User's Guide for

RAINFAL

(**R**ainwater **A**ssessment and **I**nteractive **e**Numator for **F**irm-yield **A**nalysis **L**imits)

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version: 2025-05

see appendix for log on previous versions

Download RAINFAL: meadowscenter.txst.edu/research/water-conservation/rainwater-firm-yield

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Introduction

This document describes how to use RAINFAL, the Rainwater Assessment and Interactive eNumator for Firm-yield Analysis Limits. RAINFAL allows a user to design a rainwater harvesting system and assess the reliability, including being able to design a system with a firm yield that will provide water through the worst drought of record. RAINFAL is an Excel spreadsheet-based model that uses daily rainfall data and user-assigned values for catchment, storage, and daily use to assess reliability. The version number above is also reflected in the spreadsheet name to ensure you are using the appropriate user's manual with the appropriate spreadsheet. The purpose of this document is to explain the use of RAINFAL. Note that we are maintaining this guide as a separate publication from Briones and Mace (2025) so we can provide updates to the spreadsheet (such as corrections, data extensions, and increased functionality) without needing to update the original publication. Note that Briones and Mace (2025) is based on Briones (2023) but that Briones and Mace (2025) added functionality to the Briones (2023) version of RAINFAL, namely (1) a first flush volume scaled to catchment area instead of a set value and (2) additional calculations to inform the user.

Overview of the "Front" Page

RAINFAL consists of two sheets, one named "front" (for front office) and one named "back" (for back office). Casual users will only need to use the "front" page. None of the cells are protected from overwriting to allow more advanced users to add their own functionality. For example, I have modified this version of RAINFAL for Cloudcroft, New Mexico, to allow the user to define which days water is used over a year.

Items in red are items that the user can change. Items in black should be left alone unless you are an advanced user. Numbers in black are calculated while numbers is red are user defined. There is a section titled "user-adjusted parameters" where the casual user can adjust numbers, although there are also numbers the user might change under "conversions & calculations."

Cell D3 shows the version number of the spreadsheet.

Cell A4 shows the location that the RAINFAL spreadsheet is focused on.

Cell B5 is the name of the weather station the precipitation data sourced. Cells B8, B9, and B10 will be the cells most adjusted by casual users.

Cell B8, Ar, is the catchment area in square feet. Note that catchment area is different than roof area (unless you have a flat roof). Catchment area is the effective area exposed to precipitation.

Cell B9, Vt, is the volume of storage in your tanks in gallons.

Cell B10, daily demand, is the daily demand in gallons per day.

Cell B11, runoff coefficient, is the runoff coefficient and is unitless. This is the fraction of the rain that makes it to the first flush in your system. The default here, 0.92, is for a metal roof, which means that, on average, 92 percent of the rain that falls on the roof makes it to the first flush in your system. Average runoff coefficients for other catchment types are 0.84 for clay tiles, 0.91 for polycarbonate plastic, and 0.62 for flat gravel (Farreny and others 2011); 0.9 for asphalt shingles and concrete, and 0.8 to 0.85 for tar and gravel (Downey and others 2009); and 0.23 for green roofs (TWDB 2010).

Cell B12, precip adjuster, is the precipitation adjuster and is unitless. The default here is "1" such that the precipitation is not adjusted. If, for example, you wanted to design a rainwater harvesting system for Dripping Springs and there is no long-term precipitation available for the community, you can use the precipitation adjuster to adjust the long-term average of Austin's precipitation down to Dripping Springs' long-term average. The long-term average rainfall for Dripping Springs is 35.74 inches, while Austin's long-term average is 36.25 inches. Therefore, Dripping Springs receives 98.6 percent of Austin's rainfall (100*[35.74/36.25]). That means the precip adjustment should be 0.986 (35.74/36.25). The precip adjuster can also be used to adjust rainfall down and up to investigate wetter or drier conditions for a particular location.

Cell B16, Vt, is the automatically calculated volume of storage in cubic feet.

Cell B17, Vff, is the automatically calculated volume of the first flush in cubic feet. This calculation assumes 10 gallons of first flush per 1,000 square feet of roof area. If you want to change this to a different number of gallons per 1,000 square feet, you can change the equation in the cell by replacing the "10" with a different number. If you override the equation, be sure to convert your volume to cubic feet (divide gallons by 9.48 to arrive at cubic feet).

Cell B18, daily demand, is the automatically calculated volumetric flux of the daily demand in cubic feet per day.

Cell B19, starting tank storage, is how full, in percent, the tank starts off in the model. The default is 50 percent. The reason this is here is because when you adjust catchment, storage volume, and daily use, you want to see what the lowest storage is in the tank. If you start the tank empty, then your lowest storage will always be zero. This is also here to see how the initial condition of the tank influences your results. Sometimes during a simulation, the results may depend wholly on your initial condition for water in the tank, and that's not good. At one point, we automated the starting tank volume as the longterm average of tank storage; however, this increased calculation time in the spreadsheet and increased instability.

Cell B20, starting tank storage, is the automatically calculated starting tank storage in cubic feet.

Cell B21, dead pool, is what fraction of the tank is reserved for the dead pool. The dead pool refers to the storage at the bottom of the tank that you do not plan on using. In surface-water reservoirs, the dead pool is often reserved for accumulated sediment. The same is true, although to a lesser degree, for rainwater harvesting tanks. The dead pool storage is the target storage for assessing firm yields. In other words, when you calculate a firm yield, you ensure that your lowest storage level doesn't fall below the dead pool amount. Just as in surface-water reservoirs, you can consider the dead pool emergency use, although it may require some engineering to access the last of the water.

Daily precipitation data is also included on the "front" sheet in **Column E (date)** and **Column F (precipitation)**. The date is in a Julian number format, while precipitation is reported in inches. Column G is adjusted precipitation in inches. This column is adjusted with the value in Cell B12, the precip adjuster. With the precip adjuster set to "1," the values in Column G will match the values in Column F.

The upper part of columns I through U holds a plot of the volume of water in storage in the tanks in gallons on the vertical axis versus time on the horizontal axis. We provide this plot so you can see how your system performs and to make sure RAINFAL is operating correctly. You might also use the plot to optimize your tank to your willingness to haul water when your tank goes dry. In other words, you might be willing to haul water once every 30 years if it saves you 10,000 gallons of storage. If you hover your mouse over a data point when the graph is not otherwise selected, you can see both the value and the date to which it applies.

Underneath the plot are several automatically calculated parameters related to your system inputs.

Cell K27, dead pool storage, is the dead pool storage expressed in gallons. This is generally the target for storage in the tanks to not go under.

Cell K28, lowest storage, is the lowest storage calculated over the historical record given your inputs. This value is the one you compare to dead pool storage. This is also where you have to be careful that your initial storage is not below the dead pool storage.

Cell K29, reliability, is the percent of all the days in the record that you meet your daily demands.

Cell K30, days with no water, is the number of days you do not have water in your tank. For a firm yield, you want this to be zero.

Cell K31, overflow, is how much water overflows out of your tank in gallons. This is provide for general interest (an optimized reliable system will tend to spill a lot of water), but it is also important when designing systems in drier climates (you can see what you have left to capture).

Overview of the “Back” Page

Most users will never have to look at the back page. This where all the calculations are made.

Column A, date, is simply the date copied from the “front” page.

Column B, precipitation, is the adjusted precipitation converted to feet of rain. **Column C, Vr,** is the volume of rain that fell and ran off the roof that day in cubic feet. **Column D, Vff,** inserts the volume of the first flush, in cubic feet, if it rained that day.

Column E, Vff v. precip, adjusts the volume of the first flush to be equal to the volume of rain that ran off the roof if that volume is less than the volume of the first flush otherwise the volume here is equal to the first flush.

Column F, Vr-Vff-daily demand, is the volume of rain that ran off the roof that day minus the volume of the adjusted first flush (the value under Vff v. precip) minus the volume of use that day, all in cubic feet. If the first flush fully consumes the rainfall that runs off the roof, then this value is simply the daily demand.

Column G, Vr v. 0, ensures that the daily demand for water from the tank doesn’t exceed the volume of water in the tank. If this is the case, this column sets the daily demand to no more than the volume of water in the tank and, if the tank is zero, sets the daily demand to zero.

Column H, water in storage, is the total volume of water in storage in the tank in cubic feet. The equation includes a check on the limiting maximum volume in the tank compared to the tank volume.

Column I, water in storage v. zero, is simply Column H in gallons.

Column J, Is tank empty?, is a logic test that assigns a value of “1” if the tank is empty and a value of nothing if the tank has water in it.

Column K, overflow, calculates how much water overflowed out of the tank in cubic feet.

Cell M2, total # of days, is a count of all the days in the record.

Cell M3, total number of empty days, is a count of all the days in the record during which the tank runs dry.

How to use RAINFAL

For many users, all you need to change are the values in cells B8 (Ar, catchment area), B9 (Vt, volume of storage), and B10 (daily demand), and then kick back and watch the resulting numbers and graph.

Let's say you have an existing system and you want to calculate your firm yield. And let's do this for my non-potable system in Austin. The area of my catchment is 440 square feet, the size of my tank is 5,000 gallons, the volume of my first flush is zero, and I don't have a dead pool. So I put in 440 for catchment area, 5,000 for storage, 0 for volume of first flush, and 0 for dead pool. I then input different numbers for daily demand until I found that 15.2 gallons per day of use kept the tank from going dry (it leaves 85 gallons left during 1957).

Let's say I have a roof of 2,000 square feet and need enough water for two water-efficient people in Austin. I input 2,000 square feet for the catchment, 50 gallons per day to meet the water needs for two people, and return the equation to calculate the first flush and set the dead pool at 5 percent. I now adjust the volume of the storage until I optimize the daily use so that it is just above the dead pool storage. This results in a tank size of 7,900 gallons with a low storage of 400 gallons in 1971, just above the dead pool storage of 395 gallons.

Tanks tend to come in standard sizes, so if I install this system, the tank will probably be 10,000 gallons. How much more daily water use can I support with that tank size? RAINFAL says 54.4 gallons per day.

Appendix: Version Log

2025-05: Original version released to the public

- Changed daily demand from a person-based calculation to a gallons per day entry
- Added the precip adjuster
- Changed “starting tank storage” from an entered volume to a calculated volume based on an entered percent
- Changed volume of the first flush to one scaled by roof area (10 gallons per 1,000 square- feet) from a fixed volume of 6.68 cubic feet
- Added reliability, days with no water, and overflow.

2023: Original version (Briones 2023)

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