Design of a rainwater harvesting system for a manufacturing plant

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Abstract. Rainwater harvesting systems are becoming increasingly popular. The basic concept is to collect, store, treat and distribute rainwater for use. The proposed design was developed for the CAMTAC Linamar manufacturing facility in Guelph, Ontario. The design incorporates a 22.7 m^3 underground cistern, a filtration and disinfection system, and distribution plumbing to the plant's reverse osmosis unit. Simulations indicate the proposed design has a projected return on investment of approximately 2.3 years and has potential to save 4000 m^3 of mains water per year.

Key words: Rain-water harvesting, reverse osmosis, water conservation

1 Introduction

CAMTAC manufacturing plant in Guelph, Ontario used approximately 766 m^3 of water per month in 2007 and expressed interest in substituting some or all of this use with harvested rainwater. They have sponsored the 3^{rd} year engineering design class at the University of Guelph to design a rainwater harvesting system for their plant. The project constraints are as follows:

- Collect rainwater from the existing plant roof
- Provide water at or above requirements for specific processes
- Meets Ontario Building Code Section 7
- Complies with relevant health and safety standards
- Total system cost of $30,000 or less

Design criteria are as follows:

- Delivery system gives flow and pressure not less than current supply
- Payback period of 1 year
- Solution has optimized Return on Investment (ROI)

Examining case studies of current systems helped to conceptualize major process steps in rainwater harvesting (RWH) systems. These include collection, storage, treatment, and distribution. Preliminary visits to the plant, consultation with on-site staff, and examination of building drawings and diagrams enabled the design team to create a preliminary design customized to the CAMTAC plant's layout and needs. A spreadsheet mass balance model to estimate performance was created using historic rainfall records. Cost estimates in conjunction with this model allowed for ROI optimization in selecting specific components.

Major assumptions for the design include reverse osmosis (RO) unit consumption of 19 litres per minute during production hours, similarity of future rainfall trends to historic data, roof runoff coefficient of 0.8 [1] and municipal water prices linearly increasing according to recent trends. A unique element of this design is using RO retentate for toilets flushing. This creates a significant increase in water savings over and above RWH alone.

2 Conceptual Design and Methodology

2.1 Overall Design

The main objective of this design is to collect rainwater from the rooftop and deliver it, appropriately treated, to the plants RO unit which pre-treats all of the plants process water The overall design consists of an underground concrete 22.7 cubic metre cistern catching rainwater from 2 of 4 possible sub-floor storm drains, a 1.5 horsepower (hp) variable speed pump in the cistern, a series of water treatment equipment, a 2″ pipe delivery system and a municipal mains backup connection at the RO unit.

The RO unit recovers 81% of inflow and currently processes 19 litres per minute. Permeate flow from the RO is used to dilute coolant and wash parts in the manufacturing processes. Currently the retentate is rejected directly to the municipal sewer. To maximize effectiveness of the design, the untreated retentate is stored for use in flushing toilets and urinals in the two main bathrooms of the plant.

2.2 Major Components

The three main components that require further explanation are the storage tank, treatment equipment, and the mains top-up system. The storage tank has five active connections; two drainage connections, two overflow connections, and the intake for the pump supplying water to the plant's RO unit. A 16 stage, 1.5 hp submersible pump draws water from within the tank at a depth of 15 cm below the water surface. A float switch fastened to the wall of the tank electrically activates the mains backup line at the RO unit when stored rainwater reaches 30 cm from the base of the tank.

The treatment process consists of five steps. Screening prevents the entry of large debris from the storage by means of a screened foot valve. Secondary treatment is performed by 400 micron and 30 micron Wye-Strainers in series. Final filtration is performed by a 5 micron glass fibre cylindrical cartridge filter. Lastly, bacteria and viruses are destroyed through ultraviolet disinfection.

The mains line is activated in the case of a pressure drop in the pipes or the tank water level dropping below critical height. As a failure mode the electrically activated valve is normally open to provide water in the event of a power failure or equipment malfunction. As required by the Canadian Standards Association or CSA-B64 Series, CAN/CSA-B64.10 a backflow prevention valve is incorporated into the design to avoid the non-potable source (rainwater) from entering the potable source.

3 Discussion

56 years of rainfall data from the University of Guelph Turfgrass Institute is utilized in a spreadsheet model to estimate the average yearly savings of water [2]. The model utilizes a mass balance of the incoming rainwater and outgoing daily process water requirements on a daily time step, and estimates total water savings. The model is flexible in analyzing systems with varying cistern sizes and catchment area. Combined with cost estimates, this data was used to calculate return period of different options. The 50% catchment, $22.7m^3$ cistern option was selected because of a relatively short return period and high yearly benefit, see Figure 1 and Table 1 below.

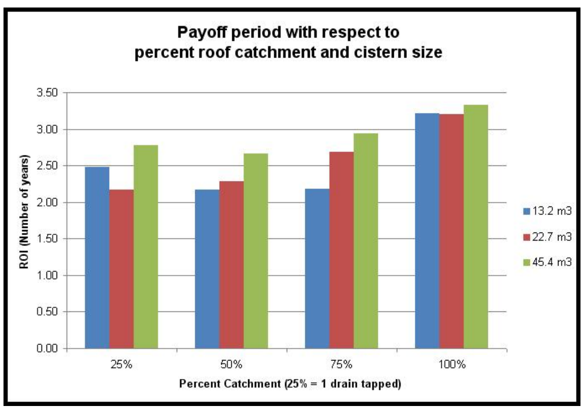

Fig. 1. Payoff Period of Different Options

Although this project does not have the lowest return period, it balances a good return period with cost of installation and high yearly savings for larger payoff years later. Combining savings from both the treated rainwater and by reusing the RO retentate, a total savings of 4000 m^3 per year is expected. At current water costs, a yearly savings of $6,800 is anticipated. Including the reduction in water softener salt used, total savings is $7,100 in the first year. Taking into account the rise in water costs, the savings increases yearly. Potential payoff over several years after initial installation is illustrated in Table 1. Initial capital cost is estimated at $19,000, with a potential city rebate of $3200 taken into account for the payoff calculations. Although a 1 year return period is a design criterion, it is not found to be possible.

	Year		
	1	2	3
Benefits:	$7,084	$7,512	$7,940
Costs:	$16,229	$494	$494
Balance:	-$9,145	-$2,126	$5,320

Table 1. Potential Payoff of Selected Option

Since the model is based on previous years of data there is inherent statistical error in estimating future years. The model provides a realistic estimation, however only implementation can fully justify the results.

The total implementation of the rainwater harvesting system is recommended. However, if full implementation of the design is not possible it is highly recommended that at minimum the RO unit retentate be used to supply the plant toilets as this represents a significant savings in and of itself.

For future projects it is recommended that detailed water use studies be carried out prior to preliminary design. This project has had to use estimations and generalized assumptions in place of hard data regarding water usage.

4 Acknowledgments

The design team would like to thank Mr. Mike Minogue of CAMTAC, Martin Lavictoire of City of Guelph Environmental Services, Dr. Medhat Moussa, Dr. Khosrow Farahbakhsh, and Antony Savich for consultation and answering questions related to this project.

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