Rainwater Harvesting: Soil Storage and Infiltration Systems

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A soil storage and infiltration system collects rainfall runoff from the roofs of buildings and directs it underground where it infiltrates into the soil. The system consists of gutters and downspouts to collect roof runoff, a catch basin to capture trash and fine particles, underground trenches that store the water while it soaks slowly into the soil, and an observation port to aid in maintenance.

When the trench is filled with water during a storm, the excess water flows from the gutter and onto the ground surface. A soil storage and infiltration system decreases the volume of runoff, contains potential pollutants, and increases the amount of water entering the ground to recharge our groundwater systems.

Conserving and Protecting Water

In its natural state, the land can absorb much of the rain that falls. Water absorbed into the soil helps recharge groundwater supplies. Growing urban populations are straining groundwater supplies by using water faster than it can be replenished.

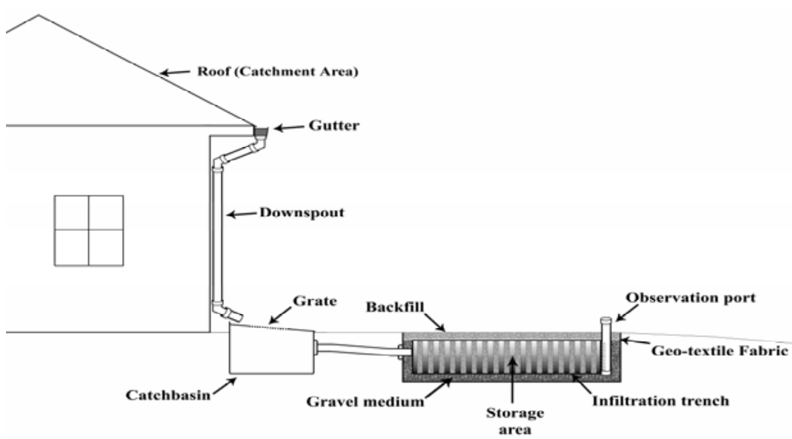

Figure 1. Rainwater soil storage and infiltration system components.

As more land is developed for new houses and businesses, the problem becomes worse because development covers much of the land with impervious surfaces. Rainwater that falls on parking lots, buildings, driveways and roads is not absorbed by the soil. Instead, it runs off into storm drains, streams and rivers. Stormwater runoff increases urban flooding and erodes the banks of rivers and streams. Table 1 shows just how much runoff is generated from impervious surfaces during common storms.

Table 1. Volume of rainwater captured in a 100-square-foot area (assuming 100 percent collection).

Rainfall Depth (in.)	Volume (ft^3)	Volume (gallons)
0.5	4.2	31
1.0	8.3	62
1.5	12.5	94
2.0	16.7	125
2.5	20.8	156
3.0	25.0	187

An average-size house has a 1,500- to 4,000- square-foot impervious roof. Thus, you must multiply the volumes in Table 1 by at least 15 to estimate the amount of water a typical roof will shed.

In addition to the flooding it can cause, excess rainfall runoff has properties that can harm the environment. Rainwater is heated by the pavement and roofs on which it falls. When this heated water enters a stream or river it raises the temperature of the water in the stream and speeds the growth of bacteria. This, in turn, depletes the amount of dissolved oxygen in the water. Oxygen depletion can kill some fish and other aquatic organisms.

Urban runoff also carries many pollutants into streams and rivers. Water flowing over roads and parking lots picks up oils, heavy metals and other chemicals that leak from vehicles. Water flowing over yards picks up excess fertilizers, chemicals, animal wastes and grass clippings. These pollutants also harm aquatic life.

Water is a valuable resource and every effort should be made to conserve and protect it. Installing a soil storage and infiltration system is one way to do that.

Feasibility of a Soil Infiltration System

It is feasible to install a storage and infiltration system at many homes and businesses. Most buildings already have gutters and downspouts, and at many sites the storage and infiltration trench can be located relatively close to buildings. The location of the system and its proximity to other structures is discussed in the next sections.

There are sites where a soil storage and infiltration system should not be installed. For example, installing such a system in heavy clay soil is not a good idea because clay swells when it is wet and shrinks when it is dry. This can put stress on foundations and cause major problems.

A system should not be installed where the land slopes toward the building. If the land slopes away from the structure, pumps and additional piping are not necessary and water moving underground will not be trapped by the foundation.

Areas with no slope can be used if the system is designed properly. However, on land that slopes steeply away from the building it is not feasible to install such a system because of the depth of excavation that would be necessary.

Installing a system in an existing landscape also might not be feasible because of the disruption it would cause. It is best to install a system before any landscaping is done.

Selecting a Site

When choosing a location for a soil infiltration system, consider geography, topography, vegetative cover, separation distances, water movement and soil characteristics.

Geographic Location

The geographic location of the site determines the climate and rainfall patterns. Almost any location can be suitable for a rainwater soil storage and infiltration system if it is properly monitored and maintained. In cold climates, there may need to be a cover over the catch basin and insulation around it to keep water from freezing within the system. In the northern United States, systems must be installed below the frost depth if they are to function during the winter.

Topography

Topography is important because rainwater infiltration systems are usually gravity fed. Thus, the surrounding land must slope away from the building and foundation. Otherwise, serious foundation and ponding problems can occur if the soil near the building is periodically saturated.

Vegetative Cover

There should be vegetative cover over the infiltration trenches at all times to help remove moisture from the soil and to prevent erosion. However, it is not wise to have woody plants or trees growing directly over or near the infiltration trenches because their roots are attracted to water and can plug the piping in the system.

Separation Distances

The system must be at the correct separation distance from other objects to protect the structural integrity of nearby buildings and to prevent possible water contamination problems. Table 2 shows the separation distances required by the Texas Commission on Environmental Quality.

Table 2. Separation distances between rainwater soil storage and infiltration systems and other site features (adapted from TableX of Title 30 TAC Chapter 285, TCEQ 2005).

Distance from	to soil absorption systems (feet)
Public water wells[1]	150
Public water supply lines[1]	10
Wells and underground cisterns	100
Private water lines	10
Wells (pressure cemented or grouted to 100 ft. or pressure cemented or grouted to water table if water table is less than 100 ft. deep)	50
Streams, ponds, lakes, rivers and creeks (measured from normal pool elevation and water level); salt water bodies (high tide only)	75
Foundations, buildings, surface improvements, property lines, easements, swimming pools and other structures	5
Slopes where seeps may occur	25

[1] For additional information or revisions to these separation distances, see Chapter 290 of this title (relating to Public Drinking Water).

Onsite wastewater treatment system separation distances can be observed as a conservative measure to ensure safe operation of the system. Limited guidance is currently available for separation distances from soil storage and infiltration systems to landscape features and drinking water system components. Therefore, separation distances associated with onsite wastewater treatment systems are shown in Table 2.

The proper separation distance between the infiltration trenches and structures depends on the soil texture, the soil moisture, and the subsurface hydrology of the site. In areas where infiltration is rapid (sandy soils) and moisture is transported away from the foundation, infiltration trenches may be as close as 5 feet from a structure. In areas with clayey soils, greater distances will be necessary, if an infiltration system can be used at all.

A distance of at least 25 feet downslope from foundations is suggested by Applied Ecological Services, Inc. in their Fulton Neighborhood Rainwater Management Fact Sheets (2002).

Water Movement and Soil Characteristics

To accurately design an infiltration system you must know the water movement (where the water is coming from and where it will go) and soil characteristics of the site.

Soil texture (which affects permeability) and soil profile influence water movement. A soil's textural class is determined by the sizes of the inorganic particles (sand, silt and clay) it contains and the percentage of each size particle.

Figure 2 shows the soil texture triangle with the different soil classifications. Sands have very coarse particles, while silty or clayey soils have very fine particles. Sandy soils are permeable, which means that water moves through them rapidly. Soils with lots of clay or silt restrict the movement of water.

Acceptable soils for a soil storage and infiltration system include sand, loamy sand, sandy loam and loam; all others are considered impermeable and should be avoided (EPA, 1999).

It is also important to know the profile of the soil in the area where you plan to install an infiltration system. A cross section of the ground may show layers of different soil textures. The most restrictive layer will determine the quantity of water that will infiltrate into the soil.

Table 3. Soil particle sizes (USDA, 1993).

Soil Particle	Particle Diameter (mm)
Gravel	>2.0
Sand	0.05 – 2.0
Silt	0.002 – 0.05
Clay	< 0.002

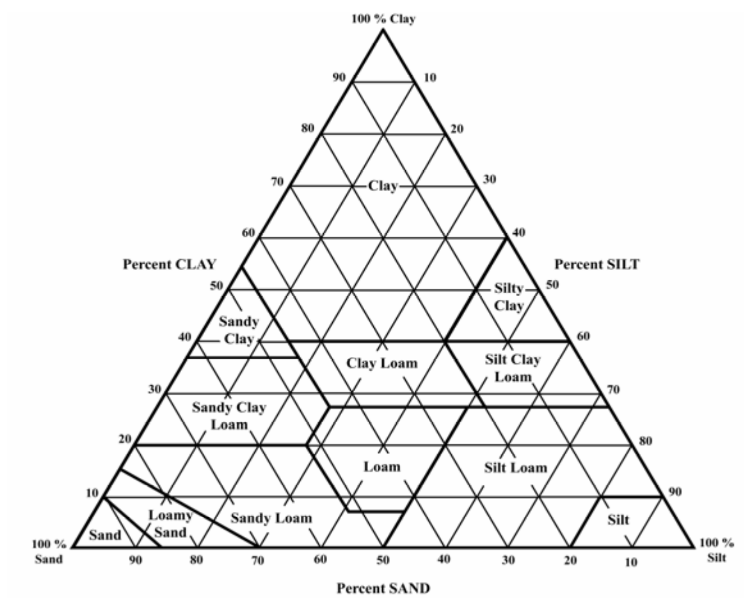

Figure 2. Soil texture triangle (USDA, 1993).

There must be at least 2 feet between the bottom of the infiltration trench and an impermeable layer or groundwater. To make sure a site is suitable, dig an observation hole 2 feet deeper than the bottom of the proposed infiltration trenches. Then look at the different horizons of the soil profile and note any impermeable layers and any gray soil colors that may indicate the presence of groundwater.

You can look up the soil texture and soil profile in your area in the Natural Resource Conservation Service (NRCS) Soil Survey Reports (available at your county Extension office). Or, you might seek help in analyzing your site from someone with advanced knowledge of soils, such as an NRCS employee.

System Design

Catchment Area

The catchment area for any type of rainwater harvesting system typically consists of an impervious surface from which the rainwater runoff is collected. The size of the catchment area affects the volume of runoff that can be collected.

Although it depends upon the roofing materials, about 75 to 95 percent of the rain that falls can be collected from a typical home with a sloped roof (Persyn, 2004). Figure 3 shows the relationship between catchment size and the volume of runoff that can be collected from a 1-inch rain.

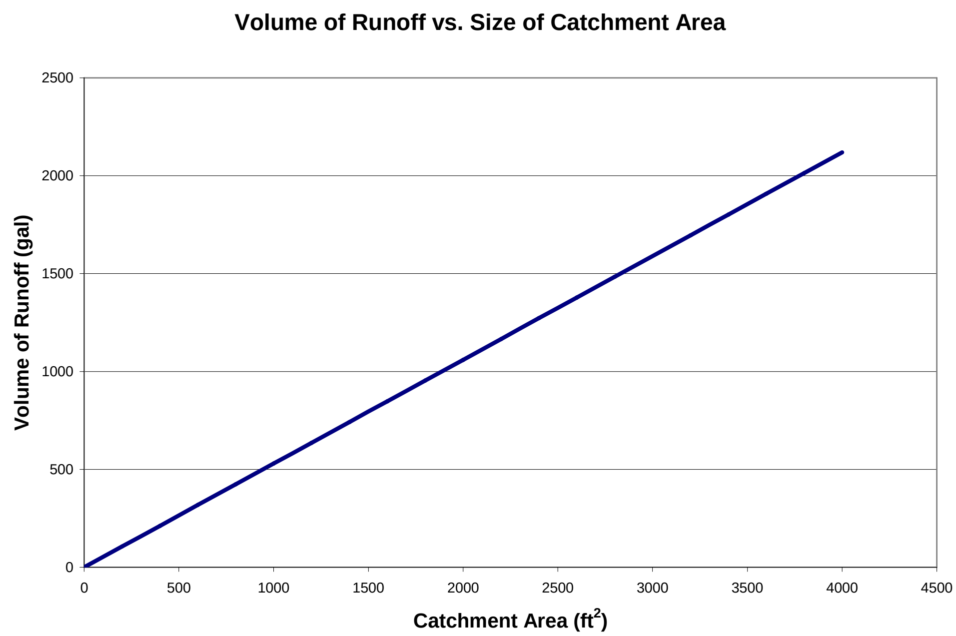

Figure 3. Relationship between catchment size (ft2) and runoff volume (gal) (assuming 85 percent of the runoff is collected from a 1-inch rain).

Guttering

Guttering will typically consist of conventional roof gutters that collect and transport rainwater from the edge of the roof to the downspouts. Water flows through the downspouts to the ground or to the next component in the rainwater harvesting system.

Debris Removal

If the runoff contains fine particles, a roof washer may need to be installed, usually between the guttering and the catch basin. Roof washers vary in complexity and components. A roof washer available for purchase consists of a tank (30 to 50 gallons) with a leaf strainer and screen inside. Another type is called a “poor man’s” roof washer (Fig. 4). It consists of a PVC standpipe and a removable cap, and works by collecting the first flush of a storm event. Once the stand pipe is filled with water, the water then flows through the downspout. After a rain, the water in the standpipe must be drained to prepare for the next rain.

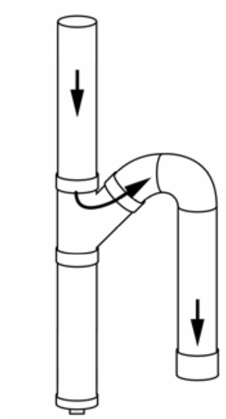

Figure 4. Diagram of a “poor man’s” roof washer.

If a roof washer is not installed, the catch basin is the first component specific to the rainwater soil storage and infiltration system. It should be designed to slope away from the building so that water flows easily away from the building when the system is full. The catch basin should have a removable, screened grate that allows water to enter while filtering out large debris.

Trench Options

The trenches store rainwater until it infiltrates the surrounding soil. These trenches can be constructed in various configurations using different materials.

Gravel trench with perforated pipe. In the onsite wastewater treatment system industry, a gravel trench with perforated pipe is one of the most common methods of applying wastewater to the ground for final treatment and dispersal. It is simple and easy to construct. The same kind of gravel trench and pipe system also will work for rainfall storage and infiltration. The perforated pipe conveys water down the trench and it is stored in the porous gravel. Figure 5 shows the layout of a gravel trench with pipe system.

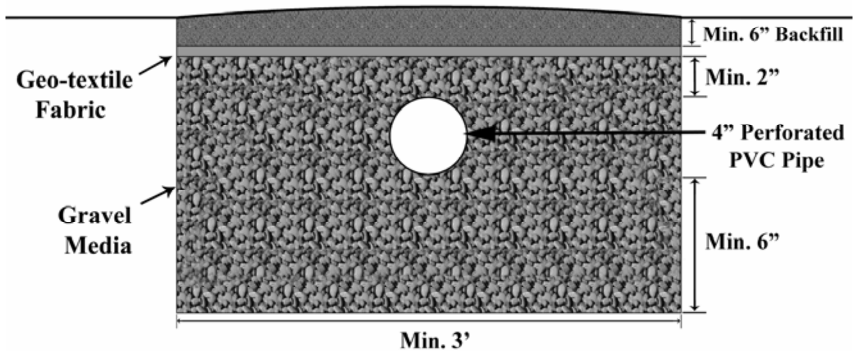

Figure 5. Trench construction using a gravel media with perforated pipe.

The gravel used should be a stone aggregate of 1 to 3 inches in diameter. This size gravel has a void space of 30 to 35 percent. A layer of gravel at least 6 inches deep should be placed along the bottom of the trench. The perforated pipe should be located in the middle of the excavation and it should be covered with at least 2 inches of gravel. A geo-textile fabric should then be placed over the top of the gravel to help keep soil from clogging the media. The trench should be backfilled with at least 6 inches of native soil and slightly mounded to facilitate drainage.

Leaching chamber. Figure 6 shows the proper layout of the trench when a leaching chamber is used. The same size gravel used with a perforated pipe (1 to 3 inches in diameter) should be used with a leaching chamber. A layer of gravel at least 6 inches deep should be placed along the bottom of the trench.

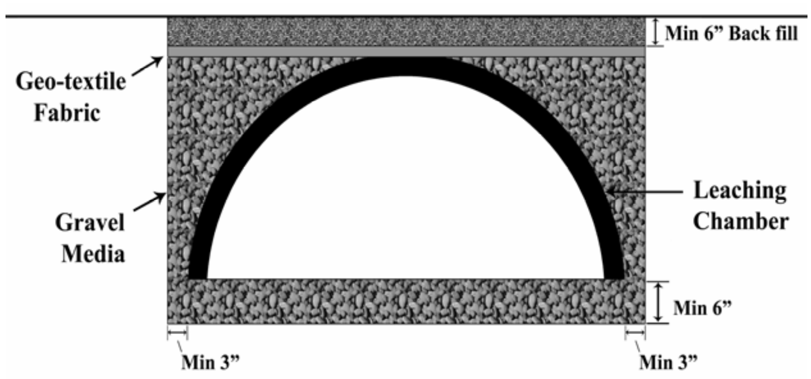

Figure 6. Trench construction using a leaching chamber.

The trench should be at least 6 inches wider than the chamber and the chambers are placed in the middle of the excavation. Gravel should be backfilled to the top of the chamber and then a geo-textile fabric placed over the top of the gravel. The trench should then be backfilled with at least 6 inches of native soil and slightly mounded to facilitate drainage.

Polystyrene media trench. Another method of water storage uses polystyrene media (Fig. 7). Each bundle of polystyrene media (peanuts) is 12 inches in diameter. With that information, the storage volume per foot can be calculated based on the media's porosity. Equation 3 can be used to determine the length needed. The trench is constructed with packaged polystyrene media in the same way as the gravel trench with perforated pipe.

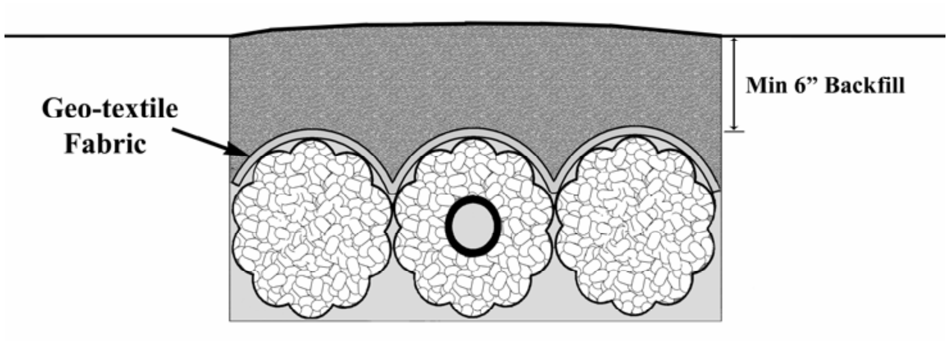

Figure 7. Trench construction using polystyrene media.

Observation port. It is necessary to have an observation port so you can observe what is happening with the water under the ground. Figure 8 describes the observation port and its placement in the system. An observation port should be located at the end of each trench excavation. Ports should extend from the bottom of the excavation to the soil surface and have removable caps for making inspections.

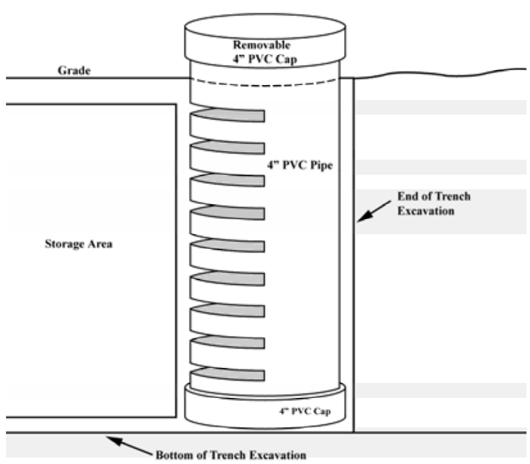

Figure 8. Placement of an observation port in a soil storage and infiltration system (drawing not to scale).

Required storage volume. The most important factor in designing a system is the volume of water that needs to be stored. This will be determined by the size of the catchment surface area (roof area) and the amount of runoff you want to capture. Table 4 shows the trench lengths necessary to capture various amounts of runoff from various sizes of catchment areas.

Use Equation 1 to determine the volume of water expected during a certain size storm.

Equation 1:

$$\text{Roof area (ft}^2\text{) contributing to downspout} \times \frac{\text{Rainfall (in)}}{12\frac{\text{in}}{\text{ft}}} \times \text{Runoff coefficient} = \text{Total volume (ft}^3\text{)}$$

The runoff coefficient is the percentage of total rainfall that can be captured from a particular surface. The higher the runoff coefficient, the less absorbent the surface is. Table 5 shows runoff coefficients for different catchment surfaces.

Table 5. Runoff coefficients for common catchment surfaces (from Persyn, 2004).

Run-off Coefficients		
Character of Surface	**High**	**Low**
Roof		
Metal, gravel, asphalt shingle	0.95	0.75
Paving		
Concrete, asphalt	0.95	0.70
Brick	0.85	0.70
Gravel	0.70	0.25
Soil		
Flat (2% or less), bare	0.75	.20
Flat (2% or less), with vegetation	0.60	0.10
Lawns, Sandy Soil		
Flat (2% or less)	0.10	0.05
Average (2% to 7%)	0.15	0.10
Lawns, Heavy Soil		
Flat (2% or less)	0.17	0.13
Average (2% to 7%)	0.22	0.18

Most people will use Table 4 to estimate trench length. With advanced knowledge, the following calculations can estimate length of trench.

If chambers are being used, use Equation 2 to determine the number of chambers needed per downspout.

Equation 2:

$$\text{Total volume (ft}^3) \div \text{Volume (ft}^3) \text{ per chamber} = \text{Number of chambers per downspout}$$

If any other system is used, use Equation 3 to determine the length of the storage needed.

Equation 3:

$$\text{Total volume (ft}^3) \div \text{Volume (ft}^3) \text{ per length of storage} = \text{Length of storage per downspout}$$

Table 4. Relationships between rainfall depth, types of storage, roof area, and required trench length.

Rainfall depth (in)	Type of storage	Roof area contributing to a downspout (ft^2)							
		500	1,000	1,500	2,000	2,500	3,000	3,500	4,000
		Corresponding trench length (ft)							
0.5	Gravel Trench[1]	20	39	59	79	99	119	138	158
	Leaching Chamber[2]	3	6	9	12	15	18	21	24
	Polystyrene[3]	26	51	76	101	126	151	176	201
1	Gravel Trench[1]	40	79	119	158	197	237	276	315
	Leaching Chamber[2]	6	12	18	24	30	35	41	47
	Polystyrene[3]	51	101	151	201	251	301	351	402
1.5	Gravel Trench[1]	59	119	178	237	296	355	414	473
	Leaching Chamber[2]	9	18	27	35	44	53	62	70
	Polystyrene[3]	76	151	226	301	376	452	527	602
2	Gravel Trench[1]	79	158	237	315	394	473	551	630
	Leaching Chamber[2]	12	24	35	47	59	70	82	94
	Polystyrene[3]	101	201	301	401	502	602	702	803
2.5	Gravel Trench[1]	99	197	296	394	492	591	689	787
	Leaching Chamber[2]	15	30	44	59	73	88	103	117
	Polystyrene[3]	126	251	376	502	627	752	878	1003
3	Gravel Trench[1]	119	237	355	473	591	709	827	945
	Leaching Chamber[2]	18	35	53	70	88	105	123	140
	Polystyrene[3]	150	301	452	602	752	903	1053	1204

Assumptions:

85 percent of runoff is captured.

1 Porosity of gravel: 30 percent
Cross-sectional area of gravel trench: 3.0 square feet

2 Cross-sectional area of leaching chamber: 6.07 square feet

3 Porosity of polystyrene: 30 percent
Polystyrene trench contains 3 bundles, each 12 inches in diameter
Cross-sectional area of polystyrene: 2.35 square feet

Installation

Do not install a soil storage system during periods of heavy rain. Use the lightest equipment available to reduce compaction in the landscape.

Track equipment is preferred over wheeled equipment when the soil is wet because its weight is more distributed, which reduces compaction. Subsoil compaction will dramatically change the characteristics of the soil and decrease the soil's ability to transport water.

Proper construction of the trench is critical to the success and useful life of the system. The bottom of the trench should be level to within 1 inch over 25 feet or within 3 inches over the entire length of the excavation. This will ensure that water does not back up in the system before the desired volume of water enters the storage area.

The soil backfill over the trenches should be slightly mounded to allow for settling, to direct water away from the trench, and to ensure that ponding does not occur.

Operation and Maintenance

Proper operation and maintenance of the rainwater soil storage and infiltration system are important to its long-term performance. If there is a roof washer, it must be cleaned periodically. Otherwise, the screen may become clogged and restrict the flow of water.

The screen grate over the catch basin should be removable so it can be cleaned easily. All deposited material or floating debris should be removed from the catch basin. In a cold climate, there may need to be a cover over the catch basin screen to keep water from entering the system where it can freeze and cause problems. The cover will also restrict the movement of cold air into the system to limit the freezing of the soil surrounding the trench.

Once the project is completed, no vehicular traffic should drive over any part of the system. Large voids in the soil created by chambers or other forms of water storage decrease the weight that the soil can support. Vehicular traffic can increase compaction and even cause cave-ins.

The inspection port at the end of the excavation should be checked regularly to ensure that water is infiltrating the soil and is not ponding in the trench for extended periods after a rain. The system should be cleaned out on an as needed basis and monitored regularly. Monitoring means checking all components to ensure that they are functioning properly and as designed. Regular monitoring and periodic cleaning of the roof washer and catch basin will prevent sudden failure of the system and ensure a long system life.

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