Rainwater Harvesting System as an Alternative Water Source

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Abstract

The objectives of this study were to install RCR systems at a typical single family house and a school in Alabama, and evaluate the feasibility and efficiency of using the RCR systems for water harvesting in Alabama. The RCR systemswere equipped with a control system and a CR10X data logger to monitor the system operation and to collect data on precipitation, temperature, overflow, water depth in the storage tank and daily uses of toilet flushing. Daily average water use of the home for toilet flushing was 95 liter and 2100 liter was used at the school during the school days. Rainwater harvesting efficiency was 83.3 and 89 percent and RCR use efficiency was 18 and 98 percent from the home and the school, respectively. A computer program was developed to estimate potential effectiveness of RCR systems. From the analysis result with 10 years rainfall data, a total of 67,000 liters of rainwater could be harvested for domestic uses from a typical single family house which supplies 190 liters per day.

Keywords : Rainwater harvestin, Roof catchment of rainwater, Alternative water source.

1. Introduction

Rainwater harvesting methods are nowadays receiving renewed attention because they can contribute to increased water supplies for agricultural and domestic uses. In the United States, for instance, an estimated 100,000 residential rainwater harvesting systems were constructed primarily for rainwater collection particularly in Arizona, Colorado, and Central Texas (Lye, 1992, 2002 Brown et al., 2005). A Roof Catchment of Rainwater (RCR) system consists of an impervious roof, collection system (gutters, downspouts and conveyance pipes), a storage tank with flow control, a pump with pressure switch, a supplement supply from the existing water supply system, and a separate plumbing. The objectives of this study are (i) to develop and implement RCR systems for a single family house and a public building in rural Alabama to provide an alternative water source for non-potable domestic uses (ii) to monitor water uses, harvested rainwater, excess water overflow, rainfall and temperature (iii) to analysis efficiencies of rainwater harvesting and RCR uses through the measured data and (iv) to determine maximum harvestable rainwater and water use of a single family house RCR system to make better use of the system.

2. Roof Catchment of Rainwater(RCR)

Roof Catchment of Rainwater (RCR) system is a system to capture, divert, and store rainwater for a number of different non-potable water uses; toilet flushing, washing, outdoor cleaning, and landscape irrigation. The first RCR system was installed at a rural single family house 5 miles south of Opelika, Alabama. The system was completed and monitoring started in February, 2007. Second study site is a small private school in north Opelika, Alabama. The

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system was completed in the spring of 2008 and system monitoring started in April, 2008(Case 3). Only one toilet was initially connected to the RCR system at the single family site during initial period of the study, from February 28 to September 28(Case 1). The second toilet was connected to the same RCR system on September 29. 2007(Case 2) (Table 1).

Figure 1. An RCR system installed at a rural single family house (rain gage, control system and datalogger, storage tank, HS flume and gutter).

Table 1. Base information at the single family house(Case1 & 2) and the school(Case 3).

Contents	Case 1	Case 2	Case 3
Number of toilets	1	2	11
Study period	Feb. 28. 2007 Sep. 28. 2007	Sep. 29. 2007 Apr. 15. 2008	Apr. 8. 2008 May 12. 2008
Average use per flush	1.8 gal/flush		2.5 gal/flush
Number of people	Four		250 students and 50 others
Roof size	1,860 sq ft		3,750 sq ft
Tank size / Max. depth	1,550 gallon tank / 1.42m		Two 1,700 gallon tanks/1.64m

3. Monitoring and data analysis

The sites were instrumented to determine amount of harvested rainwater and rainwater bypassed the RCR system per storm event. Also measured is amount of harvested water which is actually used for toilet flushing. A pressure transducer was installed in the tank to measure water depth changes and a 0.8ft-HS flume was used to measure overflow which bypassed the RCR system. CR10X dataloggers(Campbell CSI) are used to measure the data; water depth in tanks and flumes, flow rate from the tanks and water mains, rainfall, and water temperature, etc. The volume of rainwater available from rooftop runoff was determined through measurement of water level changes in the storage tank by following Eq. (1). Rainwater harvesting efficiency and RCR use efficiency are defined as Eq. (2), (3).

$$\textit{Total rainwater available} = \textit{Water use} + (\textit{Water left} - \textit{Initial volume})\ \textit{tank} + \textit{Overflow} \quad (1)$$

$$\textit{Rainwater harvesting efficiency} = \textit{Total rainwater available}/\textit{Total rainfall received on the roof} \quad (2)$$

$$\textit{RCR use efficiency} = (\textit{Total rainwater available} - \textit{Overflow})/\textit{Total rainfall received on the roof} \quad (3)$$

A computer program was developed to calculate RCR use efficiency and daily maximum water-use available (DMWU) from an RCR system. A storage equation (McCarthy, 1938) was employed to calculate DMWU and RCR use efficiency through analysis of daily water balance.

For the water balance analysis in tank storage, Inlet factor is rainwater collected from the roof and outlet factor is supplying water use and overflowed rainwater. Initial amount of water use is assumed and then the amount is subtracted from tank storage of the pervious day until the water use will be the largest amount within ranging of maximum and minimum depths. When an assumed amount meet the minimum depth, the amount is assumed again and exceeds the maximum depth, the excess amount is added as overflow. Finally, the largest amount defines as DMWU.

4. Results and discussions

4.1 A single family house site

Harvesting efficiency in Case 1 was computed at 82.5 percent as the harvested amount was 17,623 gallons of rainwater from the total 21,341 gallons of rainwater that fell on the roof(Table 2). The efficiency of Case 2 was 83.3 percent, computed in the same manner by Eq. (2). This study suggests approximately 83 percent is the harvesting efficiency in a single family house , and this volume is similar to the results shown by Brown (2005), who reported that approximately 0.62 gallons per square foot of collection surface per inch of rainfall can be harvested. Most rainwater harvesting system installers often assume an efficiency of 75 percent to 90 percent (Brown, 2005). Despite the acceptable harvesting efficiency, RCR use efficiency was computed with 6.3 and 18 percent using Eq. (3) in Case 1 and 2, respectively. Overall, just 20 percent of the water obtained from the RCR system was used, even though over 80 percent of the rainwater could be harvested for the two cases.

Table 2. Statistics of the RCR system for Case1 and Case 2 during the study period.

Contents	Case 1	Case 2
Water depth and volume in the tank	Feb. 28: 1.426m (1,421)	Sep. 29: 1.386m (1,381)
(gallons)	Sep. 28: 1.403m (1,398)	Apr. 15: 1.275m (1,270)
Depth of rainfall	467mm	706mm
Rainwater fell on the roof	21,341gal	32,264 gal
Overflow	16,537 gal	22,068 gal
Water use data		
Volume used from the RCR	1,109 gal	4,932 gal
Number of flushing	616 flushes	2,740 flushes
System Efficiency		
Harvested rainwater	17,623 gal	26,889 gal
Rainwater Harvesting efficiency	82.5% (17,623/ 21,341)	83.3% (26,889/ 32,264)
RCR use efficiency	6.3% (1,109/ 17,623)	18.3% (4,932/ 26,889)

4.2 A school site

Table 3 show a statistics of RCR system for Case 3 installed at a school. The municipal water was used about 400 gallons higher than that of RCR use with the total use at 13,490 gallons. The harvesting efficiency was calculated at 89 percent and RCR use efficiency calculated was as high as 93 percent. The high RCR use efficiency is due to the high water use rate from the RCR system including ratio of roof area, 3,750sq ft vs. storage capacity, 3,400 gallons which approximately 1.02 gallons per square foot of collection surface per 10 mm of rainfall can be collected. Due to the formation of the school building used for this study only a portion of 32 percent of the total roof area, 11,500 sq ft is used for the RCR system.

Table 3. Statistics of the RCR system at Case 3 during study period (Total school days; 25, non-school days; 10 and no school break days).

Contents	Case 3
Water depth and volume in the tank (gallons)	Feb. 28: 1.424m (2,706)
	Sep. 28: 1.544m (2,934)
Depth of rainfall	85mm
Rainwater fell on the roof	7,828 gallons
Overflow	256 gallons
Water use data	
Volume and number of flushing	13,490 gal(5,396 flushes)
Volume used from the RCR	6,553 gallons
Volume used from the city main	6,937 gallons
System Efficiency	
Harvested rainwater	7,037 gal
Rainwater Harvesting efficiency	89% (7,037gallons/ 7,828gallons)
RCR use efficiency	93% (6,553gallons/ 7,037gallons)

4.3 Evaluation of water abailability from RCR systems

The computer program was applied under two conditions to decide the daily maximum water-use avbailability(DMWU). First, water consumption continuously added to the actual water use monitored until the DMWU was determined, with the data from Case 2. Second, the program computed the DMWU using the historical rainfall data of the last 10 years to evaluate an RCR system as a sole alternative water source assuming that existing well water orcity main is not available.

The daily water use range of simulation to determine DMWU started at a daily average of 25 gallons. Figure 2 shows results simulated by 40, 50, 60 and 69 gallons of water use. Water depth simulated in the tank met the minimum storage, 100 gallons shown in Figure 2, when 69 gallons was used as the daily water use rate. It was calculated that 13,800 gallons used from RCR system, the volume is that 8,868 gallons are added to the actual RCR water uses, total of 4,932 gallons by 25 gallons in daily use during the study period.

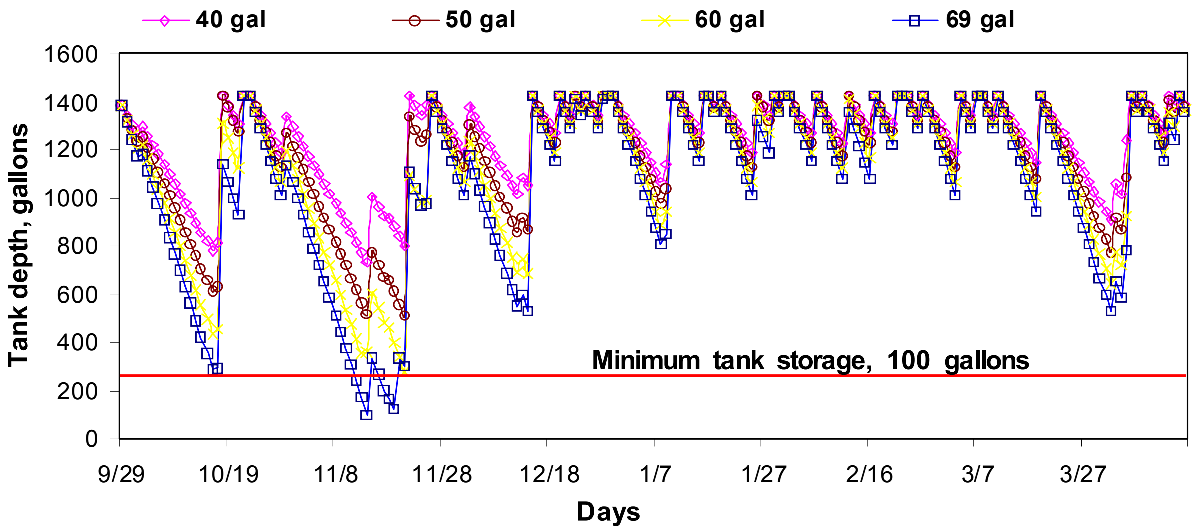

Figure 2. Simulation results to determine a DMWU in Case 2 during the study period.

DMWU was determined at approximately 50 gallons/day during the 10-year period and the largest and smallest DMWU were computed at 68 gallons/day in 2002 and 37 gallons/day in 2007, respectively(Table 4). Thus, this study suggests that 50 gallons per day, which is 1,475 per month and 17,703 gallons per year, is the optimum available non-potable water use from the harvested rainwater at the house site.

Table 4. Simulation results of an RCR system as an alternative water source using daily rainfall data at Auburn, Alabama.

Years	Rainfall (mm/y)	Harvested rainwater(gal/y)	Overflow (gal/y)	RCR use			RCR use
				gal/day	gal/month	gal/year	Efficiency (%)
1998	1,087	41,380	23,844	49	1,490	17,885	43.1
1999	979	37,268	18,074	53	1,612	19,345	51.7
2000	862	31,814	19,203	37	1,125	13,505	40.9
2001	1,086	41,342	27,071	40	1,217	14,600	35.2
2002	1,081	41,152	16,205	68	2,068	24,820	60.1
2003	1,434	54,590	39,127	42	1,277	15,330	28.2
2004	1,148	43,702	23,633	56	1,703	20,440	46.7
2005	1,361	51,811	33,355	50	1,521	18,250	35.1
2006	1,114	42,408	22,543	55	1,673	20,075	47.2
2007	792	30,150	17,479	35	1,065	12,775	42.2
Average	1,094	41,562	24,053	49	1,475	17,703	43.0

5. Conclusion

Roof Catchment of Rainwater(RCR) systems were installed to provide an alternative water source for non-potable domestic uses, primarily toilet flushing.

1. The RCR systems to collect rainwater were installed with a control system to monitor the system operation at a rural single family house and a school.
2. The average efficiency of rainwater harvesting was 83.3 percent. Despite the acceptable harvesting efficiency, RCR use efficiency was computed only 18 percent. Harvesting and RCR use efficiencies at the school site were 89 and 98 percent, respectively.
3. The program determines the DMWU according to water balance of the RCR system. The simulation showed that 69 gallons/day is an optimum amount of water use per day and this result indicates that 13,800 gallons used from RCR system, the volume is that 8,868 gallons are added to the actual RCR water uses, total of 4,932 gallons by 25 gallons in daily use during the study period.
4. DMWU was determined at approximately 50 gallons/day during the 10-year period. This result suggests that a total of 17,700 gallons of harvested water is available as an alternative water source for a typical rural single family house in the east Alabama.

6. Reference

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