Rain Tanks / Cisterns Design Model

OVERVIEW

The Rainwater Harvester 2.0 was developed by Matthew Jones, BAE Stormwater Engineering Group, Biological and Agricultural Engineering Department, North Carolina State University can be used for the sizing of cisterns in Nashville. The model, user manual and local data can be found at http://www.nashville.gov/stormwater/LIDManual.asp and current water/sewer rates for return-on-investment analysis can be found at http://www.nashville.gov/water/rate_schedule.asp .

The model, updates, and the original user manual can also be found at http://www.bae.ncsu.edu/topic/waterharvesting/model.html.

RAINWATER HARVESTER 2.0 INSTRUCTION SUMMARY

Step 1: Site Characteristics

Before using the Rainwater Harvester Model to determine an appropriate cistern size, determine the general effectiveness of this BMP for treating an existing water quality concern or removing the required volume of runoff.

Specific information necessary to utilize this Model includes:
- Rooftop drainage area
- Water use type (what will the cistern water be used for)
- Water use demand (how much water will be needed) in gallons / day

Step 2: System Design Tab Inputs – Figure at the Right

- <u>Rainfall Input File</u> – click "browse" and navigate to the daily rainfall file for Nashville stored on your computer: NashvilleDaily.csv
- <u>Roof Area</u> – enter total contributing roof area in square-feet
- <u>Capture Factor</u> – use 0.95 for Nashville rooftops
- <u>City</u> – choose "other" and fill in the Water and Sewer cost (see page 4 on calculating these numbers)
- Ignore nitrogen factor (leave at 1.5) for the present
- Fill in the water quality capture depth. The default is 1". The program will calculate the actual percent annual capture – this is the value to be used in total volume capture for site design.
- <u>Cistern Volume</u> – A trial sizing value must be entered here. Fill in an estimated size based on contributing roof area; a good starting point may be 1 gallon per 1 square foot.

- <u>Cistern Cost</u> – A value must be filled in here, but it does not impact the model outputs. It is used for return on investment analysis.
- <u>Backup Water Supply</u> – This is typically NOT checked. It is only used for designs where potable water is must be used as a backup system to fill the cistern for critical use (e.g. irrigation of commercially grown plants).

Step 3: Water Usage Model Inputs

Accurate water usage data is essential. Ideally, water usage measurements should be collected at the location where the cistern will be installed. These usage estimations can be collected with a variety of inexpensive flow metering devices. A good estimate for the flow in a residential garden hose is 8-10 gallons/minute.

Fill in water usage data on the appropriate tab; "Basic Usage", "Custom Usage" or "Irrigation". The information input on all tabs will be used to simulate situation.

- Basic Usage tab should be utilized if the cistern will be used to flush toilets, or if you have data on how many gallons will be used per day (consistently). Do not use the Basic Usage tab for gallons per day in a given month. This refers to a constant source of water.
- Custom Usage tab should be utilized if you have data on how many gallons will be used per week (consistently on a given day). This is the most commonly used.
- Irrigation tab should be utilized if cistern will be used for irrigation;
  - Load PET data (button on right – Nashville PET data is in the file Nashville-PET.pet)
  - Irrigated Area – enter total area in square feet that will be irrigated
  - Irrigation System – choose from drop down list – this will fill in Irrigation Efficiency
  - Soil Texture – select a soil texture and this will load the Plant Available Water
  - Irrigated Crop – select from the drop down list – this will fill in Effective Root Depth
  - Allowable Water Depletion can be customized, based upon how dry the crop will be allowed to become prior to irrigation (default setting is 50%)
  - Months of Irrigation – select these based upon landowner guidance

Step 4: Model Simulation

Select "Output" tab (far right) and click "Simulate" in lower right-hand corner.

The desired outputs are when the frequency of a dry cistern is balanced with the frequency of the cistern overflowing. The cistern may be too small if Usage Replaced and Total Volume Captured are low and Overflow Frequency is high. The cistern may be too big if Dry Cistern Frequency and Overflow Frequency are close to zero and Usage Replaced and Total Volume Captured are close to 100%. The GOAL is to determine the best scenario for the least amount of money. It is recommended to run the model several times, changing the cistern volume, to find the optimal situation (you may wish to chart the 4 major outputs, based on cistern size).

Step 5: Output

Once a compromise has been reached between system design and cost and an appropriate size has been determined you can save your Output by clicking on the button at the bottom of the Outputs tab. This will allow you to Save the

Excel file to a location on your computer. Please note that ONLY the 1st page of the file should be printed (the file is many pages).

Of significant concern to meeting Nashville's design standard is to understand the average annual volume reduction from the cistern (not the site). To obtain the total reduction from the rooftop cistern combination you must take into account the "Capture Factor" of the roof. The default value is 0.95 which is equivalent to an Rv factor for the rooftop. The first value in the Outputs Tab is the percent of inflow that is captured and reused by the cistern-use combination.

Using the example at the right where the Total Volume Captured is 64% the total capture is:

$$64\% + 5\% = 69\%$$

The 5% accounts for the average annual rainfall capture on the roof surface.

Other outputs assist in adjusting the design, understanding true costs and cost recovery, understanding the potential need for overflow drainage and supplemental water.

Total Volume Captured: Percentage of total runoff volume the cistern was able to capture without overflow

Usage Replaced: Percentage of total water demand that the cistern was able to supply

Note: The total volume captured and usage replaced serve as quick indicators of how well the cistern performs with regards to water quality and water supply

Annual Water Usage: Average amount of water used from the cistern in a given year

Annual Water Savings: Average amount of monetary savings from using the cistern to replace municipal water supply

Ann. Backup Water Usage: Average amount of backup water supplied to the cistern in a given year

Ann. Backup Water Cost: Cost associated with obtaining backup water from municipal sources
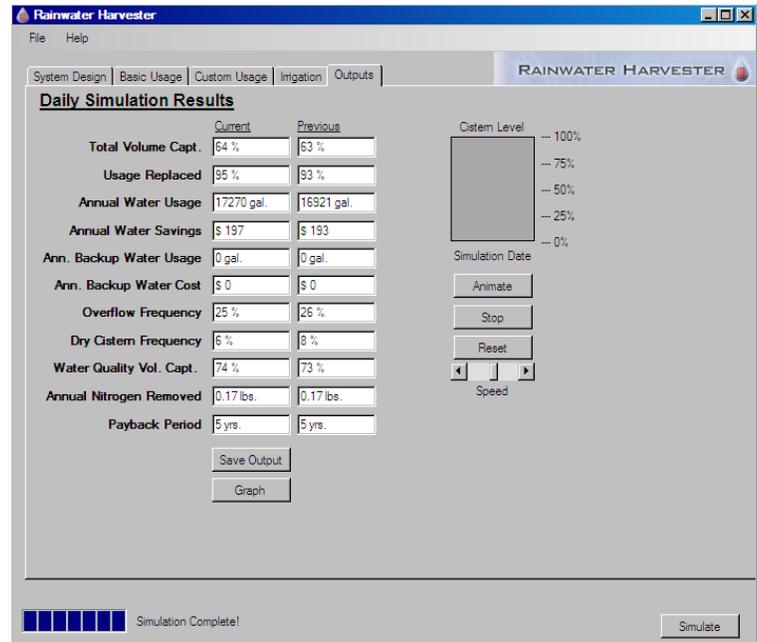
Overflow Frequency: Percentage of rainfall events that resulted in overflow from the cistern

Dry Cistern Frequency: Percentage of days when there was a water demand, but not enough water stored in the cistern to meet that demand

First Flush Volume Captured: Percentage of runoff volume associated with the first flush rainfall depth that the cistern was able to capture without overflow

Annual Nitrogen Removed: Weight of nitrogen removed from runoff, assuming that all nitrogen captured by the cistern is removed via the cistern itself or subsequent water usage

Payback Period: Number of years of water use required for total water savings to equal the cost of the cistern

CALCULATING WATER AND SEWER COST

Overview

Water and sewer rates are based on a flat rate charge for a minimum consumption of 200 cubic feet. It is assumed that the comparable costs are the unit costs above this flat rate are based on the incremental costs per 100 cubic feet of water and sewer (i.e. we are working on the marginal use not within the base rate).

From April to November, customers' bills are automatically adjusted to reflect a sprinkler credit. The winter quarter average (January, February, and March) plus 30% will be the maximum sewer charges billed for the April to November time frame.

Water and Sewer Cost

Water cost has a 9 ¼% sales tax. Sewer cost has a 10% add-on for recovery of state loans. These are factored into the cost in the table below. However, for years beyond 2011 please see the web site for current rates.

Table 1. Customer Class Determination

Class	Anticipated/Historical Usage
Residential	Up to two housing units on a common meter
Small Commercial and Industrial	Up to 1,600 cubic feet per month
Intermediate Commercial and Industrial	1,600 to 200,000 cubic feet per month
Large Commercial and Industrial	Over 200,000 cubic feet per month

Table 2. Customer Class Charges Per 100 Cubic Feet/ Per Gallon

Category	Water Charge	Sewer Charge	Total Charge
Residential	$2.546/$0.0034	$5.214/$0.0070	$7.760/$0.0104
Small Commercial	$2.709/$0.0036	$5.830/$0.0078	$8.539/$0.0114
Intermediate Commercial	$2.338/$0.0031	$4.752/$0.0064	$7.090/$0.0095
Large Commercial	$1.977/$0.0026	$3.586/$0.0048	$5.563/$0.0074