RESEARCH HIGHLIGHT

July 2009 Technical Series 09-110

Evaluating the Feasibility and Developing Design Requirements and Tools for Large-scale Rainwater Harvesting in Ontario

INTRODUCTION

Rainwater harvesting (RWH) is the process of collecting run-off rainwater from roof surfaces and storing it for later domestic use. Fuelled by a growing interest among homeowners and municipalities to conserve water and improve stormwater management, RWH is rapidly becoming a major part of sustainable building practices across Canada.

This *Research Highlight* describes a project carried out in anticipation of this growing trend by the University of Guelph School of Engineering in partnership with Canada Mortgage and Housing Corporation (CMHC), the Canadian Water Network and several other private and public partners. The goal of the two-and-a-half year project was to investigate the feasibility of widespread residential rainwater harvesting in Ontario.

RESEARCH PROGRAM

At the start of the research program it quickly became evident that rainwater harvesting is both technically feasible and of interest to consumers and the housing industry. The researchers therefore shifted the focus of the project to capacity development.

Specifically, the project partners looked at four key areas where improving capacity could help accelerate the adoption of RWH in Ontario: the quality of rainwater; the design and performance of RWH systems; the economic feasibility of widespread rainwater harvesting; and the role and impact of public policy and regulation.

FOCUS 1: RAINWATER QUALITY

The Study

The question of whether or not rainwater is safe for household use is an essential step in the acceptance of RWH by homeowners and all levels of government.

Several factors can affect rainwater quality. These include the proximity of the collection site to heavy industry or major freeways, the presence of birds or rodents, the prevailing weather conditions, and the materials used in the roof where the water is collected and the cistern where it is stored.

To assess the quality of rainwater in the Guelph area, the researchers conducted a one-year assessment from October 2006 to October 2007 at seven different households with RWH systems, all located within a 30-km radius around the City of Guelph. At each site, approximately 30 samples were collected throughout the year from both the rainwater cistern as well as at the point of use (following any post-cistern treatment).

The samples were analyzed to assess their pH, turbidity, colour, total and fecal coliforms, total organic carbon (TOC), total nitrogen (TN) and UV absorption (254 nm). This data was then used to identify the impact on water quality of each of the following factors:

- Contact with the catchment (collection) surface;
- Storage in a rainwater cistern;
- Temperature and rainfall patterns;
- Seasonal climate variations;

Canada

CMHC SCHL
HOME TO CANADIANS

- Post-cistern treatments; and
- The collection site environment.

Key Findings

The key findings of this yearlong assessment included the following conclusions:

- The physicochemical properties of rainwater were impacted primarily by the roof and cistern material and site environment. Microbiological quality, on the other hand, was affected primarily by the season, temperature and water treatment.
- In general, water quality was found to be better at sites with steel roofs than at those with asphalt shingle roofs. Concrete cisterns also tended to raise the pH of stored rainwater, whereas the pH remained constant when stored in plastic cisterns.
- The colour, turbidity and TN concentration of stored rainwater increased during dry periods, while rainwater quality tended to improve during the winter months.
- Pre-treatment devices (such as gutter screens, leaf-catchers, first-flush devices or coarse filters) and post-cistern treatment devices (such as 20-micron particle filters, carbon filters and UV lamps) reduced turbidity, colour and odour issues, as well as the number of coliforms in the water.
- In general, cistern-stored rainwater was found to be safe for such non-potable applications as toilet flushing and outdoor use. Following treatment, harvested rainwater may also be suitable for additional indoor applications such as laundry.

Table 1 Physicochemical properties of rainwater observed for cistern-stored (CS) and point of use (POU) samples (values: mean ± standard deviation).

Sample Location	pH	Turbidity (NTU)	TOC (mg/L)	TN (mg/L)	Colour (CU)	UV-ABS (254 nm)
Site 1 CS	7.1 ± 0.6	1.1 ± 1.6	3.1 ± 1.9	1.8 ± 0.7	11.1 ± 7.8	0.023 ± 0.026
Site 1 POU	7.2 ± 0.4	0.3 ± 0.1	2.3 ± 2.1	1.6 ± 0.6	7.1 ± 6.4	0.027 ± 0.092
Site 2 CS	5.8 ± 0.9	1.0 ± 0.5	1.8 ± 1.0	1.5 ± 0.4	11.6 ± 10.6	0.031 ± 0.064
Site 2 POU	5.9 ± 1.1	0.8 ± 0.3	2.7 ± 2.1	1.3 ± 0.6	15.2 ± 17.3	0.027 ± 0.040
Site 3 CS	7.2 ± 0.4	1.5 ± 0.7	6.3 ± 4.5	2.0 ± 0.6	25.5 ± 17.0	0.169 ± 0.114
Site 3 POU	7.3 ± 0.3	1.5 ± 0.8	6.9 ± 4.9	2.3 ± 1.5	27.4 ± 19.8	0.191 ± 0.139
Site 4 CS	7.5 ± 0.7	2.6 ± 3.1	8.5 ± 8.3	1.5 ± 0.5	32.8 ± 28.7	0.193 ± 0.177
Site 4 POU	7.0 ± 1.2	1.2 ± 0.5	6.4 ± 5.2	1.5 ± 0.6	24.9 ± 19.4	0.142 ± 0.113
Site 5 POU	8.1 ± 0.7	1.4 ± 0.6	7.4 ± 5.5	1.5 ± 0.5	23.4 ± 10.1	0.188 ± 0.170
Site 6 CS	8.2 ± 0.9	0.9 ± 0.5	2.9 ± 1.7	1.8 ± 0.9	13.1 ± 8.0	0.032 ± 0.056
Site 6 POU	8.2 ± 0.8	0.9 ± 0.3	3.2 ± 1.6	1.7 ± 0.7	13.8 ± 8.1	0.029 ± 0.034
Site 7 POU	7.5 ± 0.4	1.3 ± 0.7	2.4 ± 1.1	1.5 ± 0.3	14.9 ± 8.2	0.041 ± 0.061

TOC – Total Organic Carbon
TN – Total Nitrogen
UV-ABS – Ultraviolet Absorption

Table 2 Microbiological properties of rainwater observed for cistern-stored (CS) and point of use (POU) samples.

Sample Location	Total Coliform (CFU/100mL)			Fecal Coliform (CFU/100mL)		
	Geometric Mean	Range	Portion of Samples >1 CFU/100 mL	Geometric Mean	Range	Portion of Samples >1 CFU/100 mL
Site 1 CS	<1	<1 – 128	76%	<1	<1 – 14	31%
Site 1 POU	<1	<1 – <1	4%	<1	<1 – <1	0%
Site 2 CS	<1	<1 – 86	60%	<1	<1 – 4	11%
Site 2 POU	<1	<1 – <1	0%	<1	<1 – <1	0%
Site 3 CS	<1	<1 – 255	46%	<1	<1 –234	36%
Site 3 POU	<1	<1 – <1	0%	<1	<1 – <1	0%
Site 4 CS	1	<1 – 398	89%	<1	<1 – 400	54%
Site 4 POU	<1	<1 – 12	14%	<1	<1 – <1	0%
Site 5 POU	<1	<1 – 112	42%	<1	<1 – 54	25%
Site 6 CS	<1	<1 – 51	17%	<1	<1 – 10	7%
Site 6 POU	<1	<1 – 40	10%	<1	<1 – 6	7%
Site 7 POU	<1	<1 – 24	28%	<1	<1 – 5	3%

CFU – Colony Forming Units

FOCUS 2: RWH SYSTEM DESIGN AND PERFORMANCE

The Study

Rainwater harvesting is intended to supplement municipal water supplies by providing homeowners with an alternative supply of safe, reliable water. RWH systems must therefore be designed to both ensure rainwater quality and maximize the volume of water that is collected.

The performance of RWH systems can be affected by factors ranging from the amount of rainfall and size of the collection surface and cistern, to losses from the roof or pre-cistern treatment devices. In Ontario, cold weather can also have an impact on performance, whether through the addition of melting snow or the risk of the system freezing.

To test the performance of RWH systems, demonstration sites were set up in three residential locations in Guelph. At the first site (Experimental Site 1), a rain gauge was installed, water level and temperature sensors were placed inside the cistern, and a water meter was installed on the rainwater plumbing line. All three sites were monitored for a year, and the resulting data was used to assess:

- Trends in daily rainfall and rainwater demand;
- Losses from the catchment surface (roof) and cistern overflows;
- Performance of the RWH systems during cold weather;
- Impact of pre-cistern treatment devices on the quality of the rainwater; and
- Total municipal water savings.

In addition, the researchers also created a "cistern sizing model" to determine the optimum size for rainwater storage cisterns. The model was based on historic daily rainfall data for cities throughout the province, and compared to the actual data collected at Experimental Site 1. The model was then used to evaluate the water storage requirements for two case studies: single-detached homes and townhouses.

Key Findings

The key findings from the performance analysis included:

- The RWH system at Experimental Site 1 collected 65 m^3 of water during the one-year program. This was sufficient to meet about 30 per cent of the annual water needs of a five-person household, demonstrating that the widespread use of rainwater for flushing toilets and washing clothing could reduce residential water demand in Ontario by 22-47 per cent.
- During dry periods (less than 0.5 mm of rainfall), there was no appreciable increase in water volume in the cistern. During heavier rainfalls, only 80 per cent of the additional volume of water was collected. The loss was likely a combination of loss from the catchment roof as well as overflow from the cistern.

- During cold weather, collection efficiency dropped to 60 per cent. However, this loss was largely replaced by water from melting snow. Heating or burying the cistern below the frost penetration depth could also help reduce the risk of freezing, allowing RWH systems to continue to perform adequately during winter conditions.
- For smaller cisterns (250-3,500 L), a relatively minor increase in storage capacity resulted in a substantial increase in water savings. For larger cisterns (above 10,000 L), increases in storage capacity had little impact on system performance.
- A significant difference in the potential for water savings was observed between single-detached homes and townhouses. When used for toilet flushing and laundry, RWH systems provided single-detached homes with 67 m^3 of water annually, but townhouses gained only 42 m^3. It is therefore likely that the catchment surface area is a significant limiting factor in RWH design and potential water savings.

FOCUS 3: ECONOMIC FEASIBILITY

The Study

Cost is generally considered to be one of the most compelling obstacles to the widespread adoption of rainwater harvesting. The researchers developed cost estimates for conceptual RWH systems, based on the demonstration sites installed for this project and other local RWH systems. The RWH model provided estimated water savings for different design configurations and end use patterns. Both the cost and water savings were then scaled up to reflect a scenario where RWH systems were implemented in all new residential development in Guelph from 2006 to 2051. This scenario was compared to the City of Guelph's current 2006 Water Supply Master Plan. Net present value calculations were performed from three different perspectives: the homeowner, the municipal utility, and society.

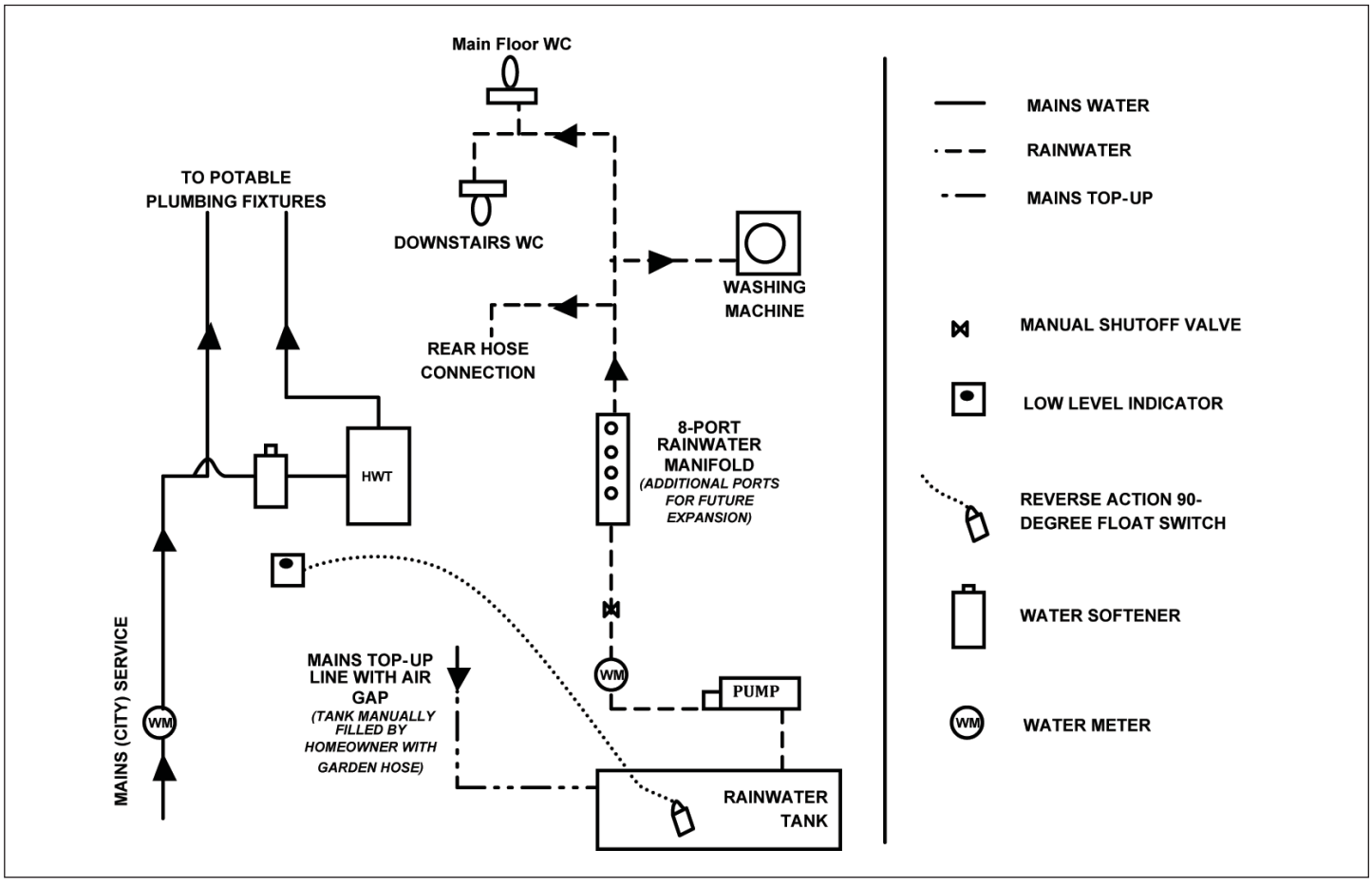

Figure 1 Schematic of the internal plumbing at Experimental Site 1.

[1] All dollar values are in 2006 Canadian dollars.

Key Findings

The economic feasibility analysis revealed that:

- The capital cost to homeowners of an individual RWH system ranged between $6,000[1] and $14,000, depending on its size and configuration.
- Regardless of the size of the tank, the maximum water savings achieved from RWH was 41 per cent for single detached homes and 23 per cent for multi-attached homes. This amounted to about 82 m^3 in water savings per household per year for single detached homes and 42 m^3 per household per year for multi-attached.
- Smaller systems are more cost effective than larger systems because the incremental cost of a larger tank is more than the financial savings realized from the additional water savings.
- Installing 5 m^3 and 3 m^3 of storage capacity in all new single detached and multi-attached dwellings, respectively, from 2006 to 2051, and using rainwater for outdoor use and toilet flushing, would reduce residential water demand in Guelph by 10 per cent.
- The widespread implementation of RWH can offer further savings by delaying the infrastructure investment needed to develop new sources of water. Rainwater harvesting (for toilet flushing and outdoor use) would allow the City of Guelph, for example, to delay the move from groundwater to surface water by two years.

FOCUS 4: THE ROLE OF PUBLIC POLICY

The Study

All the technological advances in rainwater harvesting will be of little value if the appropriate regulatory frameworks and public policies do not permit or promote their use.

The researchers therefore conducted a thorough review of the policies, support mechanisms and regulatory frameworks that are already in place in Ontario. They also carried out a series of interviews with municipal officers, building inspectors, architects, engineers, builders, RWH suppliers and other stakeholders in the Guelph area to identify any barriers or opportunities for the widespread implementation of RWH.

Key Findings

The findings of the policy and regulatory framework review noted that:

- No policies specific to RWH could be found in Ontario at either the provincial or municipal level. Those water conservation and stormwater policies that do exist are couched in broader planning legislation, with little or no visibility or enforcement.
- While the regulatory framework is currently wanting, authorities seem to be aware of the growing interest in RWH and the need to accelerate its progress. At both the provincial and municipal level, there is broad policy support for water conservation and efficiency as well as for sustainable stormwater management practices.
- The Ontario Building Code is the primary regulatory device governing RWH. It is more advanced than the National Plumbing Code in that it allows non-potable water to be used indoors, but it remains limited in that it only allows it to be used for toilet or urinal flushing. Clauses related to RWH in the Code are scattered and unclear.
- No user-oriented support mechanisms or incentives were identified for RWH. Several municipalities promote rain barrels, but there is no mention of larger systems for indoor use. In addition, current municipal pricing structures and building approval processes are generally weak in their ability to promote RWH.
- The most significant barriers to the implementation of RWH identified by the interviewees were: cost; liability; limited end uses permitted for rainwater in the Building Code; poor distinction between rainwater, greywater and non-potable water in the Building Code; and a lack of public awareness.
- The most common solutions proposed by the interview participants included expanding the list of permissible end uses for rainwater in the Building Code, encouraging stronger provincial endorsement of RWH, and educating the building sector and the public about water issues, conservation and RWH.
- According to the interviewees, the regulatory framework for RWH should include: explicit support for source substitution in provincial and municipal policy; restructuring of the Building Code to allow for expanded uses of rainwater; and the development of a best-practices manual and incentive

mechanisms to encourage innovation in water conservation and stormwater management, while establishing new and varied ways of managing risk and minimizing liability.

IMPLICATIONS FOR HOMEOWNERS, MUNICIPALITIES AND OTHER STAKEHOLDERS

Rainwater harvesting is both technically and socially feasible. However, the investment involved in implementing RWH throughout Ontario is not insignificant.

For individual homeowners, the cost of purchasing and installing an RWH system is several times higher than the current price of water. As a result, significant reductions in the cost of RWH systems and/or increases in the price of water will be required if RWH is to become economically competitive at the household level.

The participation of developers and municipalities will also be essential in achieving the economies of scale needed to make RWH more cost-effective. For developers, the benefits may include good will in their communities as supporters of "green" building practices. For municipalities, the benefits of rainwater harvesting include operational savings and a delay in the need for additional water supplies.

When viewed from the perspective of society as a whole, the benefits become much clearer. For Ontario and for Canada, RWH can be seen as an important part of building more sustainable homes and communities.

FURTHER INFORMATION

For more information, a copy of the full report – *Evaluating the Feasibility and Developing Design Requirements and Tools for Large-scale Rainwater Harvesting in Ontario* – is available from the Canadian Housing Information Centre (CHIC) at Canada Mortgage and Housing Corporation.

REFERENCES

Evaluating the Feasibility and Developing Design Requirements and Tools for Large-scale Rainwater Harvesting in Ontario Final Report, prepared by Christopher Despins and Chantelle Leidl for CMHC, August 2008.

CMHC Project Manager: Cate Soroczan

Project Lead: Khosrow Farahbakhsh, Ph.D., P.Eng; Assistant Professor, School of Engineering, University of Gueph

Housing Research at CMHC

Under Part IX of the ***National Housing Act***, the Government of Canada provides funds to CMHC to conduct research into the social, economic and technical aspects of housing and related fields, and to undertake the publishing and distribution of the results of this research.

This fact sheet is one of a series intended to inform you of the nature and scope of CMHC's research.

To find more ***Research Highlights*** plus a wide variety of information products, visit our website at

www.cmhc.ca

or contact:

Canada Mortgage and Housing Corporation
700 Montreal Road
Ottawa, Ontario
K1A 0P7

Phone: 1-800-668-2642
Fax: 1-800-245-9274

Printed in Canada
Produced by CMHC 22-07-09

66602