrete; however, this water, which ultimately evaporates, is usually not a significant quantity. Concrete roofing is noncombustible and can be a good alternative to other materials in fire-prone areas.

Fiberglass. Laminated fiberglass shingles contain the same materials as some asphalt shingles, but they last up to twice as long as regular asphalt shingles. The potential leaching of asphalt and fiberglass make this a poor choice from a water harvesting perspective. In addition, fiberglass roofing is fairly costly.

Glass and polycarbonate sheets. Sunrooms, greenhouses and solariums are some of the typical places where you will find both glass and polycarbonate roofing. Due to their extremely smooth quality, glass, polycarbonate sheets and other types of glazing are often among the most efficient surfaces available for harvesting precipitation.

Wood. Wood roofs are usually built using shingles made either of a hard wood that contains a natural resistance to rot or of wood that has been treated with a rot-resistant chemical. They are often very attractive, usually relatively expensive and typically the most flammable of standard roofing materials found in New Mexico. Wood roofs are neither the most efficient nor the most inefficient of water collection surfaces.

Asbestos. Due to its toxicity, it is wise to avoid materials that contain asbestos when designing your cistern system. Fortunately, asbestos use in building materials has declined significantly since 1980, but trace amounts can still be found in some asphalt shingles, asphalt roofing felt, cement roofing shingles and wood shingle vapor retardants. Keep in mind that serious health-related problems often occur during the removal of asbestos, so licensed professionals need to be hired when removing a roof containing asbestos.

Roof Materials (Flat Roofs)

As discussed above, while so-called flat roofs are not the preferred type of roof from a water harvesting perspective, they are quite effective at harvesting water nonetheless. When the collected water is designated for nonpotable uses such as watering plant material, the drawbacks, in terms of both water quality and quantity, are relatively minor. If your roof happens to be flat, be assured that you can create a totally roof-reliant landscape with any of the flat roof materials commonly used in New Mexico. (See Figure 7-2.)

Asphalt. A wide variety of asphalt-based roofing materials is available for flat roofs, including tar and gravel, built-up roofs, cap sheet, torch down and roll roofing. The advantage of asphalt products is their relatively low cost. The downside of these materials is that the asphalt will slowly leach toxins into your cistern system. However, your plants will be able to tolerate these low levels of toxins without difficulty. (See Figure 7-3.)

Rubber. An increasingly popular kind of roof is made primarily out of a rubber product known

Figure 7-2: Although not the most efficient surfaces for harvesting rainwater, flat roofs can serve well as catchment areas for roof-reliant landscaping systems.

Figure 7-3: Asphalt shingle roofs, which are popular because they are relatively inexpensive, can be efficient for water harvesting.

as ethylene propylene diene monomer (EPDM). Seamless, long lasting, durable and less toxic than asphalt, EPDM is becoming more price-competitive. It has none of the strong odors associated with asphalt and is sometimes touted as a "green" roof since the rubber content can be made out of recycled materials.

Modified bitumen. This material is an asphalt-based product that contains a unifying agent, or modifier, that enhances the waterproofing characteristics of the asphalt. These modifiers include rubber, polyester, fiberglass and atactic polypropylene. If properly installed, such roofs should last longer than typical tar-and-gravel roofs, but they also require more skill to install than most flat asphalt surfaces.

Polyurethane. Another alternative is polyurethane foam, which leaches fewer toxins than many of its flat-roof counterparts, making it a good choice for water harvesting projects. Although it is more expensive than some of the other roof materials, polyurethane foam is an excellent insulator. Polyurethane must be covered with either a UV-resistant coating or, like many asphalt roofs, with gravel.

NOTE: The information presented in this chapter is intended to be an overview of some of the most common roofing types and materials. Other roof materials may also provide suitable surfaces for catchment areas, and further advances in technology will no doubt result in additional choices. Some of the newest options—including PVC single sheet membrane and thermoplastic polyolefin (TPO) membrane—offer efficient catchment surfaces and low toxicity. When choosing a surface for a new roof, it is important to select a nontoxic or low-toxic material that provides a high runoff coefficient.

Chapter 8: Water Conveyance

Conveyance systems move roof water from precipitation collection surfaces to cisterns. In a roof-reliant landscape, a typical conveyance system will perform five functions:

1. **Concentration**
2. **Vertical drop**
3. **Horizontal run**
4. **Filtration**
5. **Delivery**

Concentration

Figure 8-1: Gutters collect water from a pitched metal roof.

Conveyance begins where roof water is first concentrated in specific places, such as in a roof gutter, a canale or a roof drain. All concentration points require regular monitoring and occasional maintenance.

Gutters, which are almost always associated with pitched roofs, are open channels, or troughs, that direct roof water along roof lines usually toward downspouts. Typically, gutters are made of either aluminum or galvanized steel; custom-made copper and stainless steel gutters are also available at a higher cost. A common size for residential applications is a five-inch-wide gutter that drops a minimum of one inch for every 16 feet of roof line (1/16 inch per foot of slope).[11] A gutter with more slope can handle a greater volume of water. Wider gutters are also available, and these are recommended for use in many steep roof and commercial applications.

[11] Source: Uniform Plumbing Code (UPC) provided by Construction Industries Division (CID), of the NM Regulation and Licensing Dept.

Since gutters can require maintenance, be prepared to climb a ladder to clean out debris from time to time. If your building is situated next to one or more mature trees, you will likely have to remember to clean your gutters every fall. If you do not have mature trees in your current landscape, you may not have to clean your gutters for years, although annual monitoring would still be wise.

A canale is a short, narrow trough that protrudes through the parapet of a flat roof and directs water onto the ground below. A typical canale, according to the City of Santa Fe building code, should not be responsible for draining more than 400 square feet of roof. Canales on the north sides of roofs (especially northeast corners) should be avoided because the parapet can shade them during the shortest days of the year, which can cause ice blockage and freeze-thaw damage.

Before water harvesting became popular, an architect (or builder) could place canales virtually anywhere (except over a walkway or patio) as long as the precipitation never puddled on the roof. However, if you plan to include roof-reliant landscaping in your new construction project, it pays to let your architect and/or builders know this so they can most efficiently place the canales. It is much easier and less expensive to locate canales near your cistern instead of on the opposite side of your house.

Roof drains are sometimes used on flat-roofed buildings. These drains are typically connected to

Figure 8-2: Photo of a roof drain. Note the canale opening, which is required for secondary drainage.

pipes fitted within the wall of the structure. Roof drains, as shown in Figure 8-2, can work well if properly designed, installed and maintained. (For more information, see the “In-Wall Drainpipes” section later in this chapter.)

However, expensive mistakes can result if any one of the three links in the designer-builder-owner chain is weak. If the designer underestimates the size of the drain, the roof may not be able to withstand the inevitable backup of water. Similarly, if the builder makes a mistake during construction, leaks can occur inside the walls of the building, and these can be difficult to detect. Additional problems with roof drains can occur whenever regular monitoring, cleaning and maintenance of the drain are neglected.

Vertical Drop

Figure 8-3: Photo of a downspout. Downspouts funnel water from gutters along a vertical drop.

In most water harvesting systems, there is at least one place in the conveyance system with a sharp vertical drop. From pitched roofs, this is typically a downspout. From flat roofs, this is usually the arc of projected precipitation off of the edge of a canale. Harvesting water that free-falls from a canale imposes a need to efficiently direct the runoff. This manual offers three methods to deal with the vertical-drop issues associated with canales: funnel drains, downspout-canale connections and in-wall drainpipes.

Most roofs have more than one vertical-drop point. If, however, you can limit the number of these points in your design, you often can save money in the installation process. This of course assumes that your roof can handle the limited number of vertical-drop points during large storm events.

Downspouts

Downspouts are the pipes that direct water vertically from gutters toward cisterns. It is recommended that your downspouts be made of the same material as your gutters and that you affix them to your structure, as in Figure 8-3. Connections between gutters and downspouts should be monitored periodically for leaks and blockages.

Downspouts are highly efficient at conveying water along a vertical drop. They are also very precise at directing runoff, so the water they convey is less expensive to control than the water associated with canale drains (see next section). Aluminum, galvanized steel and vinyl downspouts normally come in two-inch by three-inch or three-inch by four-inch rectilinear sizes, but downspouts can also be cylindrical pipes made of polyvinyl chloride (PVC), steel and corrugated metal.

For the do-it-yourselfer, vinyl is a good downspout choice since it comes in manageable lengths with an assortment of parts that can be fit together quickly and easily. Aluminum gutters and downspouts are economical and relatively easy to install. Wood gutters are used primarily in special applications, such as historic preservation, due to their extra expense and fire-hazard potential.

Funnel Drains

A funnel drain catches water that falls from a canale. It does this by directing roof water through a rubber or vinyl liner (such as EPDM pond liner, which is a highly flexible synthetic rubber material that is commonly used to line decorative ponds) into a below-grade box drain. A top dressing of gravel or river rock covers the liner to protect it from degrading in the intense New Mexico sun and hides the drain from view. Most importantly, the gravel prevents mulch, soil and other particulate from being conveyed toward your cistern. This gravel becomes the first step in the filtration of the captured water.

Figure 8-4. An above ground demonstration of how a funnel drain works. Materials, shapes and proportions of funnel drains can vary.

When determining the location for a funnel drain, take into account the fact that roof water can arc far away from a structure (especially during intense storm events). Other times—at the beginning and the end of storm events, during light storms and when snow melts off of a roof—significant quantities of roof water drip straight down from the canale along what is called the drip line. In storm events that are associated with gusty winds, the collected roof water may be blown against your building, away from your building, or sideways, out of range of your funnel drain.

To combat the variable nature of the trajectory of the water, funnel drains are located in the ground at least four inches below grade and about 12 inches out from the drip line of the canale. The edge of the liner should start against the house and protrude at least three feet from the drip line, the point directly below a canale where it literally drips tiny amounts of water. Different liner materials come in different widths; standard five-foot-wide liners are typically sufficient for one-story structures, while a minimum of a six-foot-wide funnel should be used for two-story structures. Make sure that your funnel drain is pitched in such a way that water does not settle against your building, particularly in the case of adobe structures.

How to Install a Funnel Drain

After determining that your funnel drain is properly sited so that it will capture the optimal amount of water, you can install it by completing the following steps:

1. Double-check to make sure that there are no utility lines in the vicinity of your trenches. (Call 1-800-321-2537 before you dig!)
2. Place a piece of liner where you intend to install the drain.
3. Draw a line with a pick or shovel around the edge of the liner.
4. Remove the liner.
5. Determine the level of your existing grade.
6. Starting from the lines you drew, gently excavate a shallow hole that gets gradually deeper until the hole is four inches deeper in the center.
7. In the middle (and at the bottom) of this hole, dig another hole that is 12 inches by 12 inches by 12 inches. The total depth of this hole below grade will be 16 inches.
8. Dig a trench for the horizontal run pipe in the direction that you expect the pipe to go. This trench should be at a depth of 12 inches from the original grade.
9. Place some pipe in the trench and a drain box (available at landscape supply stores and home centers) in the second hole that you dug.
10. Connect the pipe to the drain box.
11. Backfill and tamp over the pipe and around the drain box.
12. Place the liner in the hole and cut out an 11-inch by 11-inch square piece of liner directly over the drain box.
13. Remove the grate on top of the drain box and then squeeze the grate back onto the box in a manner that locks the liner in place over the box.
14. Using standard landscape staples (purchased at your local garden/hardware center), tack down the liner with staples at 18-inch centers.
15. Cover the grate and the liner with gravel, round river rocks, smooth pebbles, etc.

See Figure 8-4 for a depiction of a funnel drain. This aboveground demonstration shows how a funnel drain can collect and filter water. The filtered water exits from the bottom of the drain.

Important Tips
Drainage mistakes close to the foundation of a wall should be avoided no matter what the cost. When installing your funnel drains:

- Be sure water flows away from buildings. When water collects against a wall, it can create expensive structural damage and mold problems.
- Do not cut corners by eliminating the liner. Without it, you will harvest much less water, and the roof water that you do not harvest may soak into the soil at the foundation of your home.
- Ensure that the connections between parts and materials are tight and secure. Although conveyance piping does not technically move water under pressure, the force under a canale can be substantial.

Downspout-Canale Connections

Figure 8-5: A toilet flange can connect a canale to a downspout.

For many people, all of the work described in the previous section about constructing a funnel drain may seem like too much labor and too much expense for a system that cannot capture all of the rainwater during high winds and/or large storm events. An alternative to a funnel drain is directly connecting downspouts to the bottom of canales.

There are a number of ways to direct roof water from a canale toward a storage tank. One common way, shown in Figure 8-5, is to install a toilet flange in the bottom of the canale, seal the flange, connect the flange to a downspout and partially dam up the outer edge of the canale. (Shown in Figure 8-6). The partial dam helps direct water into the drain at the top of the downspout. In the event that the drain gets clogged with debris, however, water can spill over the dam and flow off the canale to the ground below. This reduces the chance of creating a potentially damaging standing pool of water on the roof.

Figure 8-6: Partial dams installed on both sides of a drain directs the flow of rainwater.

There are other potential risks in connecting a downspout to a canale. A weak connection between canale and downspout can leak into the roof and walls of your structure. If undetected or neglected, significant structural and/or mold damage can occur. In addition, ice, especially on the north side of a structure, can prevent snowmelt from running off of buildings. Standing water and heavy icicles, along with the freeze-thaw conditions associated with winter weather, can cause significant damage either to a roof or its associated walls.

Another common method of directing roof water from a canale, presented in Figure 8-7, is to use a rain chain to direct water downward.

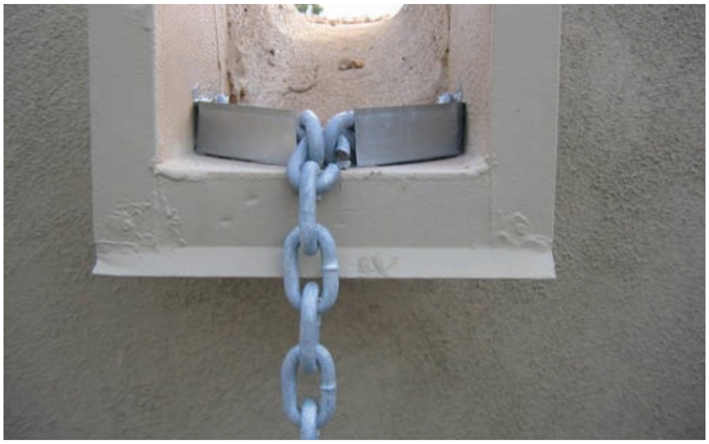


Figure 8-7: A rain chain is a simple but effective way to direct water downward from a canale.

In-Wall Drainpipes

Some downspouts, especially those associated with roof drains, are built into the walls of structures and are called "in-wall" drainpipes. Such systems are often installed for aesthetic reasons to keep the downspouts out of sight.

In-wall drainpipes are not only more difficult to fix, but also problems are more difficult to detect because they are so well hidden. Even small, undetected leaks can cause major damage to a wall in a relatively short time. In residential applications, these in-wall systems are relatively uncommon. However, in commercial applications, especially for tall buildings with flat roofs, roof drains associated with in-wall drainpipes are currently a typical method for controlling roof-water runoff at the vertical-drop point.

Horizontal Run

Figure 8-8: Conveyance pipes being installed, which will carry water to a cistern.

Almost all cistern systems require conveyance pipes that run perpendicular to the system's vertical-drop line. To maintain positive drainage toward the cistern, however, these pipes only appear to be horizontal and, in fact, must not be level. The horizontal runs should drop a minimum of one-quarter inch per linear foot until they connect with your storage area.

There are two kinds of horizontal runs: aboveground pipes and underground pipes. Aboveground runs are generally associated with aboveground and partially buried cisterns. Underground runs are typically used with underground cisterns.

Horizontal runs should be installed at least three feet away from any building or wall. Assuming sufficient depths and compacted soil between lines, your trenches for these conveyance runs can also be used for other conduits such as drip irrigation tubing and pressurized distribution pipes, as well as low-volt and high-volt electric lines. (Check local building codes to verify required burial depths.)

An important job for every cistern system designer is the proper sizing of the diameter of horizontal run lines.[12] Pipes that are too small will not be able to harvest the entire system's potential and will cause flooding wherever the flow is constricted by an excess volume of water. Pipes that are too large will cost more money than is necessary for both the materials and labor.

Before installing the pipes, it is critical to determine that there are no buried utilities anywhere in the vicinity of your proposed trenches and that the pipes will not be placed in the way of any other future landscape feature. You are required to call New Mexico One Call (also known as the toll-free Buried Cable Locating Assistance Hotline) at 1-800-321-2537 or New Mexico One Call at 811. Information is also available online at www.nmonecall.org to locate existing utilities.

To install an underground horizontal run, complete the following steps:

- Double-check to make sure that there are no utility lines in the vicinity of your trenches.
- Excavate along the lines.
- Lay pipe and fittings with a 1/4" drop per linear foot. Use sanitary tees and other fittings made for drainage. (SDR35 DWV fittings are commonly used in outdoor settings.)
- Connect horizontal run(s) to the vertical-drop point(s).
- Connect horizontal run(s) to the chosen method of prefiltration.
- Connect the final horizontal run to the cistern at the delivery point.

[12] See Appendix 7 (Pipe Sizes and Drainage Capacities). NOTE: Unless you are using an aboveground cistern, you will need underground conveyance piping. Often, four-inch-diameter pipe is sufficient to convey peak flows to the cistern.

- Install cleanouts at every 135-degree or greater bend and at the end of continuous runs.
- Make sure there is a cleanout for every run of more than 100 feet of conveyance pipe.
- Take pictures of the trenches (which include aboveground reference points so you can find the pipes once they are buried). Keep these photos in a file for future reference.
- Backfill and tamp trenches.

Conveyance pipes are typically PVC or ABS plastic pipes. PVC is the most expensive, but it is usually the most durable. ABS, the least expensive horizontal pipe material, is made of a corrugated, flexible plastic material that bends easily around obstacles. This makes the pipe relatively simple to work with. However, ABS is more susceptible to damage than other conveyance materials (it can be punctured with a shovel or a spade), and it has more creases that can collect sediment. Horizontal run piping does not have to be buried below the frost line as pressurized piping does. Conveyance pipes can be placed under the surface of the soil, covered with at least six inches of backfill material. However, conveyance piping along north-facing slopes is prone to freezing, so it is best to bury these runs below the frost line at a minimum of 12 inches deep.

Glue and/or tightly fit all of the pipe connections and install cleanouts for any horizontal runs of more than 100 linear feet. Conveyance pipes that run parallel to the foundation of a structure should be installed at least three feet away from the foundation.

Filtration

The conveyance system presents an easy and effective opportunity to filter the roof water being delivered to your cistern. You will have other chances to filter your water before distributing it to your plants—for example, in your cistern, in your pump house and during distribution through a drip irrigation system—but you should not neglect this first valuable opportunity. Conveyance, or “inlet,” filtration is your best defense against preventing particulate from getting into your tank and against the growth of algae inside your tank, both of which can clog drip irrigation systems and cause pumps to burn out.

Note that the kind of filtration described here does not remove toxins, viruses or bacteria. It is possible to eliminate these and other contaminants during the water-distribution process, but this type of filtration is not necessary for landscape irrigation purposes.

The need for precistern filtration increases as the number and size of mature trees around your roof grows. Branches, leaf matter, bird and animal droppings and other natural debris associated with trees can all pose slightly different problems later on if ignored and not effectively filtered out of the system.

The following conveyance filtration systems are neither “high tech” nor particularly expensive. However, replacing a number of drip irrigation emitters because of improperly filtered water can be a frustrating and costly experience. It is recommended, whenever practical, to install precistern filters and a standard particle filter between your system’s pump and any irrigation valves. When it comes to filtration, a redundant system means a clean system.

Debris Prevention

For roof-reliant landscapers, the first level of defense against allowing particulate into a cistern is a leaf screen. (Leaf screens are also known as gutter guards, debris traps and leaf catchers.) Typically, leaf screens are placed in gutters at the entrance to a downspout, although some types are designed to be placed at the bottom of a downspout. These devices allow roof water into the conveyance system while preventing some of the larger pieces of debris from being conveyed. Although leaf screens are effective and inexpensive methods of filtration, they are typically not considered adequate by themselves. (See Figure 8-9.)

Even though flat roofs tend to collect more debris than pitched roofs, leaf screens are not recommended for canales because as soon as a

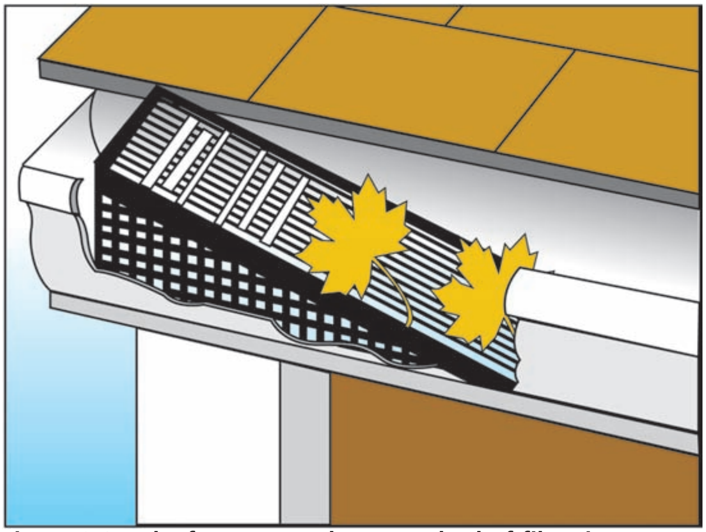


Figure 8-9: A leaf screen used as a method of filtration

small amount of debris collects behind such a screen it begins to prevent roof drainage, which could ultimately cause the roof to leak. Sometimes a layer of gravel is placed in a canale to act as a simple debris filter. Most roof-reliant landscapers working with canales will install funnel drains, which also act as reasonably effective leaf screens.

Small-Particle Removal

There are a number of simple strategies for removing small particles of debris from the roof water entering your cistern. These can be divided into two categories: one type uses some form of filtration, and the other uses a method called the “first flush.” Neither type will prevent all particulate from entering your cistern, but each should yield a significant increase in your water quality.

Filters for Small Particulate

Inlet filter. An inlet filter is any of a number of various types of barrels, containing one or more filters, through which roof water is conveyed to a cistern. Inlet filters can be relatively self-cleaning when positioned at a proper angle and if they are sufficiently sized for the amount of water and particulate that will pass through. Many of these and similar products are available online at a reasonable cost.

Sediment trap. For our purposes, a sediment trap is similar to an inlet filter in that it traps sediment.

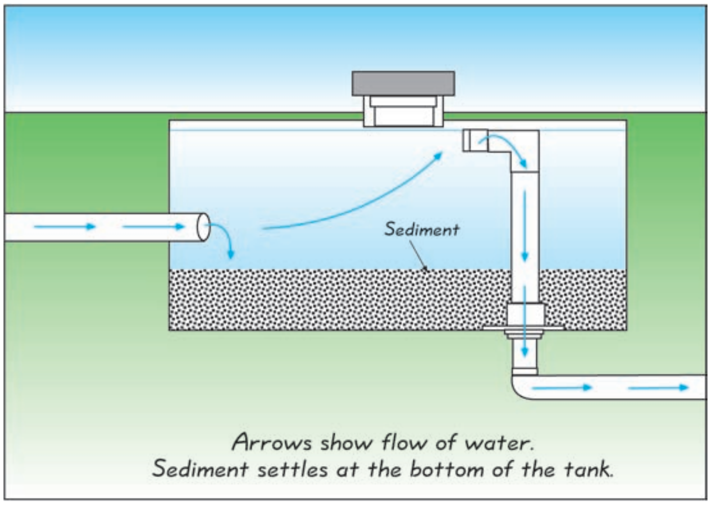


Figure 8-10: Example of a sediment trap. The top photo shows the installation of two traps; the illustration depicts how water flows through a trap.

Unfortunately, much of the water harvesting literature uses terms like sand filters, settling tanks and sediment traps interchangeably. One version of a sediment trap is shown in Figure 8-10.

Settling tank. Like the first-flush devices described in the next section, a settling tank is not actually a filter but serves the same purpose as the particle-filtration devices described above, so they are included in the category of small-particle filtration devices. The basic operation of a settling tank is quite simple: water pours into the tank, debris settles to the bottom and cleaner water flows out the top toward the cistern.

First-Flush Diverters

First-flush diverters are technically not filters, but they perform the same function as any of the devices defined above. First-flush devices cause the initial (dirtier) amount of collected water during a storm event to be directed away from the cistern. Two of the most common types of first-flush diverters are described below.

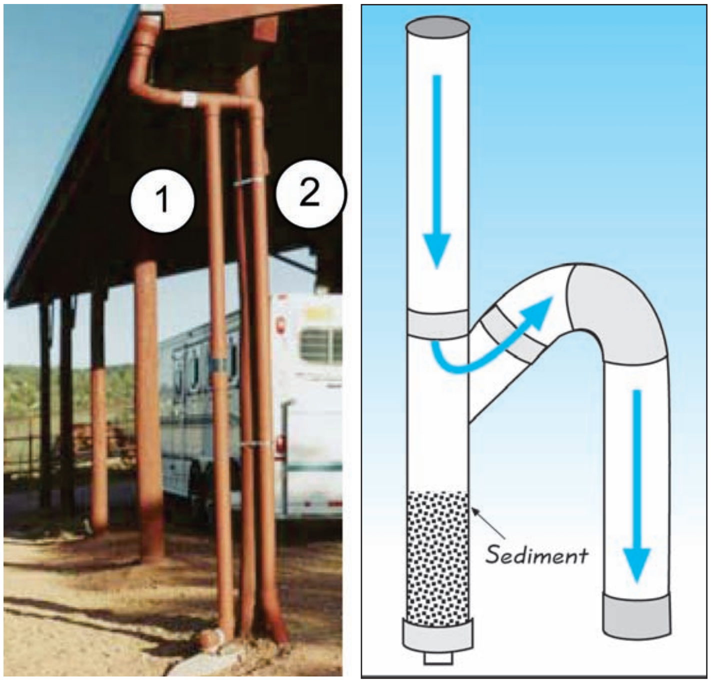


Figure 8-11. Roof water is initially conveyed from the downspout into a pipe (#1) that dead-ends (preferably near a planting bed). After that pipe fills, the cleaner water flows through pipe #2 to a cistern. The cutaway illustration shows how sediment settles in the first pipe.

Dead-end pipe. The most common type is the dead-end pipe. Associated only with downspouts and not canales, these diverters direct the first quantity of water that comes off a roof into a pipe that dead-ends at a removable cap. The remaining roof water, which is always much cleaner than the "first flush," runs straight over the dead-ended water and directly into the cistern via the remainder of the conveyance system.

First flushes serve two purposes: the initial flush of dissolved and suspended solids is diverted and heavier sediments are continuously trapped. After a storm, the cap is removed and the first flush of water and debris drains away from the house (and optimally, into a nearby garden bed). This allows for the debris and particulate matter that was on the roof to be diverted away from the cistern and toward an appropriate place in the landscape. After the dead-end pipe has fully drained, you simply screw the cap back on. If a 1/8-inch hole is drilled in the cap at a "3 o'clock" or "9 o'clock" position, water in the dead-end pipe will slowly drain by itself. Debris in the pipe will still need to be cleaned out periodically.

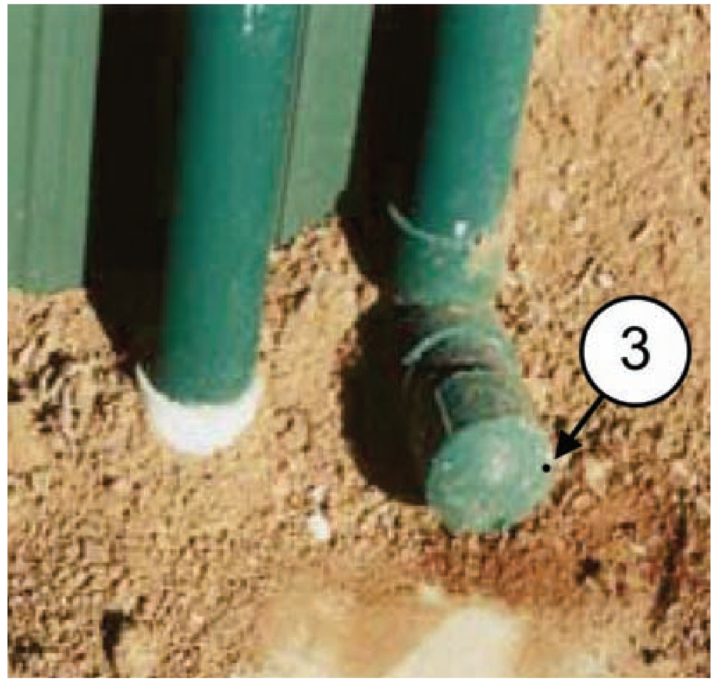


Figure 8-12. The cap on the first-flush pipe has a small hole drilled in the cap. Positioning the hole at the "3 o'clock" position enables water to slowly drain from the pipe while leaving sediment behind. The cap can be unscrewed for cleaning out the sediment.

Pulley pourer. A less common form of diverter, the pulley pourer uses a bucket, a pulley and a counterweight to pour first-flush water into neighboring garden beds. An empty bucket is set under a gutter or downspout with a counterweight equal to the weight of about two-thirds of a full bucket of water. When water pours off the canale, it fills the bucket to the point at which it dumps the first flush into a thirsty garden bed (or some other appropriate place). The system is manually set up between storms so that the counterweight keeps the bucket in a ready position.

Delivery

The last step in the water conveyance process is delivery to your cistern at a supply point (also known as the delivery point), where conveyed water reaches a cistern. Most conveyance systems require only one supply point, but multiple supply points are sometimes cost effective. Instead of cutting additional holes in a cistern for more than one supply point, it is recommended to join the conveyance lines together near the cistern so that a single delivery point can be used.

Landscape design can both influence and be influenced by cistern system design. If you are planning a pitched-roof house with gutters and downspouts, your landscape design should call for some plants that will make good use of your first flush in the immediate vicinity of all of your dead-end pipes. Similarly, if you are planning sediment traps off a flat roof, an effective landscape design might include a convenient place to clean the filter, mesh, sand or gravel.

Figure 8-13: An assortment of water cisterns, clockwise from top left: a metal tank, two 54-gallon rainbarrels stacked on each other, two partially buried tanks, and an assortment of colorfully painted tanks.

Chapter 9: Water Storage

The core of a cistern system is a water-storage tank with a water delivery point, a properly sized overflow pipe, an accessible serviceway (remaining locked when not in use), a working vent, an operational water-pump line, pump and tank walls. Optional items include electric lines, a float switch, in-tank filters, a level reader line, an auxiliary water line, and a ladder, rope or cable (for accessing some of the components).
The **delivery point** (labeled point A in Figure 9-1) is the place where roof water enters the tank. It is located near the top of the tank.

The **serviceway** (B), also known as the "access way" or "manhole" is needed for cistern maintenance, including servicing the pump, float switch(es), level reader, vent pipe, water lines and electrical lines. The above-grade serviceway opening should remain locked when not in use for safety reasons.

The **vent pipe** (C) of the depicted cistern begins to the right of the serviceway. This vent is necessary both for effective pumping and for the effective intake of a high volume of water during extreme events. (Vent pipes should be covered with a fine-mesh screen to prevent mosquitoes and small animals from entering the system.)

The **pump line** (D) directs harvested water to the plant material via the distribution system using a **pump** (E). In the case of a separate inline pump and pump house, the pump line would still direct the flow of water to the pump to be distributed. The

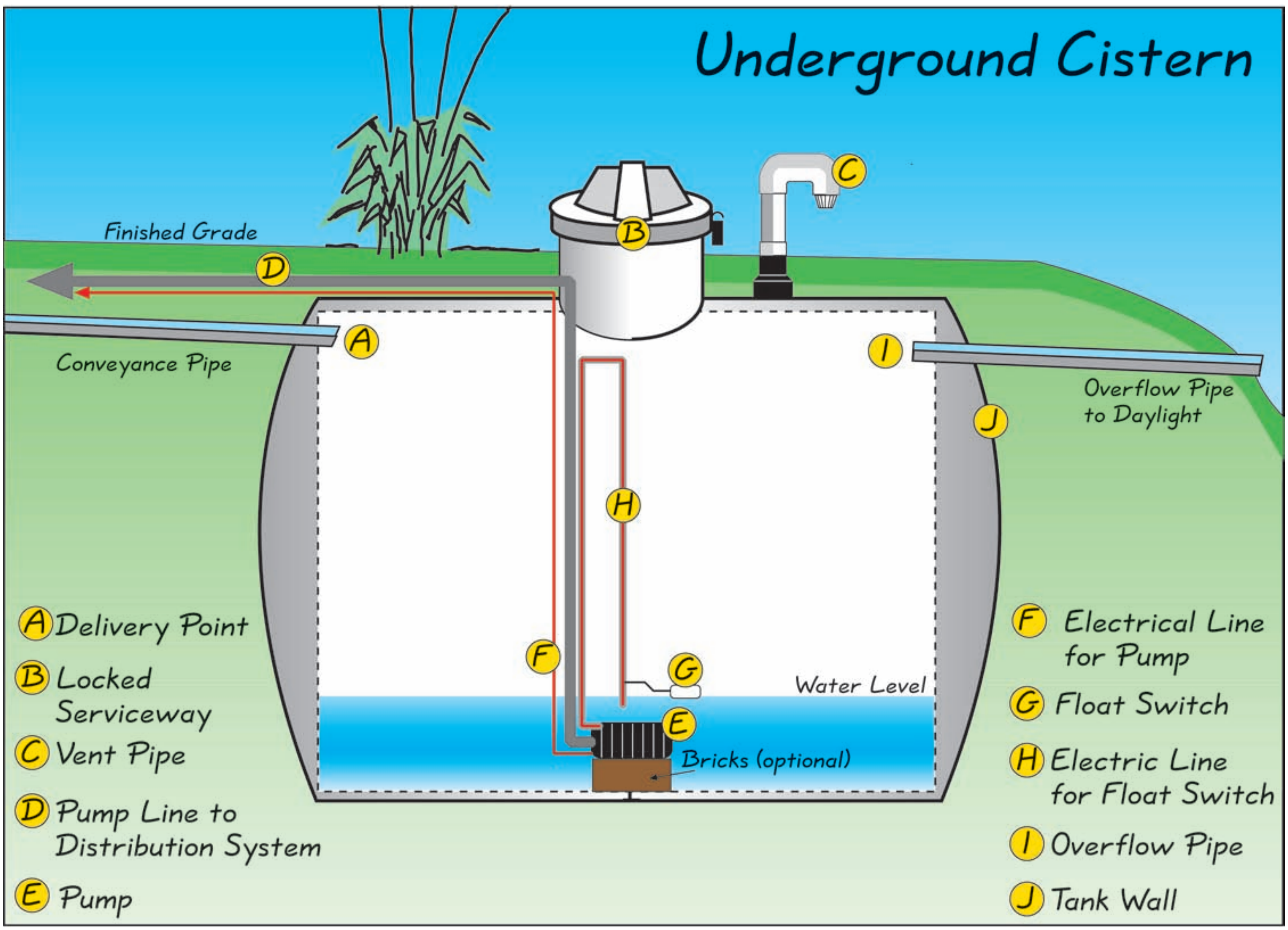


Figure 9-1: This cutaway illustration shows the components of an underground cistern system.

one difference is that the line would typically have a foot valve at the bottom of the line in the tank so that the pump outside the tank will remain primed (full of water) during the watering season. In many cases, this foot valve is removed during the colder months to prevent freeze damage.

An electric line (F) is required for a sump pump. The electric line is shown entering the tank near the top left side of the serviceway in Figure 9-1. Use professional electricians licensed with the state of New Mexico for this and all electrical work other than 24-volt (and lower) electrical lines.

Float switches (G) like the one under the serviceway in Figure 9-1, are balloon-like devices that float on the surface of the water in the tank in order to tell a pump to turn on or off. Typically, when the water level in a cistern reaches a certain (low) depth, the float switch drops into the "OFF" position, which turns off the pump. (These are also commonly called "pump down switches.") A float switch can prevent a pump from burning out when the cistern is empty. Also available are submersible pumps with thermal protection shutoffs, so a float switch is not always needed.

The **overflow pipe** (I) must be large enough to carry runoff in a "100-year storm," and it must not be the cause of any soil erosion. Erosion-control treatments such as French drains, swales, riprap and wire gabions are often necessary at such points. It is also important to prevent insects and small animals from getting into the overflow pipe. A swing-check valve (that opens only when water is flowing through it) provides this protection.

The **tank walls** (J) come in a variety of shapes and sizes. Tank walls may be constructed out of a variety of materials, many of which are described later in this chapter. Underground tank walls must resist both the inward pressure from the soil and the outward pressure from the stored water. Aboveground tank walls should be dark colored, opaque and UV resistant in order to prevent algae growth that is associated with sunlight exposure.

A level reader (not shown) can be as primitive as a stick with units of measurement etched on the side. The stick is lowered carefully to the tank bottom to determine the height of the water. If you are familiar with the dimensions of your tank, knowing the depth of the water should be enough to give you a ballpark figure of how much water is in storage. Inexpensive level readers, which provide a digital readout of the percentage of water in your cistern, are also available.

If a cistern is empty, manually adding auxiliary water with a hose or via a manual valve may be the only way to use the installed water-delivery system to irrigate the landscape. An auxiliary water source can be used when the cistern system is not associated with a strict water budget and when the goal is something less than total roof reliance. However, because the focus of this manual is roof-reliant landscaping, the use of an auxiliary water source is not emphasized in this manual nor is it endorsed by the New Mexico Office of the State Engineer. A better option is to provide a secondary water source that can hook directly into your distribution system. This leaves the cistern available for the next precipitation event.

Elevation Options

You will need to determine in the early stages of your water harvesting system's design whether your cistern will be aboveground, partially buried or underground. Here, are some of the advantages and disadvantages of each of these water-storage options.

Figur 9-2: An underground cistern being installed.

Aboveground Cisterns

Figure 9-3: Aboveground cisterns can be painted to help them blend into the nearby buildings and surroundings.

An aboveground cistern is a water-storage tank situated on grade or on a concrete or gravel pad on or just above grade with no significant berming or excavation associated with the installation of the tank.

Advantages. For the majority of people, the most important benefit of an aboveground cistern is cost. The design, materials and installation costs of aboveground tanks are significantly lower than those of partially buried and underground alternatives. The most significant cost savings is due to the fact that relatively little work is needed to put aboveground cisterns in place. The relative ease of installation associated with aboveground water-storage tanks is an important consideration, especially for the do-it-yourselfer. Aboveground cisterns range from very simple rain barrels to more complex gravity-fed systems. The simplest systems require only basic common sense, some "handyman" skills, a thorough reading of this and other similar texts[13] and a permit (when required).[14]

[13] See Appendix 8 for additional reference sources.
[14] Always check with the Construction Industry Division (505-476-4700, www.rld.state.nm.us) and local governing bodies for details concerning specific requirements.

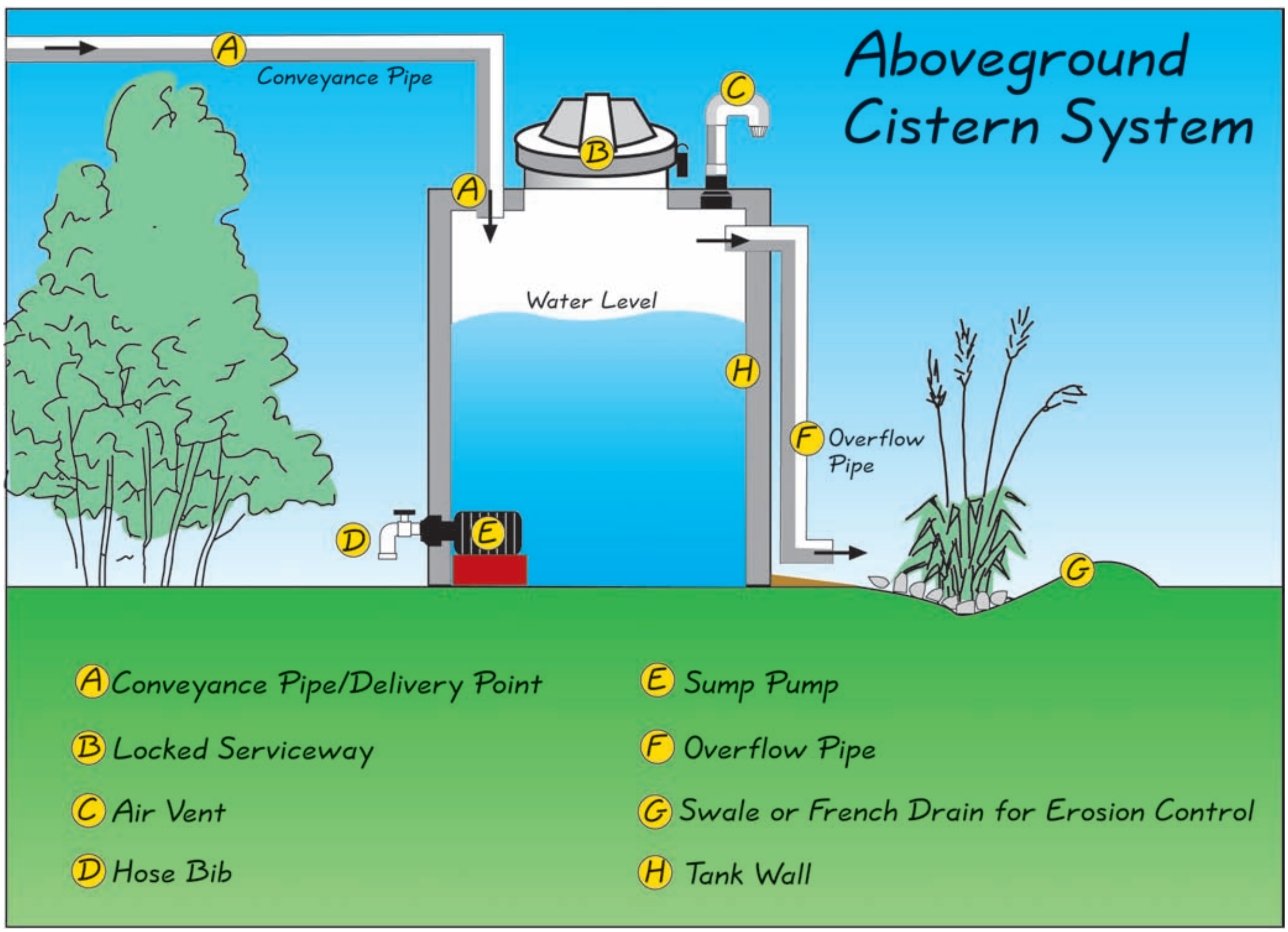


Figure 9-4: A "cutaway" drawing of an aboveground cistern system

Another reason to choose an aboveground cistern is if you plan to water your roof-reliant landscape using gravity. Given the right terrain and landscape design, a properly elevated cistern and a hands-on owner can eliminate the use of a pump for both hose watering and drip irrigation. (For more information on this subject, see Chapter 10, Distribution.)

An aboveground cistern can provide wind protection, privacy, shade and even serve as an inspirational conversation piece. In addition, aboveground cistern systems can be easier to maintain than underground systems. Leaks are more easily spotted when they occur aboveground, and they can be repaired without any of the excavation often necessary when leaks occur underground.

Disadvantages. Many people fail to see the inherent "beauty" of a big, opaque, industrial-looking aboveground cistern, so the potential costs of visual screening should not be overlooked. Screening a cistern can be accomplished least expensively by planting young trees, shrubs or trellised vines in front of your tank. Although they are more expensive, large trees, fencing, stucco walls and fine masonry make great screening options. Painting a mural on the tank is one way to increase the aesthetic appeal of an aboveground cistern. (See Figure 9-5.)

Figure 9-5: Aboveground cisterns can be painted to give them a distinctive look.

If you are successful at creating a roof-reliant landscape and your tank is well-hidden or attractively presented, it is quite possible that your property will increase in value. Certainly, homebuyers who appreciate beauty, comfort, convenience and water consciousness will consider a concealed above- ground cistern to be an important property asset.

Another important disadvantage of aboveground systems is that cisterns, pipes and pipe connections can freeze during the winter. This is a concern throughout the state of New Mexico. Be sure you know the frost depth for your area, and be sure to drain and/or insulate pipes so that no leaks occur.

If you must situate an aboveground cistern on the north side of a building in the northern part of the state where freezing temperatures are most likely to occur, you may wish to drain your tank before the first hard frost of winter. If you can place your aboveground cistern on the south side of your structure or if you live in southern New Mexico at a relatively low elevation, you may be able to store winter moisture with minimal fear of discovering freeze-related leaks when temperatures warm up. One way to insulate an aboveground cistern is to berm it into the ground at a depth such that the outlet pipe from the side or bottom is below the frost line. (See next section, Partially Buried Cisterns.)

Because plants often need supplemental moisture in the spring and early summer, storing water throughout the winter is extremely important for the roof-reliant landscaper. The disadvantages associated with ineffectively insulated aboveground cisterns and their fittings should be seriously weighed against the cost advantages that such cisterns provide. An inexpensive system that has to either be quickly drained in the middle of a cold winter night or repaired every spring is usually not worth the potential cost savings in the long term when compared to the price of a frost-free underground or partially buried cistern.

Aboveground cisterns also have the greatest tendency to harbor algae due to the intense New Mexico sunlight to which they are exposed. Be sure that the cistern you are using is opaque and UV resistant. Typically, darker colors are preferable to light colors in this regard.

Another disadvantage is the water in an aboveground cistern, especially a dark-colored cistern, can often get too hot to use on plants during certain times of day in the summer. Of course, watering should not be done during the hottest parts of the day to prevent evaporative loss (and because it is not allowed in many communities in New Mexico). Keep in mind, however, that the water in your cistern may remain too warm for landscape use well into the evening and sometimes into the nighttime hours, which leaves the morning as the best time to water from an aboveground cistern in the hot summer months.

Partially Buried Cisterns

Figure 9-6: Two partially buried cisterns

A partially buried cistern is a water-storage tank situated such that the bottom portion of the cistern and its pressurized pipe are protected by the soil from freezing. The remainder of the tank is exposed to the elements (particularly sunlight).

Advantages. In certain situations, partially buried cisterns offer an excellent alternative for people on a limited budget. Compared to an underground cistern system, installation cost savings for partially buried cisterns are significant and the aesthetic issues associated with aboveground cistern systems are easier to solve. Partially burying a cistern also solves the potential problems of water freeze damage, and partially buried cisterns also have the potential for eliminating the need for a water pump.

If your storage tank is small enough, it may be possible to excavate the hole for a partially buried cistern with picks and shovels as opposed to using a backhoe. If you dig the hole by hand, the cost savings could be considerable, but be aware that this is very strenuous work. Renting a backhoe can be cost-effective, but manual excavation makes the most sense in situations where backhoe access is difficult. In the case of new construction, consider excavating your hole when a backhoe is already on site—another cost-benefit of landscape planning.

Manufacturers are not inclined to endorse partially burying a cistern that is intended for underground use. That is because underground tanks are typically not UV protected, which means they will not last long in the bright New Mexico sun. Also, the walls of underground tanks use the earth around them to support the massive weight of water in a full cistern, so the walls of underground tanks are often much thinner than their aboveground counterparts and often cannot be used without the support of properly compacted earth around them.

Typically, the most important reason to partially bury a cistern is to keep your pipes from freezing. Before renting a backhoe, determine your local frost depth. (Contact your local County Cooperative Extension Office, http://cahe.nmsu.edu/county/). Then, if you plan to partially bury an aboveground cistern, make sure your tank can withstand the inward pressure on the tank's walls at the selected depth when your cistern tank is empty.

Disadvantages. The main disadvantage of a partially buried cistern is that after all of your hard work digging, the tank looks like a smaller version of an aboveground cistern. Yes, money has been saved and the pipes are less likely to freeze, but many people will still want to invest in a fence or dense plants to hide the exposed portion of the tank.

In many situations, a partially buried cistern is a perfect mix of cost savings and frost prevention. However, just as partially buried systems come with many of the advantages of aboveground and underground cisterns, they also come with many of the same disadvantages. Therefore, if you are already thinking of excavating with a backhoe for a partially buried cistern, you may wish to choose an underground cistern instead.

Underground Cisterns

Figure 9-7: Once this underground cistern is installed and the hole is backfilled with dirt, only the serviceway will be visible.

An underground cistern is a water-storage tank that is situated below grade. Here is a description of the advantages and disadvantages associated with underground cistern systems:

Advantages. The advantages of storing water underground are frost protection, invisibility, landscape versatility, less chance of algae growth in the tank and cooler water temperatures.

A cistern buried at the proper depth is extremely unlikely to result in problems associated with frozen water. Underground leaks can still occur, but these would more likely be associated with the water-pumping system.

An underground cistern is literally out of sight. Not only will your views be unencumbered by the tank, your quality of life may be improved by the absence of a large, industrial-looking vessel in your yard. This could also translate into a greater return on your investment when it comes time to sell your property.

Buried cisterns do not get in the way of many other potential uses of your property such as planting (plants and shrubs, though not trees), entertaining, etc. Just remember to avoid putting a permanent structure (such as a storage shed or a concrete patio) on top of an underground cistern—blocking future access if it ever needs repair or replacement. Many underground cistern materials can withstand vehicular traffic, but others cannot, so make sure your cistern suits your landscape goals.

Since no appreciable light enters an underground cistern, it is unlikely that the harvested water will breed many forms of algae. This is an important advantage because one of the disadvantages of underground cisterns is that they can be difficult to clean.

Since the cistern is not exposed to sunlight and the water is well insulated by the earth, the water temperature in an underground tank will never be too hot for irrigation purposes. This means you could water from your underground cistern at any time of day (remembering, of course, that midday watering is not recommended and is often not allowed).[15]

Disadvantages. The disadvantages of storing water underground are higher costs, more difficult access, increased safety concerns and the necessity for a pump.

For most people, the biggest disadvantage is the cost of installation. As a general rule, an underground system costs about twice as much as a comparable aboveground system. This often prices people out of the underground-cistern market right from the start.

Excavation and backfill, required for the installation of both the cistern and its underground conduits, are the main reasons for the higher cost of an underground system. There are extra costs incurred by machinery and its skilled operator(s),

[15] Check with your local municipality or water service provider for any ordinances, administrative policies or water conservation restrictions.

designing and permitting a large excavation project and all of the properly executed backfilling and/or tamping that underground cisterns require. Another cost of burying a cistern that often surprises people is that of removing the large quantity of excavated earth that is left over at the end of the project.

Underground cistern systems often require longer runs of pipe, conduit and electrical wire, which adds to the expense side of the ledger. In order to get the necessary fall from conveyance piping (of 1/4 inch per linear foot) and in order to give the backhoe operator plenty of room in which to work, underground cisterns are usually situated farther from the house, and this means more pipe, conduit, electrical wire, etc.

If and when problems occur, having most of your system buried can also become an issue. Repairing the tank wall of an underground cistern is typically much more difficult than repairing that of an aboveground cistern. Although rarely necessary when prefiltration is adequately installed and maintained, cleaning an underground tank becomes a challenging job.

Underground cisterns, even when empty, can be dangerous, and the process of installation includes inherent risks. OSHA regulations (www.osha.gov) must be followed at all times during the installation process, and access to cisterns must always be locked (whenever the tank is not being accessed or maintained). Your highest priority should be the prevention of any accident and injury associated with your cistern system.

Underground cisterns are not conducive to water distribution via gravity; they almost always require a pumping system to get the water out of the lower depths of the tank. Also, since underground cisterns need access and venting, both of which will protrude from the ground, some screening is typically required.

Cistern Placement

To help determine the best location for your cistern, a set of seven guidelines for cistern placement are presented below. These guidelines are intended to help save time and money, as well as to make your whole system as efficient and productive as possible.

While many cistern tanks are added to residential properties after construction of the house has been completed, in new construction cistern design and placement issues should be considered at the beginning of the design process rather than as an afterthought. Designing the cistern system as an integral part of the site can add additional options for cistern locations including within buildings and on a structure's foundation.

1. Understand the Size and Shape of Your Tank

In Chapter 3, Sizing Your Cistern, we explained how to calculate the amount of water that can be harvested off your roof in a "normal" year. You were then instructed to multiply that number by one-third to get an approximate number of gallons you might consider storing in your cistern. Knowing the capacity of your cistern enables you to calculate the overall dimensions of your tank. Start by asking your tank supplier what size tanks are available in the number of gallons you require. Depending on the type of cistern material, this can often eliminate the need for you to calculate the dimensions of your tank on your own.

The dimensions of your tank are important for a number of reasons. First, you need to know how to get the tank to its desired location on your property. Some tanks need to be craned over trees and buildings, while others can slide right off of a truck and be rolled by one person to their proper place.

Second, there needs to be enough physical space available to excavate the hole and trenches. A backhoe, a big hole, piles of earth, the tank, tools and vehicles take up a tremendous amount of space. It is important to place your cistern so that it can be installed with ease instead of creating any extra cost and the potential for accidents and injury, which is another advantage to new construction and thoughtful landscape planning.

Third, being aware of the dimensions of your tank is useful if there is a chance you might hit bedrock or other materials that are difficult to excavate. Although there are tools for removing bedrock, this type of work can get loud, expensive and dangerous.

You will also want to know approximately how much your tank will weigh. The empty weight is important because moving such a large, heavy vessel from the street to your backyard requires planning for an appropriate crew and/or the proper equipment. Aboveground cistern system designers should also be aware of the empty weight of any tank that is being placed in a wind corridor, so that effective measures can be taken to prevent the tank from being blown out of place by New Mexico’s gusty winds.

2. Use Gravity

Let gravity fill your cistern whenever practical. Whether your conveyance system involves gutters and downspouts with little or no horizontal run piping or whether it uses funnel drains and long horizontal runs, your supply point should aim for the top of your cistern in such a manner that all conveyance piping will drain completely.

Avoid pump tanks whenever possible. These are separate, smaller cisterns used temporarily to quickly and consistently pump roof water to the system's main cistern. The additional pump, tank and float switch associated with this kind of system complicates the project significantly and can increase the long- and short-term costs of a project unnecessarily (additional pump = additional electricity and more maintenance).

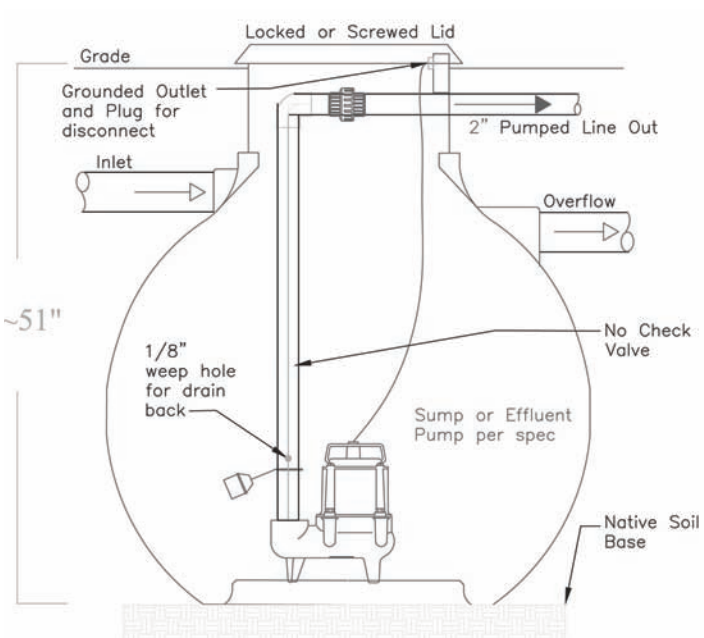


Figure 9-8: A pump tank can be used to pump water into a system’s main water storage tank.

Be careful not to install underground cisterns any deeper than necessary. This mistake can appreciably increase the excavation and dirt-removal costs of the project. In addition, the labor and material costs associated with conveyance piping, sediment traps, overflow piping, vent piping and distribution piping will rise. Also, some tank materials may not be able to withstand the extra weight of the earth that will be backfilled onto a tank that has been installed too deeply.

Ideally, the proper placement of your cistern with respect to gravity could provide enough water pressure for your drip irrigation system. Most people, however, have neither the necessary terrain nor the requisite patience to use gravity in this way.

3. Keep Conduit Lengths to a Minimum

Another very important factor in cistern placement is its proximity to your roof, the distribution system and the electrical utility. Unnecessarily long runs of these and any other type of conduit will add to the price of your project. Long runs require wire sizing and voltage drop calculations. Not only does this make the project more expensive to install, it can also create work later if the runs of pipe and wire are accidentally cut during future work in your garden.

Your cistern and its associated parts should be located in a place where they are easy to observe, maintain and fix. If possible, place your level reader, pump, irrigation clock and any other feature requiring conduit in one convenient place.

4. Situate Overflow Pipe in an Appropriate Place

The location of your cistern’s overflow pipe is critical when considering the placement of your cistern. In a properly designed system, excess water flows through an overflow pipe to a point called “daylight,” which is where any underground drainage pipe emerges to the open air.

Of course, the best use of "overflow" water is to irrigate plants, such as trees that can benefit from occasional deep waterings. To handle a large volume of overflow water, simple but essential erosion-control measures should be installed at your daylight point. Often a hole filled with gravel and a swale that pours gently into a mulched bed planted with a few shrubs or a tree works well. When flows are high and/or your slope is steep, riprap and/or wire-wrapped gabions might be required to prevent soil erosion at the daylight point.

Note that on flat properties your run to daylight will be longer than the overflow run on the typical steep site. However, the erosion-control work needed at the daylight point of a flat site is usually less extensive than the work that is often required on steep sites. Civil engineers, drainage contractors and/or appropriate government regulators will need to be consulted in high-volume, steep-slope situations.

5. Locate Your Vent and Serviceway Appropriately

Part of determining the location of an underground cistern is making sure that the vent and serviceway access can be inexpensively hidden from view. Sometimes this is reason enough to move a cistern from one side of a house to another. If everything else is equal except that the vent and serviceway to your cistern would be seen through a living room window, why not (during the design phase of your project) move the cistern to a less-prominent place?

For cases in which moving your serviceway and vents to a less visible place is impossible, here are a few tips for hiding these necessary parts of your cistern system. Since vent pipes have a theoretically unlimited horizontal run, they can usually be hidden at a relatively low cost around the corner of a building or behind some plant material. This work shouldn't be too expensive, but your cost estimate should include all five steps in the process: digging a shallow trench, laying vent pipe, fitting the pipe, backfilling over the trench and tamping the backfill until properly compacted.

For ease of access and to prevent debris and other forms of runoff from falling into cisterns, serviceways should protrude out of the ground. Some of the best ways to camouflage a serviceway are to install earthen berms, plants, decorative boulders, mulch and fencing. Remember to keep your serviceway locked when not in use to prevent injuries.

6. Synergize Your Cistern with Your Landscape

Consider the placement of your cistern in relationship to your landscape plan. The consequences of a poorly placed cistern can be serious, so make sure your cistern works not only with its collection, conveyance and distribution components but also with every component and feature of your roof-reliant landscape project.

Will your cistern and its associated components (such as its horizontal runs and its main distribution pipe) work with your landscape design? If at all possible, avoid placing your cistern in a place that prevents you from having some other important landscape feature. Try to place your tank in such a way that it improves your quality of life and increases your property's value.

Where might the placement of your cistern help reduce the total cost of your landscape? Do particular placement options put constraints on the size of your tank and therefore shrink your water budget? Will the placement of your tank affect your installation schedule? The answers to these questions will help you finalize the decision about your cistern's place in the landscape.

7. Get a Second Opinion

Once you have determined the best site for your cistern, it makes sense to get a second opinion. Ideally this opinion would come from a professional in the field, but second and third opinions can also come from acquaintances, friends and family. Given that inappropriate placement of your cistern could be the most costly mistake that you might make in this process, determining the most appropriate place for the heart of your roof-reliant landscape is critical.

Cistern Materials

Water-storage vessels come in a wide variety of materials, ranging from high-density polyethylene, epoxy-coated steel and fiberglass on the high-tech side to wood, rock and concrete on the low-tech side. Each type of material has its advantages as well as disadvantages. The following alphabetical list does not endorse any one material or system over any other.[16]

Concrete

Even taking into account the rising price of concrete in recent years, reinforced concrete tanks can be an economical choice. Such tanks can be custom-built on-site, or they can be prefabricated off-site. One important advantage of concrete tanks is that they are usually strong enough to support vehicular traffic.

To prevent water from leaching slowly out of the tank, the inside of a concrete tank is often coated with tar. However, tar can leach into your water supply and then subsequently end up in your soil. Your plants will survive, but over time, your soil might suffer from the increased quantity of low level toxins associated with tar.

Concrete can be used in aboveground, partially buried and underground systems. Plastic liners may also be used inside concrete tanks, which solves the problem of tar leaching and helps to prevent potential leaks.

Ferrocement

Ferrocement, often called ferroconcrete, is a form of concrete tank that uses significant amounts of rebar and chicken wire in the form of a skeleton, upon which a specific mixture of sand, cement and water is spread. Since ferrocement is thinner than concrete, it has the potential to be the least expensive of all cisterns. It also has a greater tendency to leak compared to other materials. Such tanks can easily increase the cost of your project if improperly installed or if leaks are not quickly and effectively addressed.

These tanks can be made into almost any shape. They can be used in any of the three relationships to grade (aboveground, partially buried or underground). They are used throughout the developing world with great success, but an on-site ferrocement-tank building project requires serious construction and management skills as well as some significant research.[17]

Fiberglass

Figure 9-9: A fiberglass tank being installed.

Underground fiberglass cisterns are commercially available and start becoming cost-effective in the 5,000- to 10,000-gallon range. You may have to crane an underground fiberglass tank into your hole due to its size (even though it is relatively lightweight), but this is also often true of other cistern materials including concrete and metal. Fiberglass is an extremely durable and long-lasting material that can be patched with relative ease.

Some underground fiberglass tanks can withstand vehicular traffic, which means that placement of the tank underneath a driveway becomes an option. Aboveground fiberglass tanks are available in smaller sizes, but they must be shaded and/or be UV resistant. Fiberglass fittings are integral parts of the tanks themselves, so they are less prone to leaks at pipe connections than are other materials.

16 Please note that nothing herein should be construed as an endorsement of any product, person or corporation. Any and all references to products, persons, and corporations herein are intended merely to provide a brief and general sketch of the ever-expanding field of cistern technology. Since new advances in cistern technology are being made constantly, the Office of the State Engineer strongly encourages you to do your own due diligence when it comes to choosing the cistern material that is best suited for your particular situation.

17 See *Water Storage* by Art Ludwig, p. 41.

Even though cisterns in roof-reliant landscaping are intended to provide water for landscape irrigation only, to be on the safe side you should consider having your tank coated with a USDA-approved food-grade coating. The extra cost is relatively low and the safety benefit is considerable since uncoated fiberglass can be dangerous if ingested. Your plants probably will not mind the leaching from your tank, but in case anyone accidentally puts his/her mouth to your hose to drink, you will not have the ingestion of fiberglass particles to worry about.

Metal

Figure 9-10: Steel tanks are a cost effective option at 5,000 gallons and larger.

Most metals are not used for storing water due to their cost, but there are two types of metal tanks that can be cost-effective. Galvanized steel, which is often corrugated, is one option. Another option is a non-galvanized underground steel tank, which can be a good choice for large-tank and heavy-vehicular-traffic installations.

As aboveground options go, galvanized steel is a good choice from an aesthetic perspective, as Figure 9-10 shows. These tanks come in a variety of sizes, but they are not the most durable of cistern materials.

Due to the high expense, underground steel is not an option for small scale projects. Steel tanks begin to become cost effective in the 5,000- to 10,000-gallon range. Steel tanks need to be coated on the outside with coal tar epoxy or another coating or they will rapidly corrode in New Mexico’s alkaline soils.

Plastic

Figure 9-11: A plastic tank can be very cost effective.

Plastic has become an increasingly common cistern material, in part because it can be very cost effective. It can be used in aboveground, partially buried and underground applications. Plastic tanks do not require any type of internal coating. However, plastic tanks that are aboveground (either fully or partially) and will be exposed to strong sunlight will need an exterior UV-resistant coating. Plastic tanks should be as opaque as possible in order to prevent algae growth. For aboveground applications, plastic tanks are typically molded into one-piece cylinders that stand on flat bottoms.

A lightweight and relatively inexpensive material, plastic can be prefabricated in a variety of shapes and sizes. Individual plastic tanks, however, are not available in large sizes, but they can be connected together to attain a large storage capacity for the entire system. (See Figure 9-12.)

Underground plastic tanks are available in a variety of sizes up to about 2,000 gallons. For structural reasons, many of these plastic tanks require that a percentage of the cistern remains full at all times. Some plastic tanks can be completely emptied, such as the tank shown in Figure 9-13, which has thick tank walls, a round bottom and deeply corrugated sides.

Modular tank systems represent a new development in cistern technology. Modular systems consist of strong but essentially empty plastic blocks that are stacked on top of each other. These blocks effectively create a skeleton, completely enclosed in a plastic liner, which can withstand vehicular traffic.

Figure 9-12: Tanks can be connected together to create larger storage capacity. These tanks will be connected in parallel, so that an individual tank can be shut off for maintenance or repair without disabling the entire system.

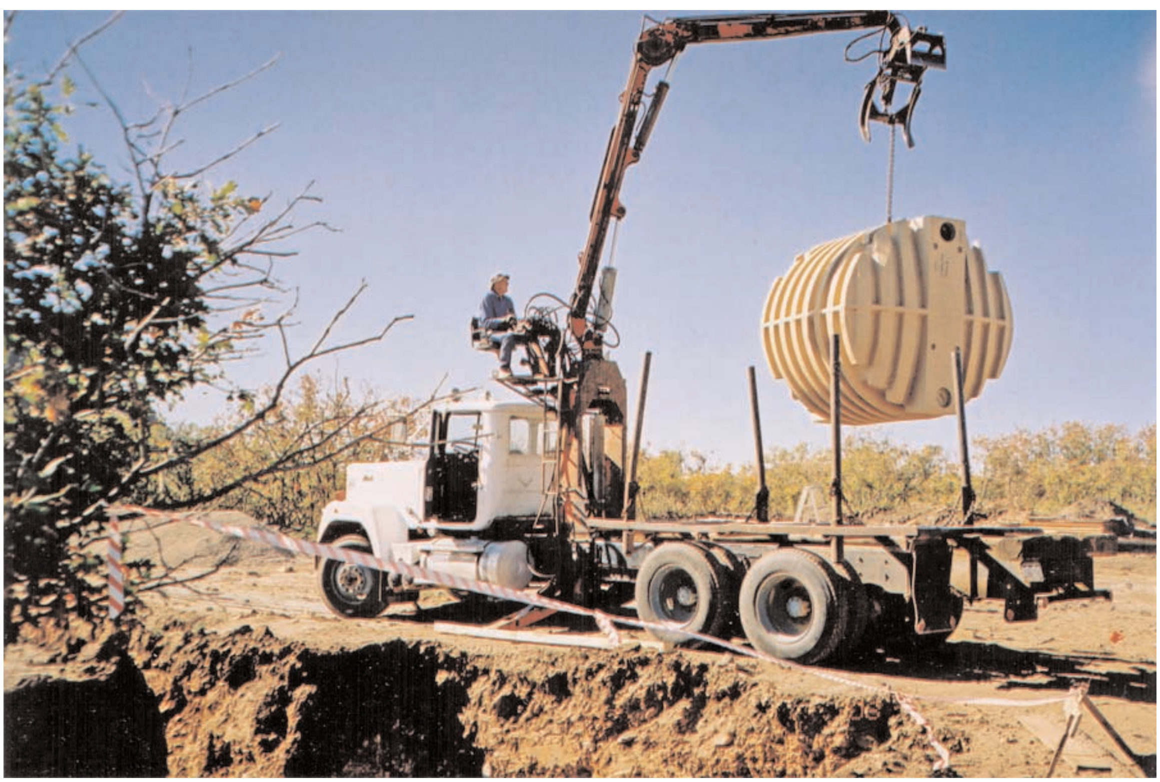


Figure 9-13: Large tanks must be delivered onsite via truck and lowered into place with a crane. The thick walls of this tank enable it to sit completely empty in the ground.

Chapter 10: Water Distribution

Particular attention must be paid to the distribution component of every cistern system because this final part of the process of rooftop rainwater harvesting is typically responsible for more water waste than the other three components (collection, conveyance and storage) combined. For example, when a pressurized pipe cracks 24" below grade, it will often go unnoticed until large quantities of water have already been wasted. Likewise, when a pump or automatic irrigation system gets stuck in the "ON" position, it doesn't take long for a full cistern to become empty. And if you get distracted and forget to turn off a hose running in your garden, your entire cistern could be drained in a short period of time.

The distribution of harvested water can be divided into two basic processes: the pumping of and delivery of water. Most conventional cistern systems require a pump to provide hydraulic lift and either a garden hose or a drip irrigation system to deliver water to the root zones of plants. Distribution systems can be manually operated, or they can be easily automated for an additional cost.

This chapter provides an overview of the components and functions of typical rainwater harvesting distribution systems.

Conventional Distribution Systems

In conventional distribution systems, water is lifted from the cistern by one of two types of electric pumps—a sump pump or an inline pump. After it is lifted out of the cistern, water is then typically delivered to the root zones of the plant material via two different irrigation techniques—hose watering and/or drip irrigation.

Sump Pumps

Sump pump systems are the least expensive kind of electric pumping systems available. Sump pumps must be submerged in water in order to work. A simple sump pump can be purchased for under $100 and be easily connected to a garden hose.

Note that the pump is kept slightly off of the bottom of the tank to prevent the intake of sediment and, therefore to reduce the frequency of having to clean, repair or replace the pump. The greatest expense associated with these types of systems is usually the hiring of a licensed electrician to connect the pump to the electricity in your home and to provide a safe and convenient ON/OFF switch. Another expense is the installation of a frost-free hydrant (also known as a hose bib), which does not require a licensed plumber or irrigator as long as the cistern is not connected to other water systems such as a private well or a local utility company.

All systems should provide relatively easy access to the cistern's serviceway so that your pump can be easily monitored, maintained, repaired and/or replaced. Inside the cistern, the sump pump should be attached to a cable, wire, rope or chain that can be used to remove the pump for such purposes.

Figure 10-1: A sump pump must be submerged in water in order to work.

Figure 10-2. Sample inline pumphouse with spin filter manifold

Inline Pumps

At minimum, inline pump systems require an inline pump and a pump house. The pump house protects the pump from the elements as well as from vandals and/or thieves. Pump houses are typically located underground (Figure 10-2), but they can also be constructed aboveground in a separate structure.

Like sump pumps, inline pumps can distribute water to plants by connecting directly into a garden hose. As with sump pump systems, in order to effectively run drip irrigation with an inline pump system a separate pressure tank is typically needed. However, one of the simplest inline pump systems features a small pressure tank built into the pump, which can be used for some drip irrigation applications.

Many inline pumps have a drain for winterization in the fall and a priming hole for start-up in the spring. The depth and slope of your pressurized lines will dictate whether you will need to drain or prime your pump.

One of the main advantages of having an inline pump is that the pump is easily accessible if it malfunctions. However, a leaky inline pump can flood an entire pump house quickly if an overflow pipe to daylight is not provided in the pumphouse.

Two Irrigation Methods

Typically, sump pumps supply the pressurized water necessary for hose watering, while inline pumps provide the water pressure needed for drip irrigation (and/or time-efficient hose watering).

Drip Irrigation

Drip irrigation (commonly known as “drip”) directs water right to where plants need it—at their root zones. Using a network of poly-propylene tubing, drip irrigation releases a slow trickle of water through properly placed emitters. As long as this type of irrigation system is properly installed, closely monitored and efficiently maintained, drip is a highly efficient water-delivery method. Drip emitters are often located under mulch, so, with a drip system, very little water is lost due to evaporation. *In most cases, drip irrigation is the preferred form of landscape irrigation in New Mexico.*

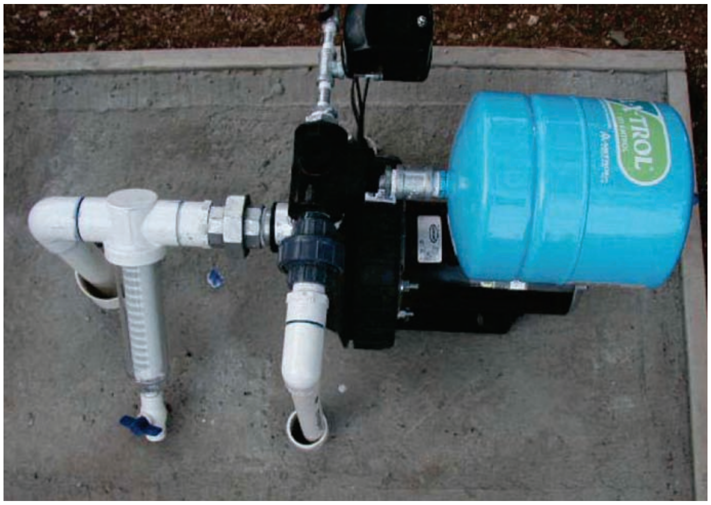


Figure 10-3: Inline pump and system controls with pressure tank

Figure 10-4: Drip emitters deliver water to plant root zones with very little waste.

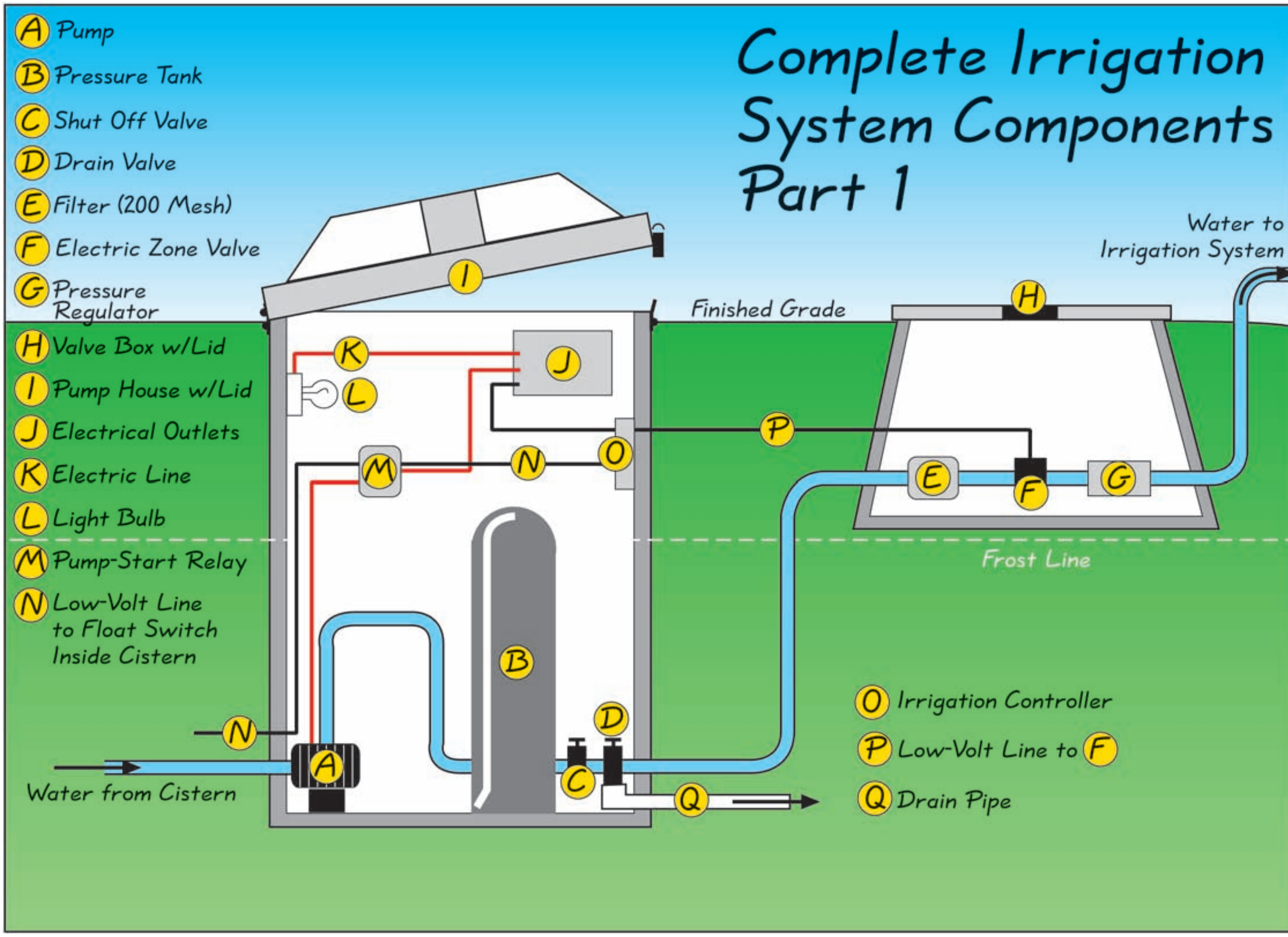


Figure 10-5: The components of a complete drip irrigation system. (Also see next page.)

For a more detailed and comprehensive discussion of drip irrigation, refer to *Low Volume Irrigation—Design and Installation Guide* published by the Albuquerque Bernalillo County Water Utility Authority (and available online from the Office of the State Engineer).

Cistern-related drip irrigation systems generally begin right after the pump lifts water from the cistern into the main water-delivery pipe. The first component that connects to this pipe is typically a pressure tank, which calls for water from your pump whenever water pressure in your system drops below a predetermined level. The pressure tank is an important item because drip irrigation requires reasonably constant water pressure in order to function effectively. For most systems, 15 to 30 PSI is a good pressure-tank setting. For most roof-reliant landscapes, an inexpensive six-gallon pressure tank is all that is necessary.

An inline filter is then connected to the main delivery line (labeled E in Figure 10-5). This small, inexpensive item, is a critical part of any cistern-related irrigation system. A standard drip irrigation filter in the 150 - 200 mesh range (i.e., between 100 to 75 microns) should be sufficient as long as the filter is regularly monitored and cleaned once a month. During the design and installation of your system, make sure you provide enough “elbow room” so changing and cleaning your filter(s) can be accomplished with relative ease.

Next in line is a small item called a pressure regulator, labeled G in Figure 10-5. The main role of a pressure regulator is to prevent water

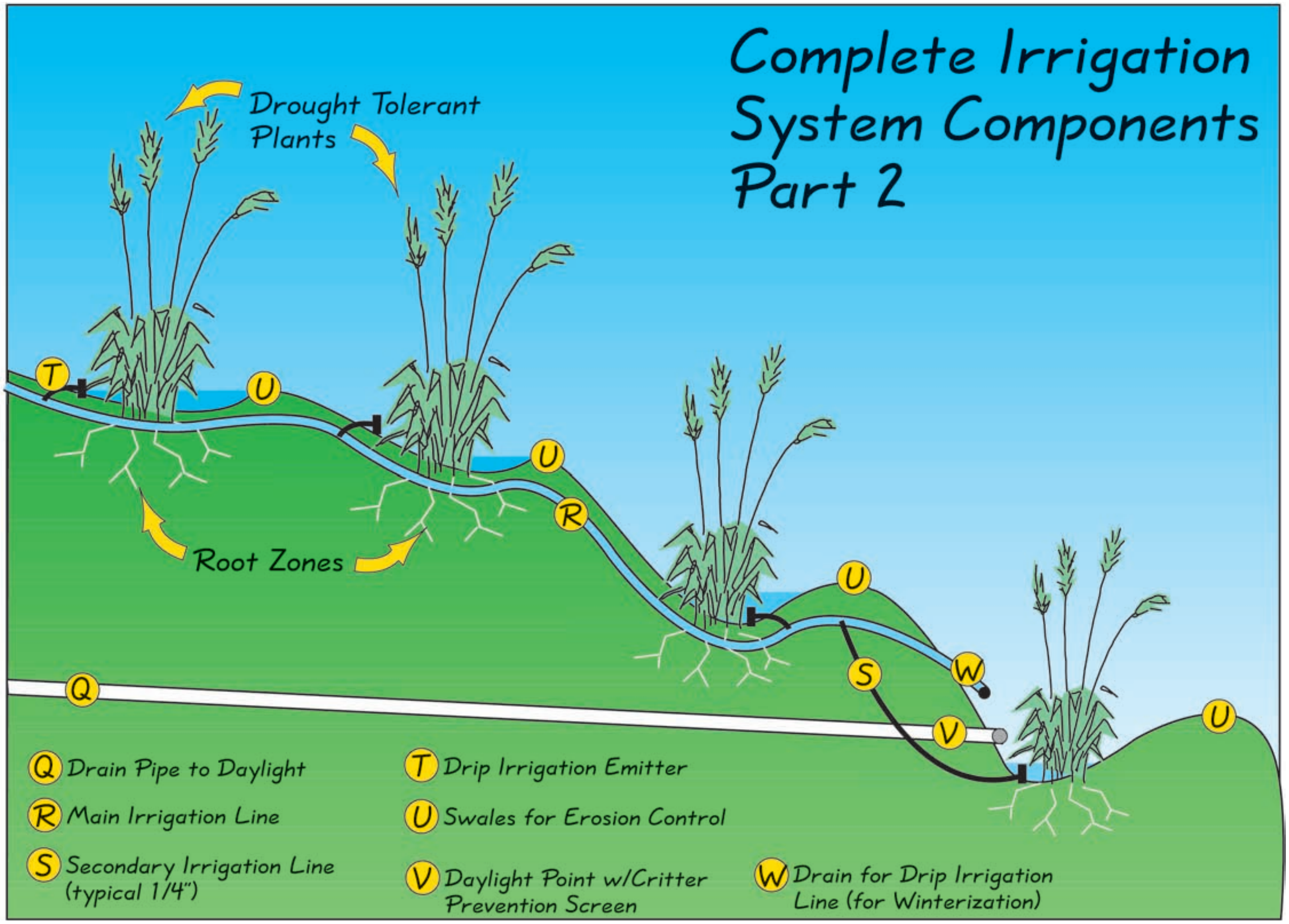


Figure 10-5 (Part 2): The components of a complete drip irrigation system.

pressure from getting too high in your system's delivery tubes.

If your system includes a frost-proof pump house or a self-draining sump pump, it makes sense at this juncture to install a frost-free hydrant, even if you plan to use drip irrigation exclusively. Frost-free hydrants can be used to water during warm, dry winters and they can be used to spot water in the summer. However, be sure to clearly identify your frost-free hydrant as a source of non-potable water and consider locking the handle. (NOTE: Purple is the Universal Plumbing Code's (UPC) color for indicating nonpotable water sources.)

This is often a good point at which to create a place for your system to drain. Most systems need to be drained before the first frost in the fall. The drain and its valve should be located at a lower elevation than all of the components that you wish to empty.

From this point, the distribution pipe will attach to an irrigation valve box (also called a manifold box). Such boxes are installed with their tops flush with grade. Inside you should have one valve for each irrigation zone.

Unless your system is manually operated, each valve will also be attached to a solenoid that is connected, with low voltage wire, to an irrigation controller. Separate watering zones are recommended for trees, shrubs and perennials, because each type of plant prefers a different watering schedule.

Figure 10-6: An irrigation controller can be programmed to automatically turn each zone of your irrigation system on and off.

After the valve box, delivery pipes are typically converted from rigid PVC pipe to flexible polypropylene tubing. Such tubing typically ranges in diameter from 1/2 to one inch. It can be buried under the soil, but, for ease of access, irrigation tubing is typically tacked to the surface of the soil with landscape staples and covered only by mulch.

Although an irrigation controller is technically an optional item, it is highly recommended to include a controller to automatically turn your drip system on and off. Irrigation controllers range from battery operated one-zone timers to high-tech clocks that offer a wide range of programming options, including controlling your irrigation system from a computer in the house (or halfway around the globe via the internet). An irrigation controller is worth the cost because of the time that it saves you from having to manually run zones from the valve box.

Another optional item is a digital water level meter. These devices provide you with a percentage of water in your cistern. Although some types can be tricky to calibrate when the tank is empty, digital level readers can be installed by the do-it-yourselfer.

Hose watering

On the other side of the distribution spectrum is conventional hose watering, which requires nothing more than an ON/OFF valve, a frost-free hydrant connected to a pump and someone willing to move a hose. A nozzle should be added to control the flow rate of water through the hose.

If you are considering watering with a hose, make sure you check your landscape design for ways that make this chore easier. Especially on steep sites, you can reduce watering time and effort by grouping your plants so that several can be watered efficiently with each hose placement. This can be accomplished by properly grading densely planted garden beds and also by placing the most water-thirsty plants closest to your spigot locations. With grading that effectively uses gravity, a hose watering system can leave much of the work to nature. Even if you are very committed to using drip irrigation, it is beneficial to also install a frost-free hydrant for spot watering with a hose.

Advantages and Disadvantages of Hose Watering

The best part about a hose watering system is the low cost of installation. There are no multiple valves, tubing, emitters, stakes or any other components of drip irrigation. There are also no trenches to dig and no water lines to cover up with mulch or soil. Hose watering includes, quite simply, a hydrant or valve at the point of hydraulic lift, a hose and a spray nozzle.

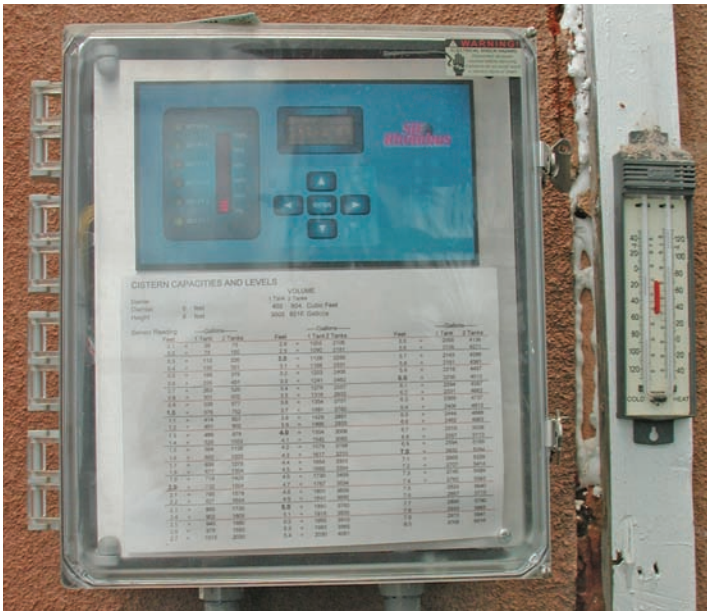


Figure 10-7: A digital water level meter indicates how much water is in the cistern.

The most difficult part of hose watering is that the watering needs to be done regularly, carefully and consistently until your plants are well-established. Many people simply do not have the time for hose watering by hand, so they often decide to spend the extra money for drip irrigation with its inherent precision and automation.

Low-Cost Distribution Alternatives

The vast majority of roof-reliant landscape designers will choose an electric pump to move water from the cistern to the distribution system. However, if the budget for your roof-reliant landscaping system is tight, here are two low-cost distribution alternatives that you may want to consider:

Hand Pump Systems

Hand pumps are traditional, manually powered devices that lift water often from a relatively shallow depth. Normally, such systems also include a watering can or bucket that gets filled up underneath the hand pump's spigot. This water is then hauled (or siphoned off) and poured onto the mulch covering the topsoil above the root zones of your plant material.

Hand pumps range in price from under $30 to about $300. Because licensed electricians and plumbers are not required for the installation of a hand-pump system, the actual cost for the installation of such systems is very low.

Hand pumps do not use any electricity, allowing you to eliminate this cost from your monthly expenses. In addition, hand pumps are not complex and therefore the long-term costs of maintenance for such systems are relatively low in comparison to conventional distribution systems.

There are a number of drawbacks associated with hand-pump, or manually powered, systems. For most people, the amount of time and physical energy necessary to pump and distribute harvested water throughout any given landscape is too much work. It is also not practical to connect a hand pump to a drip irrigation system.

Pump-Free Systems

The pump-free alternative is an option that only works in rare circumstances. Your property will need a sufficient slope and a landscape designed specifically for watering to occur using the force of gravity.

For every foot of increased elevation, the pressure in an irrigation tube increases by 0.433 PSI. The minimum pressure for drip irrigation to function properly is between 10 and 15 PSI, which means your plants need to be 25 to 35 feet below your cistern for gravity-fed drip irrigation to function as per the manufacturer's recommendations.

Just as you cannot have a pump-free system without the proper site, you can't have a pump-free system without the right person to run it. Pump-free systems take patience, a good memory and the ability to be available for a number of brief moments of time throughout the property's watering cycle.

Figure 10-8: A hand pump is an old-fashioned device that requires no electricity to operate—just human muscle power.

Chapter 11: Maintenance

After the design, installation and successful use of a rainwater harvesting system, the roof-reliant landscaper's work is not over. In order to keep a cistern system functioning efficiently, routine inspection and maintenance are required on a regular basis.

It is important to note here that good documentation of the system is a tremendous aid to ongoing maintenance—whether that maintenance is to be done by the system's owner or performed by a hired professional. Make sure your roof-reliant landscaping file or notebook is filled with design renderings, calculations, schematic drawings, and photographs and/or illustrations of pipe slopes and other important below-ground components. You should also have "as built" documentation that shows how every part of the system fits together in the landscape. One of the best ways to document the system is to give every component a name, number and insatllation date, and have photographs taken to accompany a written narrative that describes each piece of the system and how it fits together as a whole. Your file should also contain the manufacturers' information and warranties for all system components.

Some professional rainwater harvesting system installers recommend a video-recorded walk-through and explanation of the entire system just after installation has been completed. This recorded walkthrough identifies all of the system components and their operation, including such details as switch and valve settings. The video documentation also shows how some of the basic system maintenance is performed, such as how filters are cleaned and how to drain pipes and hoses in preparation for winter season shutdown, or conversely, how to start up the system in the spring.

Also, when it comes to hiring an outside contractor to maintain your system, please note that (at the time of this writing) there are no licensing or inspection regulations established by the State of New Mexico, so make sure your contractor has credible references.

Basic System Maintenance

With all rainwater harvesting systems, the best maintenance is preventative maintenance. Many problems can be avoided by proper planning and careful installation.

But whether your system is simple or quite complicated and whether your cistern is above-ground or below-ground, basic maintenance procedures are required to ensure that your system functions properly.

Every system will have specific attributes that may present some unique maintenance issues. However, for the purposes of this manual, we will look at the four areas of a roof-reliant landscaping system (collection, conveyance, storage and distribution) and offer a guide to the basic maintenance issues that arise in each area.

Collection

Many problems that occur in rainwater harvesting systems concern the debris that collects in catchment areas, such as flat roofs, canales and gutters. Because these surfaces are flat or only slightly pitched, they naturally collect a variety of debris including leaves, bird droppings and windblown dirt and sand.

Maintenance for collection areas includes the following tasks:

- Conduct an inspection of all catchment surfaces each season. Remove any large debris.
- Clean out clogged canales and/or gutters. Remove all debris such as trapped leaves.
- Clean gutter screens.
- Inspect canales and/or gutters for signs of damage. Repair any leaks or cracks.

Conveyance

Debris is also troublesome for the conveyance system. Your seasonal maintenance checklist should include these tasks:

- Clean first-flush devices. If a "dead-end pipe" (see Figure 8-11) or similar device is used as a first-flush filter, open the cap to drain any existing water and clean out the debris from the bottom of the pipe.

- Empty debris from roof-washers. If necessary, clean the filter with water and a soft bristle brush.
- Empty roof-washers immediately during cold weather to prevent the water from freezing and potentially damaging the unit.
- Check downspouts and remove any debris.
- Flush sediment from pipes with a high-pressure wash when necessary.
- Clean all filters. Inspect filters for any signs of wear or damage, and replace as necessary.

Storage

- If necessary, aboveground tanks should be cleaned at least once a year (when the tank is closest to being empty). For small tanks, drain the tank and use a wet/dry vacuum. An enzyme solution (for algae control) can be used to clarify the water.
- Check fittings for damage. (Aboveground tanks and their related hardware are more susceptible to freeze damage. To avoid freeze damage, invest in brass fittings and/or leave valves open during colder months when the system is not in use.)
- Check the cistern vent to make sure it is screened to keep out rodents. Small animals can sometimes get into vents, effectively clogging the system and preventing the vent from doing its job.
- If a substantial amount of sediment has accumulated on the bottom of the tank, remove the sediment.
- Long-term maintenance may include washing and disinfecting the storage tank.
- Check overflow pipes for signs of mice and other pests.

Distribution

- Inspect all distribution lines each season. Look for evidence of cracks and leaks. Repair or replace any damaged lines.
- Run water through all distribution piping (underground lines, drip tubing, etc.) to test for sufficient water pressure.
- Inspect all water-delivery devices, such as drip emitters. Clean and/or replace any clogged emitters.
- Clean and maintain filters, including drip filters.
- Make sure all emitters and water-delivery devices are placed properly to water plants' root zones. Move the emitters to expand the area of water delivery as plants grow.
- Prior to winter shutdown, disconnect the pump housing and drain the pump (provided the pump does not have a heat source). Disconnect and drain the inline pump (if applicable). If you have a complex system, contact a professional to winterize your system.

The goal of any rooftop rainwater harvesting system is maximum efficiency. Your system should be physically inspected throughout the watering season. Watch for any inefficiencies, such as leaks, water pooling, signs of abnormal wear or erosion, missing drip emitters, etc.

Remember, too, that your roof-reliant landscaping system can add to the resale value of your property, so make sure your system documentation is in order and kept up to date. Note any changes made to your system in the master documentation files and/or "as built" files.

Figure 11-1: Leaf and debris screens and other filters need to be cleaned regularly.

A Design Narrative

One of the best maintenance tools for a cistern system is a written description of the system's components and how the system works. This "design narrative" should be included in the permanent files and maintenance records of every roof-reliant landcaping system. Here is a sample design narrative:

This system harvests rainwater from the flat roof of the house and conveys it to a cistern. The water is moved from the roof on the south and west sides by downspouts connected to canales. On the north side of the home, rain chains are used for prevention of potential freezing problems. The harvested water is passed through a series of first-flush boxes along the conveyance line. A self-cleaning inlet filter receives and filters all of the conveyed rainwater at the northwest corner of the house. The debris particles are discharged to an overflow.

The filtered water is collected in a 300-gallon sump tank and automatically pumped to storage. The cistern system is a row of three tanks, each with a 2500-gallon capacity. These tanks were selected for shallow depth of bury to prevent potential problems with nearby shallow ground water.

The tanks are plumbed in parallel so that an inlet and outlet to any tank can be closed for service or cleaning while the remainder of the system continues in operation. Distribution to irrigation is provided by a 1/2 horsepower submersible pump to a master valve. From the master valve, water flows to a drip irrigation system.

Design Narrative Courtesy of *Earthwrights Designs,* Santa Fe, NM

Figure 11-2: A good design narrative and an "as-built" manual will give an overview of the system and its components. Top: this purple valve box cover indicates the water in this system is nonpotable. Middle: a rainwater prefilter. Bottom: a pumphouse with drain pressure gauge and manifold.

Seasonal Maintenance Checklist

Spring

- ❑ Inspect collection surfaces and remove any debris
- ❑ Check gutters for damage. If heavy snowfall has pulled gutters away from roof, reattach. Repair leaks and cracks.
- ❑ Remove debris from canales and/or gutters.
- ❑ Clean gutter screens to remove trapped leaves, etc.
- ❑ Check downspouts. Make sure connections to gutters are sound. Remove any debris from downspouts.
- ❑ Clean first-flush filters. Drain water (if any) and remove sediment and debris.
- ❑ Clean and inspect all filters. Check for signs of damage. Repair or replace if necessary.
- ❑ Clean aboveground tanks if necessary.
- ❑ Check overflow pipe to make sure it is clear of debris and small animals.
- ❑ Check all pipes and fittings for leaks or damage. Repair and/or replace as necessary.
- ❑ Conduct a thorough preseason walk-through and inspection of the entire system.
- ❑ Check all distribution lines and water-delivery devices, including drip emitters, micro-sprayers, etc. Repair or replace if necessary.
- ❑ Run water through all distribution piping (underground lines, drip tubing, etc.) to test for sufficient water pressure. Repair any breaks in the lines.
- ❑ Ensure that all emitters and water-delivery devices are placed properly to water plant root zones. Move the emitters to expand the area of water delivery as the plants' dripline grows.

Summer

- ❑ Remove debris from canales and/or gutters.
- ❑ Clean gutter screens to remove trapped leaves and other debris.
- ❑ Clean first-flush filters. Drain water (if any) and remove sediment and debris.
- ❑ Flush sediment from pipes as necessary.
- ❑ Inspect and clean all filters.
- ❑ Check all distribution lines and water-delivery devices, including drip emitters, micro-sprayers, etc. Repair or replace if necessary.
- ❑ Ensure that all emitters and water-delivery devices are placed properly to water plant root zones. Move the emitters to expand the area of water delivery as the plants' dripline grows.

Fall/Winter

- ❑ Remove debris from canales and/or gutters.
- ❑ Clean gutter screens to remove trapped leaves and other debris.
- ❑ Drain roof washers at the first frost to prevent water from freezing inside the unit.
- ❑ Drain water from valves, vacuum breaker, irrigation pipes and tubing to prevent winter freeze.
- ❑ Conduct a thorough shutdown walk-through and inspection of the entire system.
- ❑ If you have a complex cistern system, contact a professional to conduct a winter shutdown.

Glossary

Air vent—a screened opening above the elevation of a water tank's supply point designed to prevent an implosion caused when a large quantity of water is rapidly removed from the tank.

As-built—documentation that shows how every part of a cistern system fits together. Ideally, this documentation would have photographs and illustrations of all of the system components and a written narrative that describes each piece of the system, how it works and how it fits together as a whole.

Auxiliary supply—an alternative to harvested rainwater for watering landscape plants. Typically, this water would come from a well or from a municipal water system. An auxiliary supply is not recommended by the New Mexico Office of the State Engineer.

Berm—a bank of earth formed to direct the flow and/or collect rainwater. A berm placed on the downhill side of a plant is an effective way to passively harvest stormwater and encourage the water to slowly percolate into the soil.

Caliche—a zone of virtually impenetrable calcium carbonate or other carbonates in soils of semiarid regions (such as New Mexico). A layer of caliche can sometimes be as difficult to dig through as concrete.

Canale—a short, narrow trough that protrudes through the parapet of a flat roof and directs water onto the ground below.

Collection surface (Catchment surface)—the surface from which rainwater is captured, usually a roof.

Check dam—a low barrier placed perpendicular to the flow of water within a drainage area (such as a small natural ditch or arroyo) designed to slow the flow of water to prevent erosion and encourage water infiltration. A check dam should be low enough to allow water to spill over it during significant storm events.

Check valve—a mechanical device which allows fluid to flow through it in only one direction. Check valves work automatically and most are not controlled by a person or any external control.

Cistern—a storage tank for collected precipitation. Cisterns can be aboveground, partially buried or completely buried below ground. As used in this manual, cistern system also refers to an entire roof-reliant landscape irrigation system.

Compost—a soil amendment made from organic matter (leaves, grass clippings, vegetable scraps, etc.) that has been decomposed. Compost is an important ingredient of healthy soil.

Conveyance system—the conveyance system channels water from collection surface areas to storage tanks. These systems can include gutters, downspouts, pipes and other components.

Daylight pipe—an overflow pipe from a cistern with an outlet into the open air. A daylight pipe distributes overflow water from the cistern to the "daylight point" at ground level in the landscape, preferably near plants.

Delivery point (Supply point)—the point where conveyed water reaches a cistern for storage. The delivery point is the last step in the rainwater conveyance process.

Distribution system—the distribution system delivers water from the storage tank(s) to the landscape. This system can be as simple as a valve and a hose or can include pipes, a pressure tank, drip tubing, drip emitters and other components.

Downspout—a pipe for conveying rain water from a roof or gutter toward a cistern. Downspouts efficiently convey water along a vertical drop, typically from a pitched roof.

Drain box (Catch basin)—a collection box for water, typically located underneath a canale. Water collected by the drain box flows through conveyance pipes to a cistern.

Drip emitter—a device that delivers irrigation water at low flow rates, typically measured in gallons per hour (gph) or liters per hour (lph). Drip emitters efficiently apply water directly to the soil near plant root zones.

Drip irrigation—a method of watering plants that maximizes water efficiency and minimizes water waste and evaporation. Water is applied to the root zone of a plant at a slow rate (e.g., two gallons per hour) that enables the soil to absorb moisture without creating runoff.

Dripline—the edge of the leaf canopy of a tree, shrub or plant, which is the ideal area to deliver water to a plant's root zone.

Erosion—wearing or washing away of soil by natural forces, primarily wind or water.

Evapotranspiration (ET)—the process by which a plant loses moisture, which is a combination of evaporation from the soil and plant transpiration (moisture released to the air by plants). ET rates (coefficients) increase in warmer weather, which is why plants need more water in the summer than in the winter.

Filter—any device used to screen dirt and debris from water.

Finished grade—a predetermined line indicating the proposed elevation of the ground surface around a structure or in a completed landscape.

First-flush device (First-flush diverter)—a device that diverts the first water running off a collection surface, preventing it from entering a cistern. The "first flush" of water contains the most debris. The most common type of first-flush device is a length of capped pipe that captures the initial flow of water (and debris), while allowing the cleaner water to flow into the conveyance system.

Float switch—a balloon-like device that floats on the surface of the water in a tank for the purpose of turning a pump on or off. When the water level in a cistern reaches a certain (low) depth, the float switch drops into the "OFF" position, thus turning off the pump. Float switches can prevent pumps from burning out when their associated cisterns are empty. Float switches are also commonly called pump-down switches.

Foot valve—a suction valve or check valve at the lower end of a pipe.

French drain—a drainage trench filled with gravel or stones. A French drain is a simple and effective way to encourage water infiltration and prevent water runoff and soil erosion.

Funnel drain—a device used to catch water that falls from a canale. A funnel drain directs roof water through a rubber or vinyl liner into a below-grade box drain. A top dressing of gravel or river rock covers the liner to protect it from degrading in the sun and hides the drain from view. The gravel also acts as a filter, preventing mulch, soil and other particulate from being conveyed toward the cistern.

Gabion—a wire-wrapped check dam typically filled with stone.

Gutter—an open channel, or trough, that directs roof water along roof lines usually toward downspouts. Gutters are almost always associated with pitched roofs.

Gutter guard—a screen, typically placed in a gutter at the entrance to a downspout, to prevent leaves and other large debris from being conveyed into a cistern. (Also commonly known as leaf screens or leaf catchers.)

Hardscape—masonry work, woodwork and other non-plant elements of a landscape. These typically include walkways (concrete, brick, stone, etc.) walls, fences, patios, and so forth.

Inline pump—a pump used to draw water from a cistern to a water delivery system (irrigation system). An inline pump is located along the water line (unlike a sump pump, which must be submerged in water).

Irrigation controller—an electronic device that automatically turns an irrigation system on and off. Irrigation controllers range from battery operated one-zone timers to high-tech devices that offer a wide range of programming options, including controlling an irrigation system from a computer inside a house (or halfway around the globe via the internet).

Leaf screen (Leaf catcher)—the first level of defense against allowing particulate into a cistern. Leaf screens are usually placed in gutters at the entrance to a downspout, although some types are designed to be placed at the bottom of a downspout. These devices allow roof water to flow into the conveyance system while filtering out the larger pieces of debris. Leaf screens are also known as gutter guards.

Level reader—a device used to determine how much water is in a cistern. A digital level reader typically measures the water in the tank as a percentage of the cistern's total capacity. On the low-tech end of the spectrum, a long stick can also serve as a level reader. The stick can be inserted into the cistern to measure the depth of the water.

Microclimate—a highly localized climate that is usually created by the shelter of a wall, the shade of a tree or by another landscape feature. On the sunny side of a wall, the microclimate would be hotter and potentially drier than in the rest of the site. On the shady side of a large boulder, the microclimate would be cooler and is often wetter.

Mulch—a covering for the soil surface that protects it from the evaporative effects of sun and wind. Mulch can be plant material such as bark, straw or wood chips; mulch can also be gravel or another non-organic material. Mulch reduces water lost to evaporation, increases water infiltration by slowing runoff, reduces soil erosion, inhibits weeds and moderates soil temperature.

Overflow pipe—a pipe located near the top of a water storage tank (cistern) through which water can flow when the tank is filled to capacity. Ideally, an overflow pipe should lead to landscape plants such as trees that can benefit from additional water.

Perennial plant—a plant whose life cycle is longer than two years.

Potable water—water that is safe for human consumption also known as drinking water.

Pressure tank—a small tank or chamber that provides water under pressure for delivery to a drip irrigation system. A pressure tank is important because drip irrigation requires reasonably constant water pressure in order to function effectively. For most drip systems, 15 to 30 PSI is a good pressure-tank setting.

Pump tank—a separate, smaller water storage tank used temporarily to pump roof water to the system's main cistern. The additional pump, tank and float switch associated with this kind of system significantly complicates a roof-reliant landscaping system and can unnecessarily increase its long- and short-term costs.

Psi (pounds per square inch)—a unit of measure (literally the amount of pressure applied to each square inch of surface) used to describe the water pressure inside pipes, tanks, etc.

Rain chain—a chain connected to the end of a canale that helps direct rainwater downward to a funnel drain or catchment box. A rain chain increases the efficiency of harvesting rainwater from a flat roof, and it can help eliminate water freezing in cold-weather situations.

Roof-Reliant Landscaping™—a landscaping method that uses plants which can survive on local precipitation, supplemented with rainwater harvested from the rooftops of onsite buildings (houses, sheds, awnings, etc.)

Roof-washer—a general term used to refer to any kind of precistern filtration technique, such as a first-flush diverter.

Runoff—water that flows over a surface when more precipitation falls on it than the surface can absorb.

Sediment trap—a type of filter that separates sediment from water. The sediment settles to the bottom of the trap, while the clean water flows toward the cistern.

Serviceway (also known as the access way or manhole)—an opening above a cistern that provides access needed for cistern maintenance, including servicing the pump, float switch, level reader, vent pipe, water lines and electrical lines. It should remain locked for safety reasons when not in use.

Site plan— a detailed drawing of a property, showing the property lines and any structures that currently exist on that land (house, garage, fence, etc.) and where any proposed additions (cistern, conveyance piping, irrigation system, etc.) are to be located. A site plan is a bird's eye view of the property from above. The drawing should be done to scale (e.g., 1 inch on the plan is equal to 30 feet on the ground) and include a north directional orientation.

Soil type—a description of the composition of soil texture, which usually refers to the different sizes of mineral particles in a soil sample. Soil is comprised, in part, of finely ground rock particles (sand, silt and clay). In addition to the mineral composition of soil, humus (organic material) also plays a crucial role in soil characteristics and fertility for plant life. The ratio of soil particles to humus content determines soil type: sandy, loam or clay.

Sump pump—a pump that must be submerged in water in order to work. A sump pump is used to pump water from a cistern, pump tank or pumphouse.

Supply point (see "delivery point")

Swale—a small earthen dam or contour designed to direct and/or collect rainwater. A swale holds rainwater and allows it to infiltrate slowly into the ground.

Valve—A device that opens and closes to allow water to flow through pipes.

Valve box-- a box, typically recessed into the ground, in which an irrigation system's valves are located.

Water budget—A calculation of the amount of water needed to support a landscape, and/or a calculation of the amount of water that can be collected by a rainwater harvesting system.

Xeriscape/Xeriscaping (Waterwise landscaping)—A landscaping approach that uses plants capable of thriving in arid environments. ("Xeric" is derived from "xeros," the Greek word for dry.) Xeric plants that thrive in New Mexico's arid and semi-arid climates typically go dormant during drought conditions and perk up quickly after storm events.

APPENDIX 1: INCHES OF AVERAGE MONTHLY PRECIPITATION IN NEW MEXICO

	*INCHES OF AVERAGE MONTHLY RAINFALL FOR NM TOWNS												
**NM Towns	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	**Annual**
Abiquiu Dam	0.38	0.26	0.51	0.55	0.83	0.71	1.59	2.01	1.13	0.88	0.53	0.34	**9.71**
Alamogordo	0.73	0.52	0.46	0.32	0.50	0.83	2.13	2.13	1.68	1.05	0.54	0.81	**11.68**
Albuquerque	0.39	0.40	0.48	0.50	0.61	0.65	1.31	1.52	1.02	0.81	0.48	0.49	**8.66**
Animas	0.70	0.54	0.49	0.19	0.17	0.45	2.20	2.36	1.46	0.99	0.57	1.03	**11.15**
Belen	0.28	0.40	0.40	0.26	0.31	0.63	1.40	1.32	0.90	0.98	0.20	0.39	**7.45**
Bernalillo	0.43	0.49	0.56	0.43	0.58	0.55	1.47	1.50	0.83	0.95	0.44	0.47	**8.68**
Carlsbad	0.43	0.44	0.30	0.53	1.24	1.53	1.73	1.96	2.34	1.24	0.49	0.51	**12.72**
Clayton	0.27	0.40	0.65	1.21	2.39	1.91	2.64	2.31	1.68	1.09	0.50	0.38	**15.44**
Clines Corners	1.05	0.82	0.99	1.00	1.60	1.61	2.72	3.16	2.24	1.49	1.04	1.00	**18.71**
Clovis	0.43	0.43	0.59	1.04	2.10	2.60	2.62	2.96	2.16	1.61	0.56	0.60	**17.71**
Corrales	0.43	0.39	0.67	0.65	0.68	0.82	1.63	1.95	1.18	0.85	0.91	0.64	**10.80**
Crownpoint	0.52	0.51	0.49	0.50	0.36	0.67	2.06	1.89	0.85	0.85	0.46	0.61	**9.75**
Cuba	0.89	0.69	0.88	0.68	0.80	0.80	2.07	2.28	1.38	1.11	0.80	0.72	**13.09**
Deming	0.48	0.54	0.34	0.20	0.16	0.37	2.07	1.90	1.22	0.79	0.52	0.89	**9.50**
Española	0.47	0.43	0.59	0.58	0.89	0.75	1.50	1.94	1.00	0.90	0.57	0.50	**10.12**
Estancia	0.54	0.53	0.64	0.55	1.01	0.97	2.19	2.38	1.51	1.13	0.64	0.80	**12.87**
Farmington	0.58	0.50	0.55	0.51	0.36	0.46	0.80	1.07	0.83	1.11	0.49	0.62	**7.89**
Fort Sumner	0.39	0.40	0.44	0.59	1.16	1.47	2.42	2.81	1.80	1.37	0.55	0.49	**13.90**
Gallup	0.89	0.73	0.89	0.53	0.64	0.47	1.54	1.93	1.13	1.00	0.99	0.74	**11.50**
Grants	0.51	0.43	0.52	0.45	0.57	0.57	1.71	2.10	1.35	1.10	0.56	0.66	**10.52**
Hobbs	0.48	0.45	0.46	0.80	2.09	1.83	2.16	2.42	2.66	1.58	0.57	0.58	**16.06**
Jemez Springs	1.08	0.88	1.02	0.89	1.07	1.07	2.61	3.12	1.58	1.50	1.06	0.94	**16.83**
Las Cruces	0.52	0.33	0.23	0.21	0.33	0.66	1.46	2.27	1.31	0.82	0.46	0.76	**9.17**
Los Alamos	0.91	0.79	1.10	0.94	1.31	1.38	3.14	3.78	1.82	1.42	0.98	0.98	**18.53**
Los Lunas	0.35	0.42	0.46	0.44	0.49	0.57	1.23	1.76	1.21	1.06	0.46	0.53	**8.98**
Pecos	0.66	0.65	0.86	0.73	1.14	1.29	3.00	3.48	1.86	1.09	0.80	0.63	**16.21**
Raton	0.37	0.39	0.71	0.91	2.51	2.25	2.87	3.34	1.88	0.92	0.49	0.41	**17.07**
Roswell	0.42	0.46	0.29	0.60	1.33	1.63	2.01	2.48	2.16	1.06	0.51	0.59	**13.52**
Ruidoso	1.17	1.20	1.21	0.63	0.94	1.94	4.05	4.03	2.65	1.54	0.85	1.63	**21.85**
Sandia Park	3.10	1.24	1.44	0.93	1.14	1.12	3.00	3.00	1.83	1.40	1.31	1.20	**20.44**
Santa Fe	0.65	0.74	0.79	0.94	1.33	1.05	2.35	2.17	1.52	1.11	0.62	0.71	**13.99**
Shiprock	0.51	0.43	0.46	0.40	0.52	0.32	0.63	0.98	0.67	0.86	0.57	0.59	**6.93**
Silver City	1.25	0.85	0.84	0.55	0.21	0.58	2.78	2.48	1.91	1.21	0.49	1.07	**14.17**
Socorro	0.39	0.39	0.33	0.37	0.59	0.62	2.59	1.77	1.46	0.97	0.37	0.56	**10.40**
Taos	0.71	0.63	0.83	0.77	1.17	0.89	1.62	1.98	1.25	1.03	0.84	0.68	**12.40**
Tijeras	0.63	0.97	1.06	0.90	0.78	0.88	2.45	2.42	1.57	1.46	0.80	1.18	**15.10**
T or C	0.47	0.37	0.33	0.21	0.42	0.81	1.72	2.11	1.37	0.96	0.54	0.96	**10.26**
Tucumcari	0.26	0.47	0.39	0.87	1.49	1.78	3.30	2.40	1.46	0.94	0.50	0.27	**14.11**
Vaughn	0.44	0.44	0.35	0.51	0.92	1.60	1.99	2.56	1.41	0.87	0.41	0.38	**11.87**

* Data obtained from the Western Region Climate Center and the National Oceanic and Atmospheric Agency

** The average rainfall for more specific locations may vary from the averages shown here. In Albuquerque, for example, average rainfall ranges from 8.51 inches a year at the airport to 14.00 inches a year near the Sandia foothills.

APPENDIX 2: WATER DEMAND WORKSHEET

A	B	C	D	E
Zone	**Locale**	**Irrigation requirement in gallons per sq. ft. per year**	**Square footage of irrigated area**	**Total gallons required (C x D)**
Total Column E				

For Year One (installation year) multiply the total by 120%
Year Two x 110%
Year Three x 105%
Every other year = 100%

APPENDIX 3: LANDSCAPE IRRIGATION REQUIREMENTS IN NEW MEXICO (in gallons per square foot per year)

County	Locale	Zone 1	Zone 2	Zone 3
Bernalillo	Albuquerque	5.97	14.79	37.65
Bernalillo	Coralles and Rio Rancho	5.81	14.38	36.59
Bernalillo	Los Ranchos	6.07	15.05	38.31
Bernalillo	Rio Rancho Estates	5.37	13.27	33.73
Catron	Reserve	5.50	13.59	34.57
Chaves	Roswell	6.91	17.20	43.81
Cibola	Grants	5.16	12.73	32.36
Cibola	Milan	5.13	12.66	32.17
Colfax	Cimarron	4.62	11.38	28.91
Colfax	Raton	4.40	10.82	27.48
Colfax	Springer	5.06	12.49	31.76
Curry	Clovis	6.00	14.87	37.86
De Baca	Fort Sumner	6.33	15.71	40.00
Dona Ana	Hatch	7.05	17.53	44.64
Dona Ana	Las Cruces and Mesilla Park	7.23	18.00	45.84
Eddy	Artesia	7.03	17.50	44.59
Eddy	Carlsbad	7.29	18.16	46.28
Eddy	Loving	7.37	18.37	46.80
Grant	Bayard and Central	5.77	14.28	36.34
Grant	Silver City	5.60	13.85	35.23
Guadalupe	Santa Rosa	6.16	15.28	38.90
Harding	Mosquero	5.18	12.80	32.54
Hidalgo	Lordsburg	7.01	17.43	44.41
Lea	Hobbs	6.77	16.83	42.86
Lincoln	Carrizozo	5.98	14.81	37.70
Lincoln	Ruidoso	4.89	12.03	30.57
Los Alamos	Los Alamos	4.46	10.96	27.83

(continued next page)

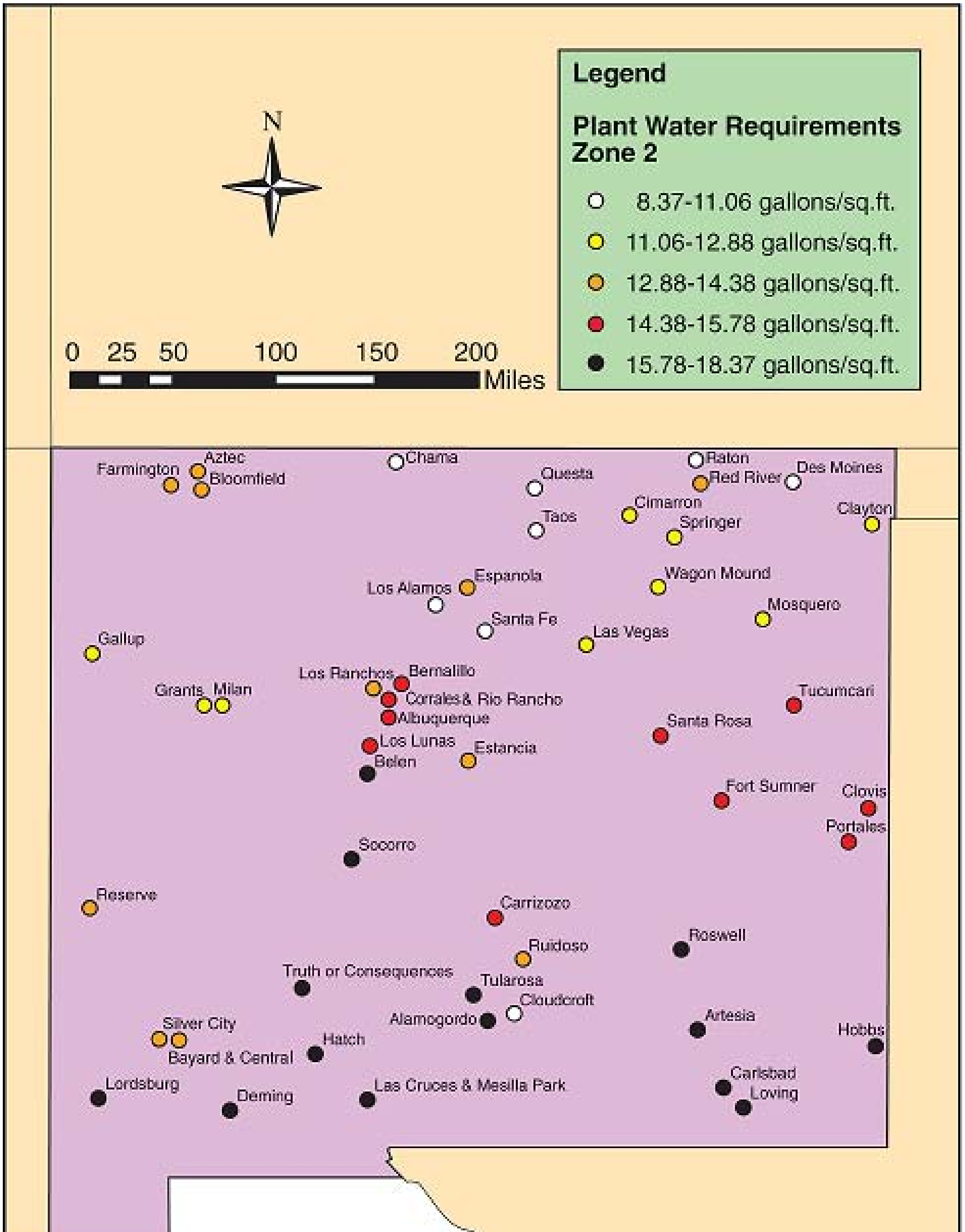
Note: The Hargreaves Samani equation was used to calculate ET_0. Irrigation system efficiency is not reflected in these numbers.

APPENDIX 3: LANDSCAPE IRRIGATION REQUIREMENTS IN NEW MEXICO, PAGE 2 (in gallons per square foot per year)

County	Locale	Zone 1	Zone 2	Zone 3
Luna	Deming	7.08	17.62	44.87
McKinley	Gallup	4.94	12.17	30.94
Mora	Wagon Mound	4.88	12.04	30.61
Otero	Alamogordo	6.59	16.37	41.70
Otero	Cloudcroft	3.45	8.37	21.20
Otero	Tularosa	6.67	16.58	42.22
Quay	Tucumcari	6.12	15.18	38.66
Rio Arriba	Chama	3.64	8.89	22.54
Rio Arriba	Espanola	5.46	13.50	34.35
Roosevelt	Portales	6.20	15.38	39.16
San Juan	Aztec	5.42	13.41	34.12
San Juan	Bloomfield	5.54	13.71	34.89
San Juan	Farmington	5.58	13.79	35.09
San Miguel	Las Vegas	4.86	11.98	30.44
Sandoval	Bernalillo	5.99	14.86	37.81
Santa Fe	Santa Fe	4.50	11.06	28.08
Sierra	Truth or Consequences	6.89	17.12	43.59
Socorro	Socorro	6.64	16.48	41.97
Taos	Questa	3.96	9.69	24.59
Taos	Red River	4.75	11.70	29.74
Taos	Taos	4.41	10.83	27.51
Torrance	Estancia	5.34	13.18	33.52
Union	Clayton	5.21	12.88	32.75
Union	Des Moines	4.36	10.72	27.22
Valencia	Belen	6.36	15.78	40.18
Valencia	Los Lunas	6.28	15.57	39.65

**Note: The Hargreaves Samani equation was used to calculate ET_0.
Irrigation system efficiency is not reflected in these numbers.**

APPENDIX 4: NEW MEXICO PLANT WATER REQUIREMENTS (ZONE 2)



NOTE: Figures are in gallons per square foot per year.

APPENDIX 5: MONTHLY WATER BUDGET SETTING REQUIREMENTS IN NEW MEXICO

Albuquerque

Month	Minutes per month	Minutes per week	Water Budget Setting
January	20	5	5%
February	34	8	9%
March	76	19	20%
April	146	37	38%
May	243	61	64%
June	337	84	89%
July	380	95	100%
August	341	85	90%
September	234	59	62%
October	133	33	35%
November	49	12	13%
December	24	6	6%

Grants

Month	Minutes per month	Minutes per week	Water Budget Setting
January	14	3	5%
February	22	5	7%
March	52	13	17%
April	99	25	33%
May	171	43	57%
June	257	64	86%
July	300	75	100%
August	262	65	87%
September	181	45	60%
October	102	25	34%
November	38	9	13%
December	19	5	6%

Carlsbad

Month	Minutes per month	Minutes per week	Water Budget Setting
January	28	7	7%
February	41	10	11%
March	89	22	23%
April	164	41	42%
May	262	66	68%
June	360	90	93%
July	388	97	100%
August	353	88	91%
September	248	62	64%
October	150	38	39%
November	62	15	16%
December	35	9	9%

Las Cruces

Month	Minutes per month	Minutes per week	Water Budget Setting
January	30	7	7%
February	44	11	11%
March	94	24	23%
April	165	41	41%
May	262	65	64%
June	366	91	90%
July	406	101	100%
August	360	90	89%
September	258	65	64%
October	157	39	39%
November	66	16	16%
December	36	9	9%

Clovis

Month	Minutes per month	Minutes per week	Water Budget Setting
January	19	5	5%
February	29	7	8%
March	67	17	18%
April	134	33	36%
May	228	57	62%
June	330	82	89%
July	371	93	100%
August	334	83	90%
September	226	56	61%
October	128	32	35%
November	48	12	13%
December	24	6	6%

Mountainair

Month	Minutes per month	Minutes per week	Water Budget Setting
January	14	3	5%
February	22	5	7%
March	52	13	18%
April	103	26	35%
May	176	44	61%
June	257	64	89%
July	290	73	100%
August	255	64	88%
September	180	45	62%
October	101	25	35%
November	38	9	13%
December	19	5	6%

Gallup

Month	Minutes per month	Minutes per week	Water Budget Setting
January	0	0	0%
February	17	4	5%
March	46	11	14%
April	99	25	30%
May	178	45	55%
June	262	66	80%
July	326	81	100%
August	284	71	87%
September	189	47	58%
October	101	25	31%
November	32	8	10%
December	0	0	0%

Santa Fe

Month	Minutes per month	Minutes per week	Water Budget Setting
January	0	0	0%
February	16	4	6%
March	36	9	13%
April	83	21	31%
May	149	37	56%
June	226	56	84%
July	267	67	100%
August	239	60	89%
September	160	40	60%
October	86	22	32%
November	28	7	10%
December	0	0	0%

Source: Albuquerque Bernalillo County Water Utility Authority

APPENDIX 6: INSTALLATION SCHEDULING CHECKLIST

Here is a sample scheduling checklist for a roof-reliant landscape:

- ❑ Plan the project
- ❑ Design the water harvesting system
- ❑ Select contractor(s), if applicable
- ❑ Obtain permit(s), if applicable
- ❑ Arrange for cistern delivery
- ❑ Excavate for cistern and associated piping, electricity, etc.
- ❑ Install cistern(s)
- ❑ Install conveyance, overflow, and other pipes/conduit
- ❑ Backfill soil and tamp appropriately
- ❑ Control potential erosion below overflow pipe
- ❑ Install hardscape and conduits for irrigation and lighting
- ❑ Construct play and recreation equipment (if any)
- ❑ Amend the soil if necessary
- ❑ Plant trees and/or other critical plant material as your water budget allows
- ❑ Irrigate as needed
- ❑ Mulch plant material
- ❑ Install outdoor furniture, garden art, signage, lighting, etc.
- ❑ Wait for some precipitation to fill your cistern
- ❑ Plant shrubs, install irrigation and mulch according to your water budget
- ❑ Wait until your plant material to become established
- ❑ Plant conservative quantities of annuals, vegetables, berry bushes, fruit trees, and other water needy plants only when your cistern is full.

Installation Tips

- If a backhoe is used for digging a hole for an underground cistern, water pipes, etc., consider using it to help break up any hard ground to which you plan to add compost and other amendments for any future plant material. If you need a backhoe for the installation of decorative boulders, you may wish to move this item up in your schedule. **(Call 1-800-321-2537 or 811 before you dig!)**

- As soon as plants are in the ground, water them! Plants need supplemental water right away, even if there is no water in your cistern. (Use a hose hooked up to municipal water if necessary!) Quickly connect your water distribution system so it can be available for irrigating your plants.

- Add mulch around your new plants and trees as soon as possible.

- In an ideal roof-reliant landscape installation schedule, planting schedules can be designed to make it easier to stay within your water budget. For example, trees can be planted during the first year, shrubs can be planted in the second year and perennials can be planted in the third year. This method makes sense when trees are needed for an important purpose such as a windbreak, shade or privacy screening.

APPENDIX 7: PIPE SIZES AND DRAINAGE CAPACITIES

Drainage Capacities in Gallons Per Minute (GPM)							
Pipe Diameter Inches	Flow Capacities Drains & Vertical Leaders	Flow Capacity in Horizontal Pipes Slope inches/foot					
		1/8 inch/foot =1%		1/4 inch/foot =2.1%		1/2 inch/foot =4.2%	
		Max roof	1.0%	Max roof	2.1%	Max roof	4.2%
2	30	sq. ft.	max. gal.	sq. ft.	max. gal.	sq. ft.	max. gal.
3	91	1000	34	1600	48	2200	68
4	191	2500	78	3500	110	5000	156
5	359	4500	139	6200	195	8900	278
6	561	7150	222	10000	314	14200	445

Source: Earthwrights Designs, Santa Fe, New Mexico

APPENDIX 8: ADDITIONAL INFORMATION ABOUT XERISCAPING, DRYLAND GARDENING, RAINWATER HARVESTING AND WATER CONSERVATION

Books and Publications

Albuquerque Bernalillo County Water Utility Authority, *Low Volume Irrigation - Design and Installation Guide*

Albuquerque Bernalillo County Water Utility Authority, *Rainwater Harvesting: Supply from the Sky*

Suzy Banks with Richard Heinichen, *Rainwater Collection for the Mechanically Challenged* (Tank Town Publishing, 2004)

Billy Kniffen, *Rainwater Harvesting in Menard County* (Menard County Extension)

Brad Lancaster, *Rainwater Harvesting for Drylands Volume 1* (Rainsource Press, 2006)

Brad Lancaster, *Rainwater Harvesting for Drylands Volume 2* (Rainsource Press, 2008)

Lower Colorado River Authority, *Saving from a Rainy Day* (Austin, Texas)

Art Ludwig, *Water Storage: Tanks, Cisterns, Aquifers and Ponds* (Oasis Design, 2005)

Russell A. Persyn, Dana O. Porter and Valeen A. Silvy, *Rainwater Harvesting* (Texas Cooperative Extension)

Judith Phillips, *New Mexico Gardener's Guide* (Cool Springs Press, 1998)

Wendy Todd Price and Gail Vittori, *Texas Guide to Rainwater Harvesting*, Third Edition (Texas Water Development Board, 2005)

David Salman and Cindy Bellinger, *Waterwise Garden Care* (High Country Gardens Publications, 2005)

Jerry Turrentine, *Wildlife Watering Facilities* (United States Department of Agriculture - Natural Resource Conservation Service, 1992)

Patricia H. Waterfall, *Harvesting Rainwater for Landscape Use* (Arizona Department of Water Resources, 1998)

Websites

www.ose.state.nm.us/ New Mexico Office of the State Engineer
Click on Water Use and Conservation
(Water conservation materials can also be requested by calling 1-800-WATER-NM.)

www.arcsa.org American Rainwater Catchment Systems Association

www.xeriscapenm.com Xeriscape Council of New Mexico

www.ircsa.org International Rainwater Systems Catchment Association

www.cabq.gov/waterconservation The City of Albuquerque's water conservation site.

www.abcwua.org/ Albuquerque Bernalillo County Water Utility Authority
(Water conservation materials can also be requested by calling (505) 768-3655.)

www.rainwaterharvesting.org Rainwater harvesting in India with an international perspective.

www.twdb.state.tx.us Texas Water Development Board

Buried Cable Locating Assistance (throughout New Mexico) 1-800-321-2537

Roof-Reliant Landscaping™

Rainwater Harvesting with Cistern Systems in New Mexico

Because New Mexico is an arid state with significant water challenges, there is a renewed interest statewide in the concept of rainwater harvesting and cistern systems. During the hottest summer months in New Mexico, approximately half of the total metropolitan water use in residential neighborhoods goes toward landscape irrigation. Rooftop rainwater harvesting, along with other outdoor water reuse practices, can reduce the demands on municipal water systems and our aquifers.

Office of the State Engineer
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