4.1 Rainwater Harvesting

4.1.1 Overview

Description
Rainwater harvesting is the process of intercepting, conveying and storing rainfall for future use. Harvesting rainwater for domestic purposes has been practiced in rural Ontario for well over a century. Interest in adapting this practice to urban areas is increasing as it provides the combined benefits of conserving potable water and reducing stormwater runoff. When harvested rainwater is used to irrigate landscaped areas, the water is either evapotranspired by vegetation or infiltrated into the soil, thereby helping to maintain predevelopment water balance.

The rain that falls upon a catchment surface, such as a roof, is collected and conveyed into a storage tank. Storage tanks range in size from rain barrels for residential land uses (typically 190 to 400 litres in size), to large cisterns for industrial or commercial land uses (Figure 4.1.1). A typical pre-fabricated cistern can range from 750 to 40,000 litres in size.

With minimal pretreatment (*e.g.*, gravity filtration or first-flush diversion), the captured rainwater can be used for outdoor non-potable water uses such as irrigation and pressure washing, or in the building to flush toilets or urinals. It is estimated that these applications alone can reduce household municipal water consumption by up to 55% (Reid Homes, 2007). The capture and use of rainwater can, in turn, significantly reduce stormwater runoff volume and pollutant load. By providing a reliable and renewable source of water to end users, rainwater harvesting systems can also help reduce demand on water resources (such as groundwater aquifers and reservoirs) from which municipal water supplies are drawn. By reducing demand on water resources, rainwater harvesting can result in significant cost savings due to:

- delayed expansion of municipal water treatment and distribution systems;
- lowered energy use for pumping and treating water; and
- lowered consumer water bills

There are two options for the design and operation of rainwater harvesting systems:

1) Some systems are designed for both outdoor and indoor uses (*i.e.*, dual use systems) with usage continuing throughout the year. In cold climate regions, such as southern Ontario, cisterns for year-round usage must be located underground below the local frost penetration depth, or indoors in a temperature controlled environment to prevent freezing.

2) Other systems are designed for outdoor water usage only, where water demand varies seasonally. Rain barrels or cisterns for seasonal, outdoor water uses can

be located above-ground or underground, acknowledging that they need to be decommissioned annually, prior to the onset of freezing temperatures.

Figure 4.1.1 Various types of rainwater storage tanks

Clockwise from top left: typical plastic rain barrel; cast in place concrete cistern integrated within a parking garage (Source: TRCA); above-ground plastic cistern; underground pre-cast concrete cistern (Source: University of Guelph)

Common Concerns

Some common concerns associated with rainwater harvesting that must be addressed during design include:

- *Winter Operation:* Rainwater harvesting systems can be used throughout the year if they are located underground or indoors to prevent problems associated with freezing, ice formation and subsequent system damage. Alternatively, an outdoor system can be used seasonally.

- *Plumbing Codes:* The 2006 Ontario Building Code explicitly allows the use of harvested rainwater for toilet and urinal flushing (See Section 7.1.5.3 of the Code). Canadian Standards Association has standards B.128.1 and B.128.2 that address the design, installation, maintenance and field testing of non-potable water systems. Systems using harvested rainwater indoors are required to have backflow preventers to keep non-potable harvested water separate from watermains carrying potable water. CSA-B64.10 provides guidance for the selection and installation of backflow prevention devices. Additionally, pipes carrying rainwater must be labeled as non-potable.

- *Standing Water and Mosquitoes:* Rainwater harvesting systems, if improperly managed, can create habitat suitable for mosquito breeding and reproduction. Designers should provide screens on inlets and overflow outlets to prevent mosquitoes and other insects from entering the system. If screening is not sufficient to deter mosquitoes, dunks containing larvicide can be added to storage tanks when harvested water is intended for irrigation only.

- *Child Safety:* Above grade home cisterns with openings large enough for children to enter the tank must have lockable covers. For underground cisterns, manholes should be secured to prevent unwanted access.

- *Drawdown Between Storms:* The extent to which cisterns reduce runoff and peak flows depends on use of the captured rainwater between storms, so that capacity exists to capture a portion of the next storm. Water demand estimations should be submitted for review along with other stormwater management system design documents.

- *On Private Property*: If a rainwater harvesting system is installed on private lots, property owners or managers will need to be educated on their routine operation and maintenance needs, understand the long-term maintenance plan, and may be subject to a legally binding maintenance agreement. An incentive program such as a storm sewer user fee based on the area of impervious cover on a property that is directly connected to a storm sewer (*i.e.*, does not first drain to a pervious area or LID practice) could be used to encourage property owners or managers to maintain existing practices.

Physical Suitability and Constraints
A number of site-specific features influence how rainwater harvesting systems are designed. Some of the key considerations include:

- *Available Space:* Space limitations are rarely a concern with rainwater harvesting if considered during building design and site layout. Storage tanks can be placed underground, indoors, on roofs, or adjacent to buildings depending on intended uses of the rainwater. Designers must work with architects to site the tanks.

- *Site Topography:* Site topography influences the placement of storage tanks and the design of the rainwater conveyance and overflow systems. Locating storage tanks in low areas of the site will likely increase the volume of rainwater that can be stored for later use, but will increase the amount of pumping needed to distribute the harvested rainwater. Conversely, placing storage tanks at higher elevations will likely reduce the volume of rainwater that can be stored due to structural limitations on the weight of captured rainwater that can be stored, but will also reduce the amount of pumping needed for distribution or eliminate it altogether.

- *Available Head:* The needed head depends on intended use of the water. For residential landscaping uses, the rain barrel or cistern should be sited up-gradient of the landscaping areas or on a raised stand. Gravity-fed operations may also be used for indoor residential uses, such as laundry, that do not require high water pressure. For larger-scale landscaping operations, locating a cistern on the roof or uppermost floor may be the most cost efficient way to provide water pressure.

- *Soils:* Cisterns should be placed on or in native, rather than fill, soils. If placement on fill slopes is necessary, a geotechnical analysis is needed. Underground tanks and the pipes conveying rainwater to and from them, including overflow systems, should either be located below the local frost penetration depth (MTO, 2005), or insulated to prevent freezing during winter

- *Pollution Hot Spot Runoff:* Rainwater harvesting systems can be an effective stormwater BMP for roof runoff at sites where land uses or activities at ground-level have the potential to generate highly contaminated runoff (*e.g.*, vehicle fueling, servicing and demolition areas, outdoor storage and handling areas for hazardous materials and some heavy industry sites).

- *Setbacks from Buildings:* Rainwater harvesting system overflow devices should be designed to avoid causing ponding or soil saturation within three (3) metres of building foundations. Storage tanks must be watertight to prevent water damage when placed near building foundations.

- *Proximity to Underground Utilities:* The presence of underground utilities (*e.g.*, water supply pipes, sanitary sewers, natural gas pipes, cable conduits, etc.), may constrain the location of underground rainwater storage tanks.

- *Vehicle Loading:* Underground cisterns should be placed in areas without vehicular traffic. Tanks under roadways, parking lots, or driveways must be designed for the live loads from heavy trucks, a requirement that could significantly increase construction costs.

Typical Performance

The ability of rainwater harvesting systems to help meet stormwater management objectives is summarized in Table 4.1.1. Except in retrofit situations, rainwater harvesting will not be a stand-alone BMP. It is part of a treatment train that will likely include practices such as vegetated filter strips and grass channels in addition to detention for stream channel erosion control requirements.

Table 4.1.1 Ability of rainwater harvesting systems to meet SWM objectives

BMP	Water Balance Benefit	Water Quality Improvement	Stream Channel Erosion Control Benefit
Rainwater Harvesting	Yes – magnitude depends on water usage	Yes – size for the water quality storage requirement	Partial – can be used in series with other practices

Water Balance

Harvested rainwater that is used for watering landscaping meets the objectives of the water balance requirement, as these flows are infiltrated or evapotranspired after storage. On a larger scale, where groundwater is the primary source of water, the reduced demand on wells within the watershed will add to the water balance benefits of rainwater harvesting. Any reduction in runoff volume achieved by rainwater harvesting will be a benefit to receiving waters with regard to mitigation of increases in stream channel erosion rates, but full mitigation will likely require rainwater harvesting to be applied in series with other LID practices.

Limited research has been conducted to evaluate the runoff reduction capacity of rain tanks and cisterns, particularly in cold climates (Table 4.1.2). Modeling research indicates that their runoff reduction capacity is limited by tank capacity, the length of time between storm events, and rainwater usage. Estimating the runoff reduction for an individual facility requires simulation modeling of rainfall and water usage. A rainwater harvesting system design tool spreadsheet has been developed for Ontario that can estimate runoff reduction, based on input of local climate data, catchment and storage tank dimensions and assumptions regarding typical water use patterns (University of Guelph and TRCA, 2009). The tool can also be used to estimate overall system cost.

Table 4.1.2 Volumetric runoff reduction by rainwater cisterns

LID Practice	Location	Runoff Reduction	Reference
Dual Use Cisterns[1]	Guelph, Ontario	89%	Farahbakhsh *et al.* (2009)
Dual Use Cisterns[1]	Toronto, Ontario	23 to 46%	TRCA (2010)
Dual Use Cisterns[1]	Australia	60 to 90%	Hardy *et al.* (2004)
Dual Use Cisterns[1]	Australia	40 to 45%	Coombes and Kuczera (2003)
Dual Use Cisterns[1]	New Zealand	35 to 40%	Kettle *et al.* (2004)
Runoff Reduction Estimate[2]		**40%**	

Notes:
1. Dual use cisterns provide a year-round supply of water for both indoor and outdoor uses.
2. This estimate is provided only for the purpose of initial screening of LID practices suitable for achieving stormwater management objectives and targets. Performance of individual facilities will vary depending on site specific contexts and facility design parameters and should be estimated as part of the design process and submitted with other documentation for review by the approval agencies.

Water Quality – Pollutant Removal Capacity

The pollutant removal capacity of rainwater harvesting systems stems from their ability to reduce the volume of stormwater runoff being generated from a site, thereby reducing pollutant load to receiving waters. During small to medium sized storm events a rainwater harvesting system with sufficient available storage capacity could capture 100% of the runoff from a catchment surface, thereby reducing the pollutant load from the surface to zero. The pollutant removal capacity of rainwater harvesting systems is directly proportional to the amount of runoff that is captured. Theoretically, if 100% of runoff is captured and used, no stormwater pollution from the catchment surface will be conveyed downstream. In applications where rainwater is harvested for use in commercial or industrial properties, runoff volume reductions in the order of 40 to 45% have been observed over the period of monitoring (Coombes and Kuczera, 2003; TRCA, 2008c).

Peak Flow Control

The storage and diversion capability of rainwater harvesting systems not only reduces runoff volume and pollutant load, but also peak discharge rates downstream. However, if cisterns are being implemented to meet peak flow control requirements, in addition to water conservation/runoff volume reduction benefits, they require additional design considerations. Depending on anticipated water usage rates, an outflow control may need to be incorporated. The outflow control would function like the outlet of a stormwater detention pond, to provide temporary detention and gradual release of incoming runoff during medium to large sized storm events, while still providing a reservoir of water in the cistern that can be drawn upon. Peak flow reductions of up to 90% are possible with large rainwater harvesting systems (Coombes, 2002).

Other Benefits to the Watershed

- Economic Benefits: Since outdoor residential irrigation can account for up to 40% of domestic water consumption in the hot summer months, rainwater harvesting can conserve water and reduce the demand on the municipal water system (LID Center, 2003b). Rainwater harvesting can reduce individual consumers' utility bills, but also represents a larger cost savings. Increased population drives the need for additional water supply infrastructure, including expansion of existing water treatment plants or construction of new ones. Rainwater harvesting, similar to water conservation efforts, reduces the demand for potable water. In particular, peak demand, driven by summertime outdoor watering, is reduced. It also reduces municipal costs associated with treating and pumping potable water to end users.

4.1.2 Design Template

Applications

Rainwater harvesting systems can be applied on most residential, commercial, industrial or institutional roofs where rainwater can be captured, stored, and used. They are particularly useful on infill and redevelopment sites that have little room for other stormwater BMPs. Rainwater harvesting systems can be installed underground, indoors, on the ground next to a building or on the roof. In the Greater Toronto Area, dual use rainwater cisterns are usually located underground, in temperature controlled parking areas or in basements to prevent freezing during cold weather.

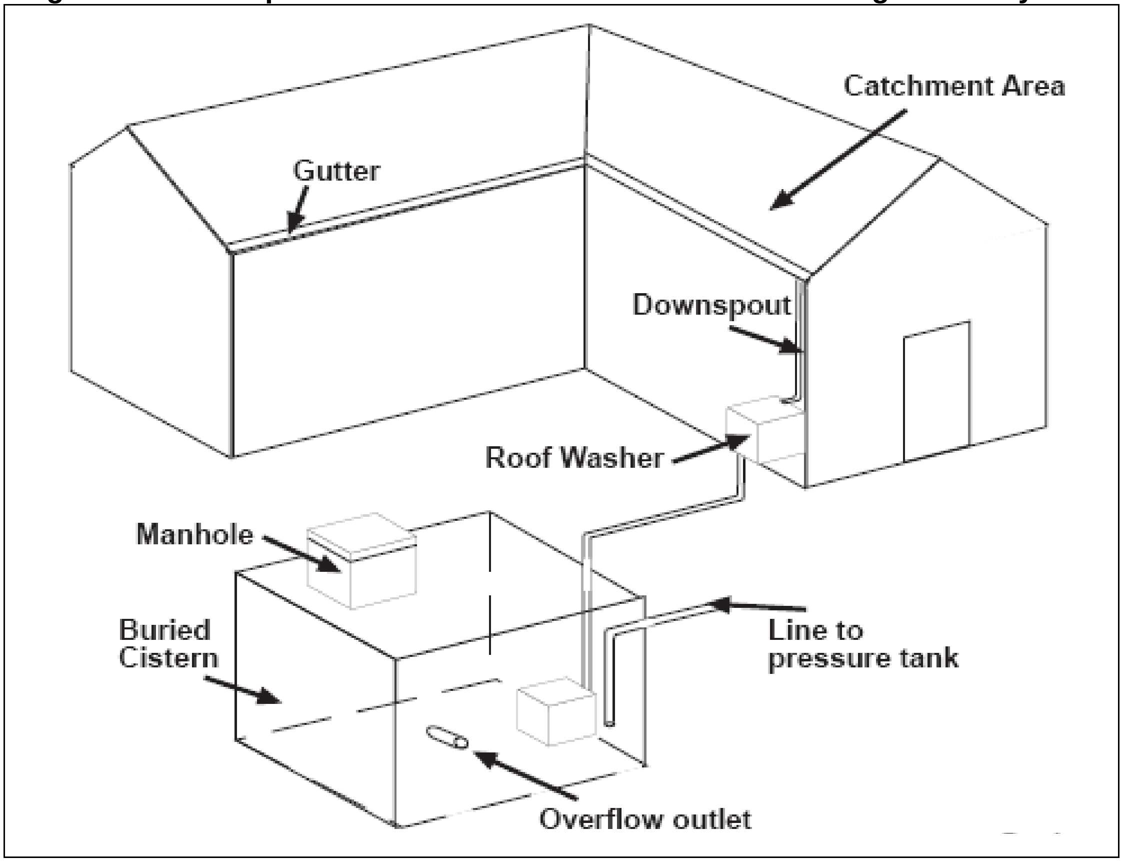
Rainwater that is captured and stored can be used to meet both outdoor and indoor non-potable water uses. Outdoors, harvested rainwater can be used for residential lawn and garden watering, commercial and institutional landscaping irrigation, decorative fountains, or other non-potable uses such as vehicle washing, building washing and fire fighting.

Typically, indoor uses of harvested rainwater are for non-potable purposes only. Toilet flushing is the most common large-scale indoor use of harvested rainwater. Laundry washing is another common residential water use with potential to utilize harvested rainwater, as it does not require potable water nor high water pressure. Separate plumbing, pumps, pressure tanks, and backflow preventers are necessary for indoor use of harvested water. Back-up water supply system arrangements,that can be drawn upon when the cistern runs dry, are also necessary for indoor uses.

Typical Details

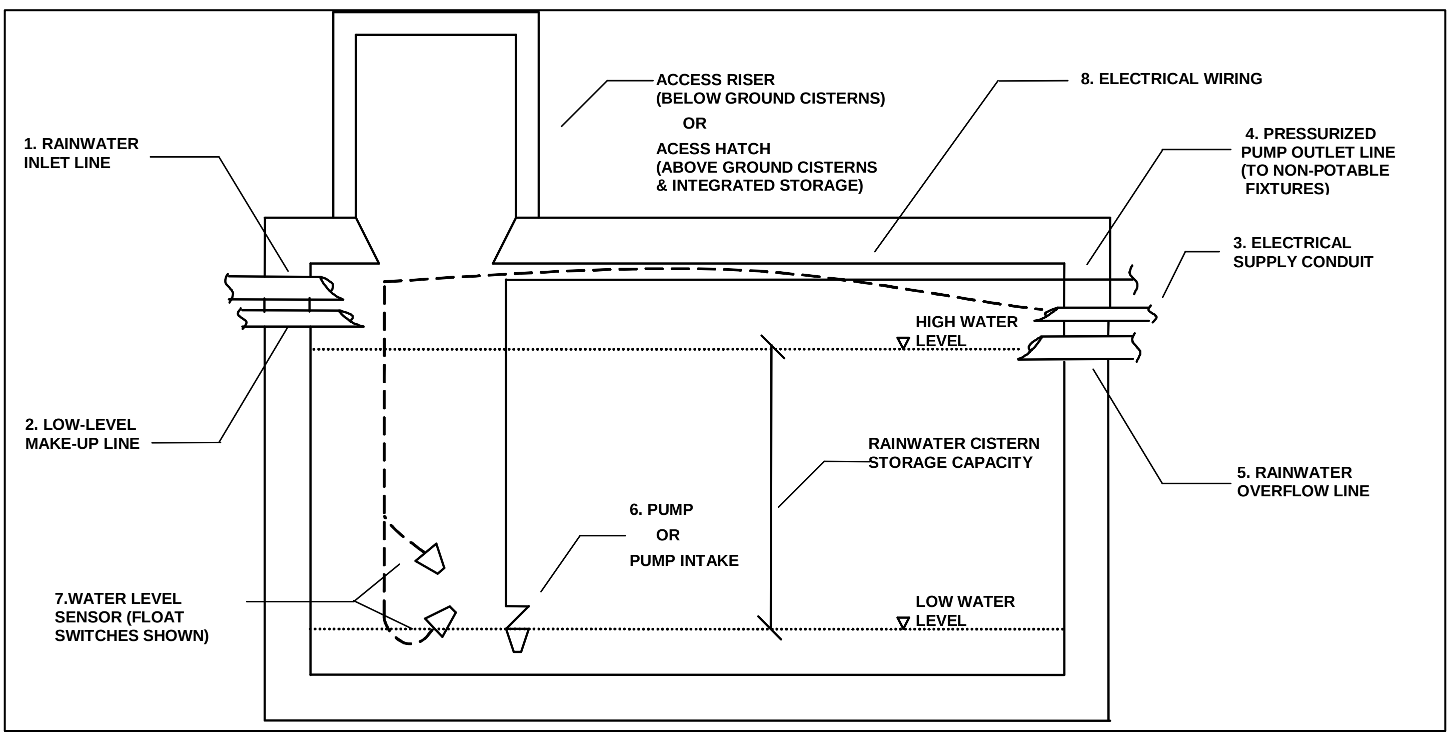
A typical residential rainwater harvesting cistern system is illustrated in Figure 4.1.2. A schematic of a dual use cistern is provided in Figure 4.1.3. Examples of common pretreatment devices are shown in Figure 4.1.4.

Figure 4.1.2 Components of a residential rainwater harvesting cistern system



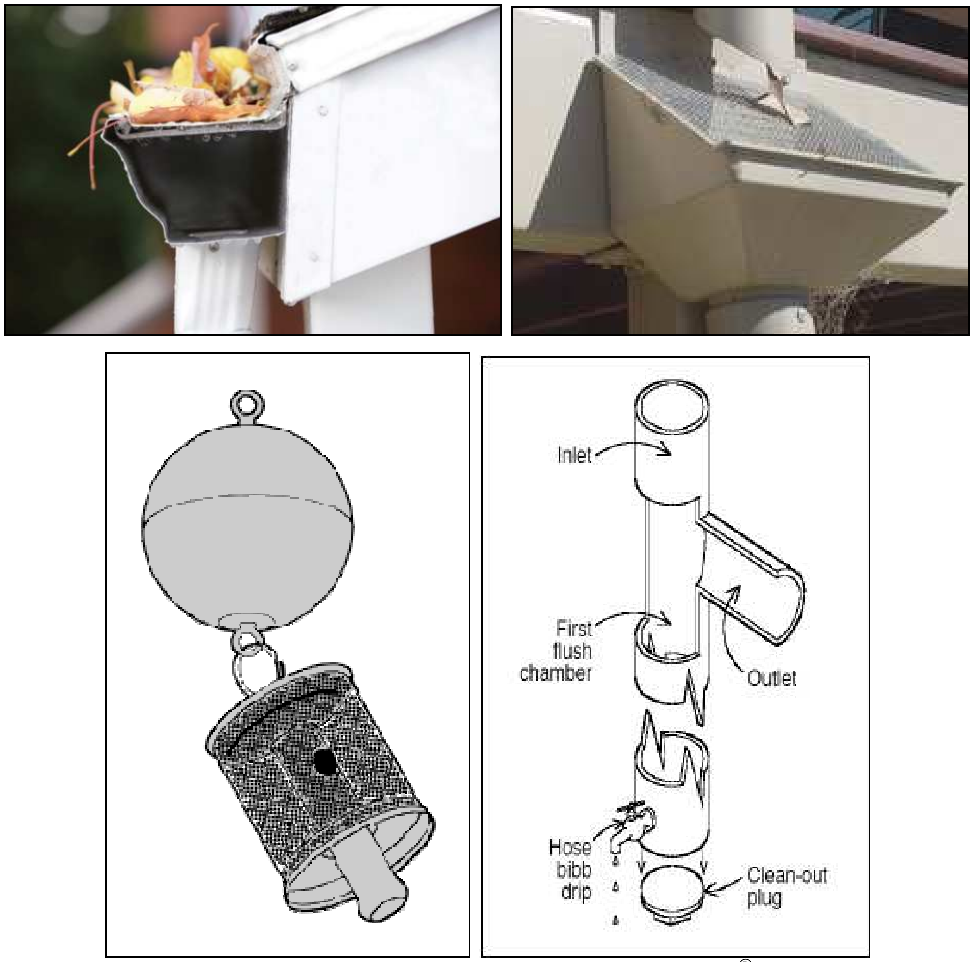
Source: Rupp, 1998

Figure 4.1.3 Schematic of a typical underground rainwater harvesting cistern



Source: University of Guelph, 2010

Figure 4.1.4 Examples of common pretreatment devices



Clockwise from top left: Leaf screens on eavestrough (Leaf Eater®, © Rainwater Harvesting Ltd.) and downspout (Fixa-Tech®, © Alu-Rex Inc.), First-flush diverter (Source: TWDB); Floating suction filter (© WISY)

Design Guidance

As shown in Figure 4.1.2, there are six components of a rainwater harvesting system:

- Catchment area;
- Collection and conveyance system (*e.g.* eavestroughs, downspouts, pipes);
- Pretreatment system (*e.g.*, filters and first-flush diverters);
- Storage tank (*e.g.*, rain barrels or cisterns);
- Distribution system; and
- Overflow system.

Guidance regarding the design of each of these components is provided below. For further detail, refer to, *Ontario Guidelines for Residential Rainwater Harvesting Systems* (University of Guelph, 2010). The University of Guelph and Toronto and Region Conservation Authority have also partnered to develop a *Rainwater Harvesting System Design Tool* to assist system designers in estimating rainwater capture, usage and overall system cost and optimizing benefits (University of Guelph and TRCA, 2009; download the tool from www.sustainabletechnologies.ca).

Catchment Area

The catchment area is simply the surface from which rainfall is collected. Generally, roofs are used as the catchment surface for a rainwater harvesting system, although rainwater harvested from other source areas, such as low traffic parking lots and walkways, may be suitable for some non-potable uses (*e.g.*, outdoor washing). The quality of the harvested water will vary according to the type of source area and material from which the catchment area is constructed. Water harvested from parking lots, walkways and certain types of roofs, such as asphalt shingle, tar and gravel, and wood shingle roofs, should only be used for landscape irrigation or toilet flushing due to potential for contamination with toxic compounds. To minimize contamination of roof catchment areas with natural debris it is recommended that overhanging tree branches be trimmed back.

Collection and Conveyance System

The collection and conveyance system consists of the eavestroughs, downspouts and pipes that channel runoff into the storage tank. Eavestroughs and downspouts should be designed as they would for a building without a rainwater harvesting system with the addition of screens to prevent large debris from entering the storage tank (also see Pretreatment). When sizing eavestroughs and downspouts, designers should design the conveyance system in a way that minimizes the frequency of overflow events. For a residential collection system, less detail may be needed. For dual use rainwater cisterns (used year-round for both outdoor and indoor uses), the conveyance pipe leading to the cistern should be buried at a depth no less than the local maximum frost penetration depth (MTO, 2005) and have a minimum 1% slope (University of Guelph, 2010). If this is not possible, conveyance pipes should either be located in a heated indoor environment (*e.g.*, garage, basement) or be insulated or equipped with heat tracing to prevent freezing. All connections between downspouts, conveyance pipes and the storage tank must prevent entry of small animals or insects into the storage tank.

Pretreatment

Pretreatment is needed to remove debris, dust, leaves, and other debris that accumulates on roofs and prevents clogging within the rainwater harvesting system. Different levels of pretreatment should be provided, depending on what the harvested water will be used for. Pretreatment devices should be easily accessible for inspection and maintenance. For dual use cisterns that supply water for irrigation and toilet flushing only, filtration or first-flush diversion pretreatment is recommended. To prevent ice accumulation and freezing damage during periods of cold weather, first-flush diverter pretreatment devices should be either installed in a temperature controlled indoor environment, buried below the local frost penetration depth (MTO, 2005) or be insulated or equipped with heat tracing. If none of these measures can be taken, it may be necessary to disconnect the device from the conveyance system prior to the onset of freezing temperatures. Additional information about some common pretreatment devices is provided below.

- *Eavestrough or Downspout Filters:* Filters designed to remove leaves and other large debris from roof runoff such as leaf screens. Screen-type filters must be regularly cleaned to be effective; if not maintained, they can become clogged and prevent runoff from flowing into the storage tanks. Built-up debris can also harbor bacterial growth (TWDB, 2005).

- *First Flush Diverters:* First flush diverters direct the initial pulse of stormwater runoff away from the storage tank. While leaf screens effectively remove large debris such as leaves, twigs and blooms from harvested rainwater, first flush diverters can be used to remove smaller contaminants such as dust, pollen and animal droppings. Simple first flush diverters require gradual release drains or active management to drain the first flush water volume following each runoff event and regular cleaning to ensure they do not become clogged. First-flush diverters should be sized according to the desired amount of runoff to divert from the storage tank, typically 0.5 to 1.5 mm over the catchment area (University of Guelph, 2010).

- *In-ground Filters*: Filters placed between a conveyance pipe and an underground storage tank, designed to remove both large and fine particulate from harvested rainwater. A number of proprietary designs are available (*e.g.*, 3P Technik, GRAF, Rainharvesting Systems, WISY). Like leaf screens, they require regular cleaning to ensure they do not become clogged.

- *In-tank Filters*: Filters installed on the intake pipe within the storage tank (*e.g.*, floating suction filters). Like leaf screens, they require regular inspection to ensure they do not become clogged.

Storage Tank

The storage tank is the most important and typically the most expensive component of a rainwater harvesting system. The required size of storage tank is dictated by several variables: rainfall and snowfall frequencies and totals, the intended use of the harvested water, the catchment surface area, aesthetics, and budget. In the Greater Toronto Area, a suggested starting point for sizing the storage tank would be based on the predicted rainwater usage (*e.g.*, toilet flushing and outdoor uses) over a 10 to 12 day period. Further details with respect to sizing of the tanks, such as a continuous simulation approach, are discussed later in this section under “BMP Sizing”.

Designers can roughly estimate the capacity required in the storage tanks by multiplying the rainfall depth of the design storm by the footprint of the catchment area. Cistern capacities range from 750 to 40,000 litres (CWP, 2007b). Typical cisterns for residential use are approximately 5,000 litres. Cisterns may be ordered from a manufacturer or can be constructed on site from a variety of materials including fiberglass, polypropylene, wood, metal and concrete. Above-ground tanks are often plastic while integrated tanks are usually cast-in-place concrete. Underground tanks may be concrete or plastic. All cisterns should be sealed using a water safe, non-toxic substance.

Regardless of the type of storage tank used, they should be opaque or otherwise protected from direct sunlight to inhibit algae growth and screened to discourage mosquito breeding and reproduction. Tanks should be accessible for cleaning, inspection, and maintenance. Underground rainwater cisterns should be installed so that the top of the tank is below the local frost penetration depth (MTO, 2005).

The location, size and configuration of a cistern on a given site depend upon several factors which need to be weighed to arrive at an optimum design (University of Guelph, 2010):

1. Whether the cistern can be integrated within the building or installed underground;
2. Accessibility for construction and maintenance;
3. Desired storage capacity;
4. Site grading;
5. Proximity constraints (*e.g.*, proximity to catchment area, overflow discharge location, control components of pump and pressure system, building foundations, underground utilities, trees).

Storage tank volume should be designed to achieve an optimal balance between meeting water demand, achieving stormwater management objectives and controlling the overall cost of the system. The volume of dead storage below the intake to the distribution system and an air gap at the top of the tank should be considered in selecting the storage tank capacity (Coombes, 2004). For gravity-fed systems a minimum of 150 mm of dead storage should be provided. For systems using a pump, the dead storage depth will be based on the pump specifications. To determine the optimum storage tank capacity, two methods are available (University of Guelph, 2010):

> *Rainwater Harvesting System Design Tool* – a spreadsheet based computer program that uses information on geographic location, catchment area, and rainwater demand to determine an optimal cistern capacity and estimate overall system cost (University of Guelph and TRCA, 2009; to download the tool go to www.sustainabletechnologies.ca).
>
> *Rainwater Cistern Sizing Tables* – Tables of optimal rainwater cistern capacities have been generated using the Rainwater Harvesting System Design Tool for a number of cities (*e.g.*, Table 4.1.3) given a variety of roof catchment areas and rainwater demand assumptions (University of Guelph and TRCA, 2009).

On sites where a rainwater harvesting system is being installed to manage runoff rates (*i.e.*, erosion control objectives), the storage tank can be sized to collect a specified portion of runoff from a storm event, resulting in a tank that is larger than needed to meet water conservation objectives alone. When used in conjunction with an appropriately designed outflow control the rainwater storage tank could provide temporary detention and controlled release of stormwater in order to achieve peak flow targets for erosion control.

Distribution System

Most distribution systems are gravity fed or operated using pumps to convey harvested rainwater from the storage tank to its final destination. Typical outdoor uses use gravity to feed hoses via a tap and spigot. For underground cisterns or large sites, a water pump is needed. This can be a typical pump for distributing non-pressurized water for landscaping applications.

Indoor rainwater harvesting systems usually require a pump, pressure tank, back-up water supply line and backflow preventer. The typical pump and pressure tank arrangement consists of a multistage centrifugal pump, which draws water out of the storage tank and sends it into the pressure tank, where it is stored for distribution. When water is drawn out of the pressure tank, the pump kicks on and supplies additional water to the distribution system. Many indoor systems also have a back-up municipal water supply line feeding into them (*i.e.*, “make-up” line) to provide a means of topping up the cistern with potable water when rainwater levels in the cistern fall below a specified level. A backflow preventer is required on “make-up lines” to prevent harvested rainwater from backing up into potable water supply lines. An alternative design switches fixtures connected to the cistern to municipal supply until additional rain or snowmelt fills the tank.

Overflow System

An overflow system must be included in the design in the event that multiple storms occur in succession and fill rainwater storage. Overflow pipes should have a capacity equal to or greater than the inflow pipe(s). The overflow system may consist of a conveyance pipe from the top of the cistern to a pervious area downgradient of the storage tank, where suitable grading exists. The overflow discharge location should be designed as simple downspout disconnection to a pervious area, vegetated filter strip, or grass swale. When discharging overflows to a pervious area, the conveyance pipe should be screened to prevent small animals and insects from entering the pipe.

Where site conditions do not permit overflow discharge to a pervious area, the conveyance pipe may need to be indirectly connected to a storm sewer. An indirect connection to a storm sewer can be created by:

1. Overflowing from the inlet line (*e.g.*, roof downspout) to a pervious or impervious area that drains to a storm sewer;
2. Overflowing to a tile drain;
3. Overflowing via overland flow to a sewer grate.

Overflow conveyance pipes can also be directly connected to a storm sewer with incorporation of a backflow preventer (*i.e.*, backwater check valve) to prevent contamination of stored rainwater in the event that the storm sewer backs up during intense storm events. Alternatively, where suitable site conditions exist, the overflow conveyance pipe can be connected to a soakaway that overflows to a storm sewer with a backflow preventer.

Other Design Aspects

- Access and Maintenance Features: For underground cisterns, a standard size manhole opening should be provided for maintenance purposes. This access point should be secured with a lock to prevent unwanted access. A drain plug or cleanout sump, also draining to a pervious area, should be installed to allow the system to be completely emptied if needed.

Other Resources

Several other manuals that provide useful design guidance for rainwater harvesting are:

Canadian Standards Association publications
http://www.csa-intl.org/onlinestore/

Portland Stormwater Management Manual
http://www.portlandonline.com/bes/index.cfm?c=dfbcc

Rainwater Harvesting Systems for Montana
http://www.montana.edu/wwwpb/pubs/mt9707.html

Texas Rainwater Harvesting Manual
http://www.twdb.state.tx.us/publications/reports/RainwaterHarvestingManual_3rdedition.pdf

Tucson, AZ Water Harvesting Guidance Manual
http://dot.ci.tucson.az.us/stormwater/downloads/2006WaterHarvesting.pdf

University of Guelph. 2010. *Ontario Guidelines for Residential Rainwater Harvesting Systems*. Guelph, ON.

University of Guelph and Toronto and Region Conservation Authority (TRCA). 2010. *Rainwater Harvesting System Design Tool.* www.sustainabletechnologies.ca

Water Sensitive Planning Guide for the Sydney Region: Practice Note 4 - Rainwater Tanks. http://www.wsud.org/planning.htm

BMP Sizing

Rainwater harvesting systems should be designed by optimizing the size of the storage tank based on the size of the catchment area, estimated rainwater demand and cost. In the Greater Toronto Area, this can be done through application of the Rainwater Harvesting System Design Tool (spreadsheet) developed by the University of Guelph and TRCA (2009), or rainwater storage tank sizing tables generated by the spreadsheet tool (*e.g.*, Table 4.1.3). Figure 4.1.5 illustrates some input and output information from the Rainwater Harvesting System Design Tool.

Table 4.1.3: Recommended rainwater storage tank capacities for various catchment areas and water demands for systems in Toronto

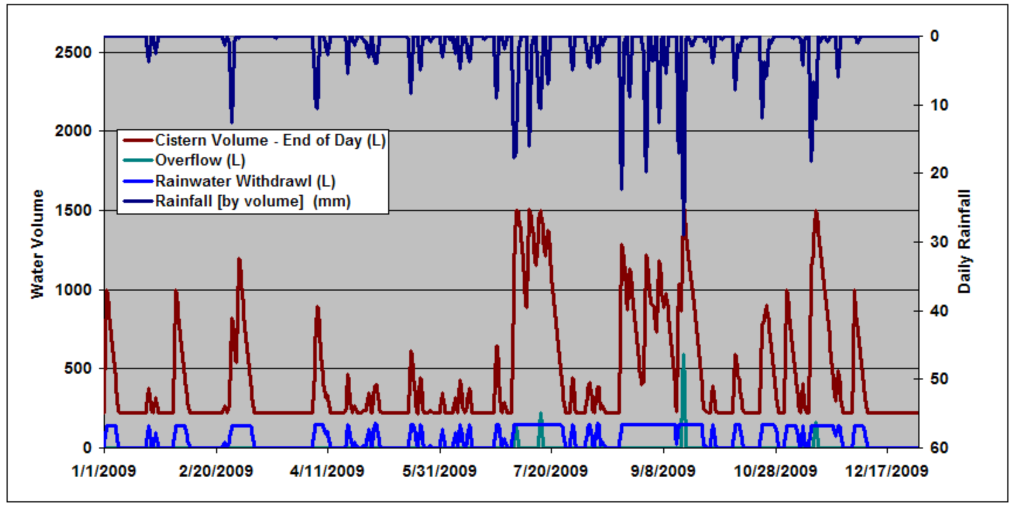
Rainwater Demand (Litres per day)	Optimum Rainwater Storage Tank Capacity (L)																		
	Roof Catchment Area (m^2)																		
	50	100	150	200	250	300	350	400	450	500	600	700	800	900	1,000	1,500	2,000	2,500	3,000
50	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	5,000	5,000	5,000	5,000	5,000
100	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	5,000	5,000	5,000	5,000	5,000
150	2,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	5,000	5,000	5,000	5,000	5,000
200	2,000	5,000	5,000	5,000	5,000	5,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	5,000	5,000	5,000	5,000	5,000
250	2,000	5,000	5,000	7,500	5,000	5,000	5,000	5,000	5,000	5,000	5,000	4,000	4,000	4,000	5,000	5,000	5,000	5,000	5,000
300	2,000	5,000	5,000	7,500	7,500	7,500	7,500	7,500	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000
350	-	5,000	5,000	7,500	7,500	7,500	7,500	7,500	7,500	7,500	7,500	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000
400	-	5,000	5,000	7,500	7,500	7,500	7,500	7,500	7,500	7,500	7,500	7,500	7,500	7,500	7,500	5,000	5,000	5,000	5,000
450	-	5,000	5,000	7,500	7,500	7,500	7,500	7,500	7,500	7,500	7,500	7,500	7,500	7,500	7,500	7,500	7,500	7,500	7,500
500	-	5,000	5,000	7,500	7,500	7,500	7,500	7,500	7,500	7,500	7,500	7,500	7,500	7,500	7,500	7,500	7,500	7,500	7,500
600	-	5,000	5,000	7,500	7,500	7,500	7,500	7,500	7,500	7,500	7,500	10,000	10,000	7,500	7,500	7,500	7,500	7,500	7,500
700	-	5,000	5,000	7,500	7,500	7,500	7,500	7,500	7,500	7,500	7,500	10,000	10,000	10,000	10,000	10,000	10,000	10,000	7,500
800	-	5,000	5,000	7,500	7,500	7,500	7,500	7,500	7,500	7,500	7,500	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000
900	-	-	5,000	7,500	7,500	7,500	7,500	7,500	7,500	7,500	7,500	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000
1,000	-	-	5,000	7,500	7,500	7,500	7,500	7,500	7,500	7,500	7,500	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000
1,500	-	-	5,000	7,500	7,500	7,500	7,500	7,500	7,500	7,500	7,500	10,000	10,000	10,000	10,000	10,000	15,000	15,000	15,000
2,000	-	-	5,000	7,500	7,500	7,500	7,500	7,500	7,500	7,500	7,500	10,000	10,000	10,000	10,000	10,000	15,000	15,000	15,000
2,500	-	-	-	7,500	7,500	7,500	7,500	7,500	7,500	7,500	7,500	10,000	10,000	10,000	10,000	10,000	15,000	15,000	15,000
3,000	-	-	-	7,500	7,500	7,500	7,500	7,500	7,500	7,500	7,500	10,000	10,000	10,000	10,000	10,000	15,000	15,000	15,000

Recommended rainwater storage tank capacities generated using the Rainwater Harvesting System Design Tool (University of Guelph and TRCA, 2009) assuming:

1. Historical rainfall for the City of Toronto (median annual rainfall 678 mm);
2. Optimum cistern is defined as a cistern providing at least a 2.5% improvement in water savings following an increase of 1,000 Litres in storage capacity.

Figure 4.1.5 University of Guelph and TRCA Rainwater Harvesting System Design Tool

	A	B	C	D	E
1					*Scenario 1*
2	City:	Toronto (Downsview)			
3	Setting:	Residential			
4	Total Number of People:	2			
5	Days Occupied per Week:	7			
6	Roof Surface Area (m^2):	60			
7	Roofing Material:	Asphalt Shingle			
8	Initial Loss Factor (mm):	0.5			
9	Continuous Loss Factor (%)	20			
10	Pre-treatment of Rainwater	N/A			
11	Initial Loss Factor (mm):	0			
12	Continuous Loss Factor (%)	0			
13	COLD				Liters per capita per day (lpcd)
14	Toilets	Dual-flush	*Flushes per day:*	7.0	33.6
15	Urinals	N/A	*Flushes per day:*	0.0	0.0
16	Washing Machine	N/A	*Loads per week:*	0.0	0.0
17		N/A			
18	Irrigation & Landscaping	Efficient - 0.25in	*Area irrigated (m^2)*	10.0	4.6
19			*No. of times irrigated per week:*	1.0	
20	Lavatory/Laundry Faucets (L)	N/A	*Uses per person per day:*	0.0	0.0
21	Other (L)	N/A	*Uses per person per day:*	0.0	0.0
22					
23	HOT				
24	Dishwasher	N/A	*Loads per week:*	0.0	0.0
25	Washing Machine				0.0
26	Shower	N/A	*Minutes per shower:*	0.0	0.0
27	Lavatory/Laundry Faucets (L)	N/A	*Uses per person per day:*	0.0	0.0
28	Other (L)	N/A	*Uses per person per day:*	0.0	0.0
29					
30			Total water use per person per day		38.171
33	**Daily water demand:**	**76 Litres per day**			
35	**Cistern Sizing Analysis**				
36	Analysis:	Standard Analysis			
37	Type of Analysis	Manually calculate based on cistern sizes I input			
39	**Cistern Volumes to be Analyzed:**				
40	Cistern Volume 1 (L)	1,500	Cistern Volume 1 (L)	0	
41	Cistern Volume 2 (L)	0	Cistern Volume 2 (L)	0	
42	Cistern Volume 3 (L)	0	Cistern Volume 3 (L)	0	
43	Cistern Volume 4 (L)	0	Cistern Volume 4 (L)	0	
44	*Advanced calculation details (hidden by default)*				
45					
46	Contribution of snow melt (%)	50.0%			
47	Rainwater cistern dead space (%)	15.0%			
48	**Analyze rainfall data by Volume**				



Sheet1 | Average House_S1REPORT | **Average House_S1** | Average House_S1P | Average House_S1A | Sheet2 | Sheet3

In situations where the runoff volume or peak flow reduction required to achieve stormwater management objectives exceeds the capacity of the optimum sized storage tank, based on water demand and catchment area, rainwater harvesting systems should overflow to another LID practice. This can be done by directing overflows from the storage tank to a pervious area (*i.e.*, simple downspout disconnection), vegetated filter strip, grass swale, or soakaway. Alternatively, the storage tank could be oversized and combined with an outflow control to provide temporary detention and controlled release of stormwater, similar to a detention pond.

Estimating Rainwater Demand

Sizing the storage tanks and catchment area for rainwater harvesting systems begins with estimation of the rainwater demand. The following factors should be considered in determining rainwater demand for outdoor uses:

- Method of distribution and associated flow rate (*e.g.* sprinkler systems, soaker hoses, pressure washing equipment);
- Frequency of watering based on season and landscaping best management practices;
- Landscaping area to be watered;
- For redevelopment or retrofit installations, the actual water usage by comparing winter and summer water bills.

Dual use rainwater harvesting systems (both outdoor and indoor use) can be sized based on the demand principles used for site-specific traditional water and wastewater design. These estimates can be broken down into usage by aspects of the plumbing system such as toilets.

The University of Guelph and TRCA Rainwater Harvesting System Design Tool (2009) can also be used to generate estimates of rainwater demand. Rainwater demand estimates and assumptions should be included with system design documents submitted for review by approval authorities.

Stormwater Management Requirements

The needed treatment volume for water quality, peak flow control, and water balance objectives should be calculated based on the relevant methodology in the CVC or TRCA stormwater management criteria documents (CVC, 2010; TRCA, 2010). Continuous simulation of rainfall and storage tank capacity is necessary to design rainwater harvesting systems to meet stormwater management requirements as the available storage fluctuates based on the temporal rainfall distribution and water usage. This can be done using the University of Guelph and TRCA Rainwater Harvesting System Design Tool (2009). If a different model is used for analysis, it should consider the available storage in the tank during a storm event which varies according to the size of the previous storm event, rainwater demand (rate of use) and the length of time since the previous storm event, all of which vary seasonally. It is important to note that the total volume of the storage tank is not the active storage volume. The active storage volume of the tank does not include the freeboard between the overflow outlet and the top of the tank nor any dead storage below the intake to the distribution system.

Sizing Secondary LID Practices

Compare the rainwater demand storage volume to the stormwater management volume required. The volume not stored in the rainwater harvesting system will have to be treated through a secondary LID practice. For water quality and water balance requirements, simple downspout disconnection, vegetated filter strips, grass swales and bioretention are possible choices. For peak flow control requirements, overflow to a storm sewer that flows to a detention pond or subsurface detention chamber should be considered. With incorporation of a suitable outflow control, an underground rainwater cistern can provide temporary detention and controlled release of stormwater (Coombes, 2002; City of Portland, 2004).

Design Specifications

Recommended design specifications for rainwater harvesting systems are provided in Table 4.1.4.

Table 4.1.4 Design specifications for rainwater harvesting systems

Component	Specification	Quantity
Eavestroughs and Downspouts	Materials commonly used for eavestroughs and downspouts include polyvinylchloride (PVC) pipe, vinyl, aluminum and galvanized steel. Lead should not be used as solder as rainwater can dissolve the lead and contaminate the water supply.	Determined by the size and layout of the catchment and the location of the storage tanks. Include needed bends and tees.
Pretreatment	At least one of the following: ▪ leaf and mosquito screens (1 mm mesh size); ▪ first-flush diverter; ▪ in-ground filter; ▪ in-tank filter. Large tanks (10m^3 or larger) should have a settling compartment for sediment removal	1 per inlet to the collection system.
Storage Tanks	▪ Materials used to construct storage tanks should be structurally sound. ▪ Tanks should be installed in locations where native soils or building structures can support the load associated with the volume of stored water. ▪ Storage tanks should be water tight and sealed using a water safe, non-toxic substance. ▪ Tanks should be opaque to prevent the growth of algae. ▪ Previously used containers to be converted to rainwater storage tanks should be fit for potable water or food-grade products. ▪ Cisterns above- or below ground must have a lockable opening of at least 450 mm diameter.	The size of the cistern(s) is determined during the design calculations.
Note: This table does not address indoor systems or pumps.		

Construction Considerations
For installation, it is advisable to have an experienced contractor who is familiar with cistern sizing, installation materials, and proper site placement. A minimum one-year warranty is recommended.

Sequencing
Stormwater should not be diverted to the cistern until the catchment area and overflow area have been stabilized.

Construction Inspection
The following items should be inspected prior to final sign-off on the stormwater management construction:

- Catchment area matches plans;
- Overflow system is properly sized and installed;
- Pretreatment system is installed;
- Screens are installed on all openings;
- Cistern foundation is constructed as shown on plans; and
- Catchment area and overflow area are stabilized.

4.1.3 Maintenance and Construction Costs

Maintenance
Maintenance requirements for rainwater harvesting systems vary according to use. Systems that are used to provide supplemental irrigation water have relatively low maintenance requirements, while systems designed for indoor uses have much higher maintenance requirements. All rainwater harvesting system components should undergo regular inspections every six months during the spring and fall seasons (LID Center, 2003b). The following maintenance tasks should be performed as needed to keep rainwater harvesting systems in working condition:

- keep leaf screens, eavestroughs and downspouts free of leaves and debris;
- check screens (1 mm openings) and patch holes or gaps immediately;
- clean and maintain first flush diverters and filters, especially those on drip irrigation systems;
- inspect and clean storage tank lids, paying special attention to vents and screens on inflow and outflow spigots; and
- replace damaged system components as needed.

Mosquito Control
If screening is not sufficient to deter mosquitoes, the following techniques can be used for harvested rainwater intended for landscaping use:

- add a few tablespoons of vegetable oil to smother larvae that come to the surface; and
- use mosquito dunks or pellets containing larvicide.

Winter Operation

Rainwater harvesting systems have a number of components that can be affected by freezing winter temperatures. Designers should give careful consideration to these conditions to prevent system damage and costly repairs. For above-ground systems, winter-time operation may not be possible. These systems must be taken offline for the winter. Prior to the onset of freezing temperatures, above-ground systems should be disconnected and drained. For below-ground and indoor systems, downspouts and overflow components should be checked for ice blockages during snowmelt events.

Installation and Operation Costs

The cost of rainwater harvesting systems includes the cost of the storage tanks, as well as any necessary pumps, wiring and distribution system piping. Storage tanks often make up the majority of system costs. Their cost varies depending on the size, construction material and whether they are located above or below ground (LID Center, 2003b). The University of Guelph and TRCA Rainwater Harvesting System Design Tool (2009) allows the user to estimate the overall cost of different system designs.

The capital cost to homeowners of an individual rainwater harvesting system can range between $6,000 and $14,000 (in 2006 Canadian dollars), depending on its size and configuration (CMHC, 2009). Based on analysis by the Center for Watershed Protection (2007b), base construction costs per cubic metre of runoff stored (in 2006 US dollars) range from $212 to $777, with a median of $530 (CWP, 2007b).

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