Stormwater Design Guidance – Rainwater Harvesting

The Maryland Department of the Environment (MDE) updated **The 2000 Maryland Stormwater Design Manual**[1] (The Manual) in 2009 to establish the minimum performance criteria for all environmental site design (ESD) practices. These practices include rainwater harvesting systems, which typically use a storage device such as a cistern, rain tank, or rain barrel for capturing rainfall for future use. In Maryland, indoor use is typically limited to non-potable water supply such as toilet flushing, cleaning, and laundry washing. The most common outdoor use for rainwater harvesting is for irrigating landscaped areas.

When rainwater harvesting is proposed for stormwater management, the Manual requires that water supply and demand calculations demonstrate that captured rainwater will be used prior to the next storm event. While a detailed supply and demand analysis is not needed in most typical residential systems (e.g., less than 150 gallons) this is an essential consideration for larger systems. This guidance will provide an acceptable approach for submitting water supply and demand calculations to determine the volume credited toward ESD requirements. The following guidelines should also be considered during the design and review of these projects:

- Sufficient demand is needed for dewatering the tank in between rainfall events.
- The full tank volume may be credited toward the ESD volume when there is enough demand to completely dewater the tank 72 hours after a rainfall event.
- Rainwater harvesting may be combined with a down-gradient practice to dewater the tank and create more storage for ESD. These practices may include rooftop disconnection, sheetflow to vegetated buffers, or discharging into other ESD micro-scale practices.
- Stable discharge of flow dewatering from the system needs to be provided.
- When the system cannot be completely dewatered, the available volume within the rain tank in between storms is the storage that can be used for (ESD) treatment. The credit will be based on the supply and demand calculations described below.

Water Balance using Supply/Demand Calculations

A water balance is provided below (see Table 1) to show the flow of rainwater into and out of a rainwater harvesting system. The calculations are based on average monthly rainfall (supply) and average monthly water use (demand). The cumulative storage provided in a rain tank through the month minus the demand will yield the total storage at the end of the month.

The example in Table 1 uses a 20,000 gallon cistern to store rainfall collected from a 12,000 square foot commercial storage and office building. Harvested rainwater will be used for irrigating 0.15 acres of landscaping and for flushing toilets in the building. The building will be occupied by 150 employees for 260 days per year. Rainfall is expressed as a monthly average based on historical data (Column B). For the most accurate and current data, MDE recommends using information available from the National Climatic Data Center obtained from the National Oceanic and Atmospheric Administration (NOAA) website[2].

Estimating Supply

The amount of rainwater collected is estimated by multiplying the monthly rainfall by the roof area in square feet (sq. ft.) by the collection efficiency. A 95% collection efficiency is estimated to convey the rainfall that lands on the roof surface. The conversion factor of 7.48 gallons per cubic foot (gal/cu. ft.) is also used. Equation 1 below, describes the amount of rainwater collected in gallons by a rainwater harvesting system:

Equation 1. Rainfall Collected:

Rainfall (inches) x Roof area (sq. ft.) x 0.95 x 7.48 gal/cu. ft. x 1ft./12inch. = gallons collected

Rainfall collected (gallons) in Table 1, (Column C), for the month of January is calculated as follows:

> 3.46 inches x 12,000 sq. ft. x 0.95 x 7.48 gal/cu. ft x 1ft./12inch = 20,489 gallons

This number reflects the total cumulative amount of rainfall collected during the month. It does not represent storage provided during an individual day. Therefore, the total rainfall collected over the entire month may be larger than what the system can hold in one day.

Estimating Demand

Designers will need to provide documentation to verify demand estimates for each project. A general rule for estimating irrigation needs in temperate climates is based on one-inch of rainfall per week[3,4]. A quick estimate of the gallons needed per week per acre is provided using Equation 2 below:

Equation 2. Estimating Irrigation Demand:

43,560 sq. ft./acre x 1ft./12inch x 7.48 gal/cu. ft. = gal/week/acre

Using Equation 2, the irrigation demand in Table 1, (Column D), is calculated for the month of July as follows:

> 43,560 sq. ft./acre x 1ft./12inch. x 7.48 gal/cu. ft. x 0.15 acre = 4,073 gal/week
> or 16,291 gal/month

For indoor use the building architect should be consulted for estimating gallons of water used per month. For the example in Table 1, demand is based on 150 employees occupying the building for 260 days per year, using low flow toilets (1.2 gallons per flush) with three flushes per person per day. The gray water demand is calculated in Table 1, (Column E) as follows:

> 150 people x 260 days /year x 1.2 gal/flush x 3 flushes/person/day = 140,400 gal/year
> or 11,700 gal/month.

The remaining columns in Table 1 are calculated as follows:

Column F: The total demand is based on the sum of irrigation plus gray water demand for that month (Column D + Column E = Column F).

Column G: Cumulative storage is determined by adding the end of month storage for the previous month (Column H) to the rainfall collected (Column C) and subtracting the total demand (Column F). If the cumulative storage is greater than 20,000 gallons, then the end of month storage will equal 20,000 gallons because any excess will overflow out of the system.

Table 1. Monthly Average Data

	SUPPLY		DEMAND			WATER BALANCE	
A	B	C	D	E	F	G	H
	Average Rainfall (inches)	Rainfall Collected (gallons)	Irrigation (gallons)	Grey Water (gallons)	Total Demand (gallons)	Cumulative Storage in Tank (gallons)	End of Month Storage (gallons)
Jan	3.46	24,587	0	11,700	11,700	12,887	12,887
Feb	2.84	20,181	0	11,700	11,700	21,368	20,000
Mar	3.79	26,932	0	11,700	11,700	35,232	20,000
April	3.18	22,597	4,073	11,700	15,773	26,824	20,000
May	4.58	32,545	16,291	11,700	27,991	24,554	20,000
June	3.76	26,719	16,291	11,700	27,991	18,728	18,728
July	4.43	31,480	16,291	11,700	27,991	22,216	20,000
Aug	4.05	28,779	16,291	11,700	27,991	20,788	20,000
Sept	4.12	29,277	16,291	11,700	27,991	21,286	20,000
Oct	3.43	24,374	4,073	11,700	15,773	28,601	20,000
Nov	3.3	23,450	0	11,700	11,700	31,750	20,000
Dec	3.27	23,237	0	11,700	11,700	31,537	20,000
Year 1 Totals	44.21	314,156	89,601	140,400	230,001		

Note: Because the installation in the first year begins with an empty tank, it is advisable to perform this analysis for the first two years of use. For the purpose of this example, the analysis for the first year is shown.

The data in Table 1 show that the cistern will be completely full at the end of each month (with the exception of June). Therefore, it appears that there is very little available storage for stormwater management. However, because on average it will rain once every three days, there will be some draw down from the cistern in between rain events, allowing some storage prior to the next rainfall. Therefore, the volume of storage available for each storm is directly related to the amount of water that is drawn down from the cistern in between rainfall events. To determine the volume of storage available per storm event, the total annual demand (sum of Column F) is divided by the average number of storms per year (122 rain storms). The average volume available for ESD storage prior to each rain event is calculated as follows:

Equation 3:

Volume of storage = Sum of Column F/122 storms/yr = 230,001/122 = 1,885 gal
Convert to cubic feet (ESD_v): = 1885 gal / 7.48 gal/cu. ft. = 252 cu. ft.

Equation 3 shows that 252 cu. ft. is the volume that may be applied toward ESD_v. This number overestimates storage for the winter months and underestimates storage during the growing season. However, MDE has determined that the analysis is acceptable as it represents the overall function of the cistern on an annual basis. Local review authorities may ask for additional information to confirm water balance calculations. This may be needed in cases where there are vastly disparate uses of rainwater throughout the year.

Conclusion

The monthly average analysis presented in Table 1 and Equation 3, will remain an acceptable approach for submitting water supply and demand calculations and determining the ESD volume available for stormwater treatment. The example shows that there is a consistent use of rainwater throughout the year, although more intense during summer months. Because each calendar year will bring a different set of conditions and the analysis of daily rain events will vary in results, MDE believes the monthly data are most appropriate for this purpose.

The local review authority may require a comparable or more detailed analysis to support the ESD volume granted for an individual project. In order to gain the most credit toward ESD, the use of the rainwater needs to be maximized. If a project uses the water exclusively for irrigation purposes, then other methods to dewater the system during non-irrigating months may be required. Each system will need to be evaluated on a case by case basis to determine acceptability.

Resources

[1] 2000 Maryland Stormwater Design Manual, Volumes I and II, MDE, October, 2000. (http://www.mde.state.md.us/programs/Water/StormwaterManagementProgram/MarylandStormwaterDesignManual/Pages/Programs/WaterPrograms/SedimentandStormwater/stormwater_design/index.aspx).
[2] National Oceanic and Atmospheric Administration, National Climatic Data Center, Climate Data Online. (http://www.ncdc.noaa.gov/cdo-web/search).
[3] Virginia DCR Stormwater Design Specification No. 6. Rainwater Harvesting, Version 1.9.5, March 1, 2011. (http://vwrrc.vt.edu/swc/NonPBMPSpecsMarch11/DCR%20BMP%20Spec%20No%206_RAINWATER%20HARVESTING_Final%20Draft_v1-9-5_03012011.pdf).
[4] Rainwater Handbook. Conservation Technology. October, 2009. (http://www.conservationtechnology.com/documents/RainwaterHandbook0911.pdf).

Additional information for tank sizing, pumping systems, and design variants:

1. The Texas Manual on Rainwater Harvesting. Texas Water Development Board. Third Edition. Austin, Texas. 2005. (http://www.twdb.state.tx.us/publications/reports/rainwaterharvestingmanual_3rdedition.pdf).
2. Virginia Rainwater Harvesting Manual. The Cabell Brand Center. Second Edition. 2009. (http://www.cabellbrandcenter.org/Downloads/RWH_Manual2009.pdf).
3. Harvesting Rainwater for Landscape Use. Waterfall, Patricia. University of Arizona Cooperative Extension. Second Edition. 2006. (http://ag.arizona.edu/pubs/water/az1052).