Ontario Guidelines for Residential Rainwater Harvesting Systems

2010

HANDBOOK

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In Ontario, Ontario's Building Code (OBC) and the Ontario Electrical Safety Code are the codes that are applicable to the design, construction and management of rainwater harvesting systems. This guidelines document and the accompanying handbook provide guidance for designing, constructing, and managing rainwater harvesting systems based on the minimum safety requirements established in these codes:

Ontario's Building Code:

http://www.e-laws.gov.on.ca/html/regs/english/elaws_regs_060350_e.htm

Ontario Electrical Safety Code Regulation:

http://www.e-laws.gov.on.ca/html/regs/english/elaws_regs_990164_e.htm

This document is not intended to convey legal advice and is not a substitute for professional technical design. While care has been taken to ensure accuracy, the examples and explanations in this guide are given for the purposes of illustration only.

Readers must refer to the actual wording of the applicable law, including the Building Code Act, 1992, O. Reg. 350/06 (the Building Code), O. Reg. 164/99 (the Ontario Electrical Safety Code) and other applicable law. Persons seeking legal advice about the matters discussed in these guidelines should consult a solicitor.

The Author and Editors do not assume responsibility for errors or oversights resulting from the information contained herein.

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Rainwater Harvesting Task Group

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2. Canada Mortgage and Housing Corporation
3. Canadian Water and Wastewater Association
4. City of Calgary
5. City of Guelph
6. Ecoshift
7. Evolve Builders Group Inc.
8. GE Water & Process Technologies
9. Interpump Supply Ltd.
10. Ontario Ministry of Municipal Affairs and Housing
11. Region of Durham
12. RH2O North America Inc.
13. Toronto and Region Conservation Authority

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Introduction

Rainwater harvesting (RWH) is the ancient practice of collecting rainwater and storing it for later use. RWH systems are comprised of a roof catchment, conveyance network, rainwater storage tank, pump, and fixtures where rainwater is utilized. Most systems also incorporate treatment technologies to improve the quality of rainwater before and/or after storage, and include provisions for periods of insufficient rainfall (a water make-up supply) and times of excessive rainfall (overflow provisions).

The most important consideration when designing and installing a RWH system are the pertinent provincial codes and regulations, standards, and municipal bylaws. Other considerations include how the design, installation and management of RWH systems can affect the quantity of water saved and the quality of rainwater harvested, as well as cold weather suitability of the system.

The design and installation guidelines are presented in several sections, organized by the different components of RWH systems. These components are as follows:

1. Rainwater Catchment & Conveyance
2. Rainwater Storage & Tank Sizing
3. Rainwater Quality & Treatment
4. Water Make-up System & Backflow Prevention
5. Pump & Pressurized Distribution System
6. Overflow Provisions & Stormwater Management

This document is aimed at a wide audience, including homeowners, engineers, architects, contractors, developers, regulators, as well as members from municipal, provincial and federal levels of government. Background information on each aspect of a RWH system is discussed and relevant clauses from existing codes and regulations, standards, and guidelines are presented, as well as additional design criteria derived from recent field experience and international best practices for rainwater harvesting. An accompanying document, *Ontario Guidelines for Residential Rainwater Harvesting Systems – 2010* is a more concise version of this document, and is recommended for individuals with knowledge of the building sector and the basic trades involved in rainwater harvesting (i.e., plumbing, electrical, and site service work). Both documents are primarily focused on residential rainwater harvesting systems designed for non-potable use.

What are the Permitted Uses of Rainwater?

As of the publication date of these *Guidelines* (July 2010) applicable provincial codes and regulations in the Province of Ontario permit the use of rainwater for flushing toilets and urinals, as well as for sub-surface irrigation and below ground irrigation systems[1].

[1] Rainwater connections must be made in accordance with Ontario's Building Code. 2006. Ministry of Municipal Affairs and Housing, Toronto, ON., and in accordance with local authorities.

Chapter 1. Rainwater Catchment & Conveyance

1.1 Introduction

A key component of rainwater harvesting is the collection of rainwater from a catchment surface, and its conveyance to a tank for storage and future use.

Rainwater harvesting (RWH) systems most often utilize the roof of a house or building for collecting rainwater. While it is possible to collect rainwater from other surfaces, such as lawns or parking lots, these catchments are not addressed in this manual due to concerns surrounding the quality of rainwater collected from these surfaces. Consequently, this chapter focuses exclusively upon the collection of runoff from roof surfaces, or 'roof catchments.'

Once rainwater has been collected from the catchment surface, it must be conveyed to the storage tank by means of a 'conveyance network.' The most common method of conveying rainwater is through the use of gravity flow, whereby rainwater is transported to the storage tank without the use of pumps or other means of assistance. The conveyance network of a RWH system is typically comprised of three main components: external gutters (also referred to as 'eavestroughs'), downspouts, and drainage piping (shown in Figure 1-1). Other means of conveying rainwater, such as 'rain leaders' (drainage pipes located inside a building), are available, however, these shall not be directly addressed.

Figure 1-1. [LEFT] 1. Gutter and 2.Downspout; [RIGHT] Conveyance drainage piping for below-ground rainwater storage tank (prior to burial)

The size and complexity of a conveyance network may be quite minimal, as is the case for most above ground storage tanks located a short distance from the catchment surface. For below ground tanks and tanks integrated within buildings, these networks can be much more extensive and complex. This chapter provides guidance on the issues to consider when selecting the catchment surface, and how to design and install the conveyance network to handle the large volumes of rainwater runoff that are generated during severe storm events.

1.2 Applicable Codes, Standards, and Guidelines

Table 1-1 references codes and standards applicable to catchment and conveyance networks.

Table 1-1. Applicable standards, codes and guidelines for rainwater catchment and conveyance networks

Applicable Codes, Standards and Guidelines	Selected Provisions & Design and Installation Implications
Ontario's Building Code O. Reg 350/06 (2006)	• **7.2.5.10. Plastic Pipe, Fittings and Solvent Cement Used Underground** • **7.2.5.12. Plastic Pipe, Fittings and Solvent Cement Used in Buildings** • **7.3.4.5. Support for Horizontal Piping** • **7.3.4.6. Support for Underground Horizontal Piping** • **7.3.5.1. Backfill of Pipe Trench** • **7.3.5.4. Protection from Frost** • **7.4.7. Cleanouts** • **7.4.10.4. Hydraulic Loads from Roofs or Paved Surfaces** • **7.4.10.9. Hydraulic Loads on Horizontal Storm Drains** • **Supplementary Standard SB-1, Table 1.2** Articles 7.2.5.10. and 7.2.5.12. specify approved pipe materials used underground and inside buildings. The OBC also provides provisions for the support and protection of piping. Subsection 7.4.7. provides provisions on the size and spacing of cleanouts, manholes, and location of cleanouts. Articles 7.4.10.4. and 7.4.10.9. specify the method for sizing conveyance drainage pipes, based upon design rainfall intensity values (15 Min Rainfall, mm) obtained from Table 1.2 in Supplementary Standard SB-1, the roof catchment area, and the slope of conveyance drainage piping.
CSA Standard B128.1 (2006)	• **10 Separation** • **12.3 Buried pipe** Provides specifications for the installation of conveyance drainage piping for underground and above ground applications. *Note: Not legally binding unless adopted in future editions of the OBC.*
NSF Protocol P151 (1995)	Selection of roofing materials, coatings, paints, and gutters with NSF P151 certification will not impart levels of contaminants greater than those specified in the U.S. EPA's Drinking Water Regulations. Recommended where high quality rainwater is needed for the intended use. *Not legally binding unless adopted in future editions of the OBC.*

Mandatory Documents   Supplementary Documents

1.3 Issues for Consideration

Catchment Area

Theoretically, for every square meter of roof catchment area, 1 Litre of rainwater can be captured per millimetre of rainfall. To calculate the catchment area:

$$\boldsymbol{Catchment\ Area}\ (\mathbf{m^2}) = Length\ (\mathrm{m}) \times Width\ (\mathrm{m})$$

The relationship between catchment area and the volume of rainwater collected is illustrated in Figure 1-2. As shown below, the larger the catchment area, the greater the quantities of rainwater that can be collected per millimetre of rainfall.

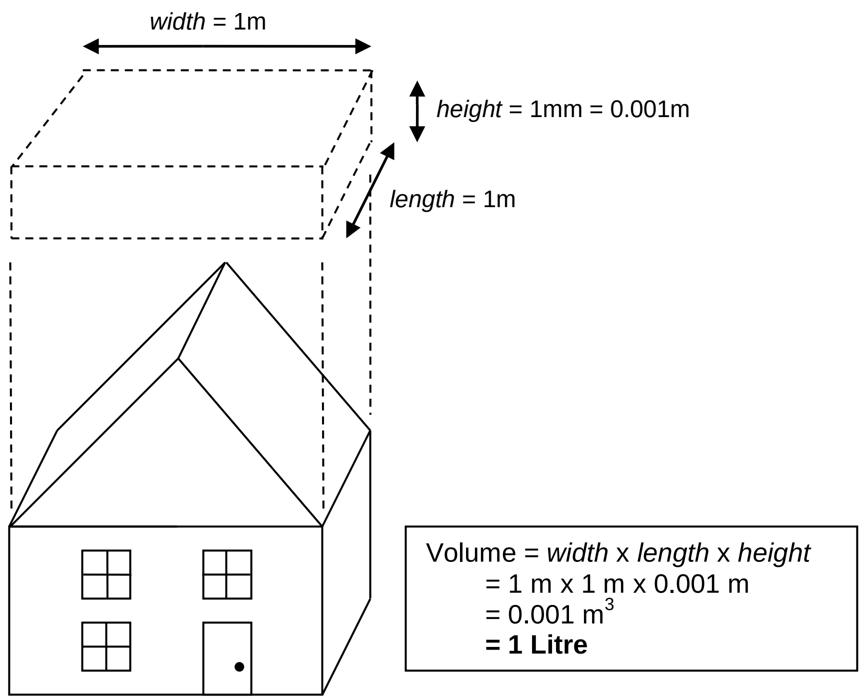

Figure 1-2. Theoretical volume of rainwater collected from a roof catchment

The catchment area has a significant impact on both the design and water savings potential of RWH systems. In general, it is recommended that the size of the catchment area used for a RWH system be as large as possible to maximize water savings. For most RWH systems collecting rainwater from a roof catchment, the size of the catchment area is usually predetermined by the size of the existing house or building. In such cases, one means of collecting additional rainwater is to utilize multiple roof catchments and convey rainwater to one central, or 'communal,' storage tank.

Alternatively, sometimes it may not be feasible or beneficial to collect rainwater from the entire catchment area due to rainwater quality concerns, location/placement of the rainwater storage tank, or for other reasons. These, and other, issues are discussed further in the Design & Installation Guidelines.

Catchment Material

In Canada, most houses have sloped roofs covered with asphalt shingles, while many industrial, commercial and institutional buildings have flat built-up roofs (which can be comprised of various materials, i.e., felt and asphalt roofs). The type of catchment material used by a RWH can affect:

1. The proportion of rainfall collected during a rainfall event, defined as the 'collection efficiency' from the roof catchment; and
2. The quality of harvested rainwater.

Rainfall Collection Efficiency

Although 1 Litre of runoff can theoretically be collected from each millimetre of rainfall contacting a 1 m^2 surface area, some losses take place following contact with the catchment surface. These losses vary depending upon the type of catchment material and the geometry of the roof and should be considered when estimating the amount of rainwater that can be collected and utilized by the RWH system. In general these losses can be characterized by an initial loss factor (in mm of rainfall) due to the absorbency of the catchment material, and continuous losses (in percentage of rainfall) from wind and leaks in the conveyance network. These losses for various roof catchment materials are listed in Table 1-2.

Table 1-2. Collection efficiency (loss factors) associated with various roof catchments[2] [3]

Roof Catchment Material	Initial Rainfall Loss Factor (mm)	Continuous Rainfall Loss Ratio (%)
Steel Roof	0.25	20.0
Asphalt Shingle Roof	0.5	20.0
Fiberglass Roof	0.5	20.0
Asphalt Built-up Flat Roof	1.5	20.0
Hypalon (Rubber) Flat Roof	1.5	20.0

[2] DIN 1989-1:2001-10. DIN 1989 Rainwater Harvesting Systems - Part 1: Planning, Installation, Operation and Maintenance. 2002. Fachvereinigung Betriebs- und Regenwassernutzung e.V, fbr, Darmstadt, Germany.
[3] Building Capacity for Rainwater Harvesting in Ontario: Rainwater Quality and Performance of RWH Systems. 2008. Despins, C. M.Sc. Thesis, University of Guelph.

Rainwater Quality

The quality of rainwater runoff from a catchment surface can be affected in two ways. First, dirt and debris can collect on the roof surface from direct atmospheric deposition, or from overhanging foliage or bird and rodent droppings. Alternatively, the roof material itself can contribute both particulate matter and dissolved chemicals to runoff water. This first issue is a concern for all RWH systems and is discussed in greater detail in *Chapter 3. Rainwater Quality & Treatment*. Dissolved particulate matter and chemicals are generally only of concern if rainwater is to be used for potable water applications and as such these issues are not directly addressed in this manual (refer to NSF Protocol P151 for further guidance on this issue, see *Section 1.2 Applicable Codes, Standards, and Guidelines* for details).

Rainwater Conveyance

Once collected from the catchment surface, rainwater is transferred to the rainwater storage tank through a series of components, referred to as the 'conveyance network.' An illustration of a typical conveyance network for a residential household is provided in Figure 1-3.

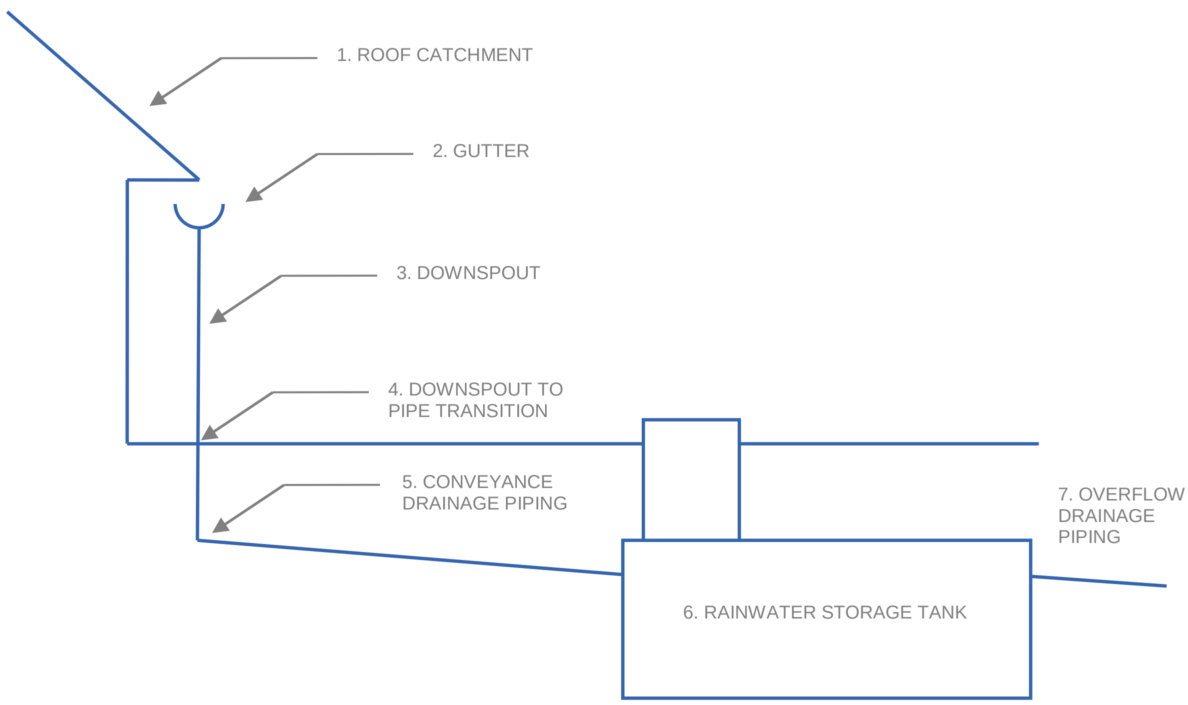

Figure 1-3. Schematic of a typical conveyance network for a below-ground rainwater storage tank

When designing and installing a conveyance network, a number of issues must be considered, including:

1. Sizing and placement of conveyance network
2. Site conditions and location/placement of storage tank
3. Cold weather issues
4. Rainwater quality

These issues are examined in greater detail in the following sections.

Size, Slope and Placement of Conveyance Network

To ensure that the conveyance network can handle the runoff from the catchment surface in severe storms, all sections of the conveyance network (gutters, downspouts and drainage piping) must be appropriately sized and sloped to promote the rapid drainage of water. The design of gutters and downspouts are generally not dependent upon building code specifications; rather, there are standard sizes and 'rules of thumb' for residential applications. Conveyance drainage pipes must be sized in accordance with the applicable provincial codes and regulations, (refer to *Section 1.2 Applicable Codes, Standards, and Guidelines* for details).

When sizing pipes and other parts of the conveyance network, it is important to consider what proportion of the catchment surface a particular section of the network is handling. In a majority of cases, the catchment surface will be divided into sections for the collection and conveyance of rainwater (i.e., a peaked roof will have at least two distinct drainage areas where rainwater will be collected). As such, it may be necessary to have multiple smaller conveyance drainage pipes that transfer rainwater to a larger-sized pipe prior to the rainwater storage tank.

Site Conditions and Tank Location

When planning a conveyance network, it is important to take into consideration the site conditions and location/placement of the rainwater storage tank. It may be difficult to connect some sections of the catchment surface to the conveyance network due to the grading and/or layout of the site, distance to the storage tank, or complex roof shapes. For instance, when designing the layout of conveyance drainage pipe transferring rainwater to a tank located below ground, the length of pipe and pipe slope can affect the burial depth of the tank (i.e., force it to be buried deeper below ground). Some tanks, however, cannot be buried below a maximum rated burial depth, and consequently, the location of the tank or pipe slope may need to be adjusted. Alternatively, a reinforced tank designed for deeper burial must be selected. Refer to *Chapter 2. Rainwater Storage & Tank Sizing* for further details.

Another concern when designing conveyance networks leading to below-ground tanks is the presence of buried service lines (gas, water, phone, etc.). An inspection of the site to locate the service lines must be performed to ensure that the planned route is free from buried lines.

Conveyance Network Materials Selection

Part of planning the conveyance network is selecting the appropriate material for each of the network's components. Gutters and downspouts are generally manufactured using aluminum or galvanized steel, and both are considered suitable for use with RWH systems. When selecting a pipe material, a number of criteria must be considered. The pipe selected shall be rated as suitable for Ultraviolet (UV) light exposure and burial (where applicable), and if rainwater quality is of concern, be rated for handling potable water. In addition, the selected pipe must be approved by the applicable provincial codes and regulations. In general, a type of Polyvinyl chloride (PVC) pipe, referred to as "sewer grade pipe" or "PVC SDR35" is recommended for RWH systems, as it meets these criteria. Acrylonitrile butadiene styrene (ABS) is another type of pipe that can be used, and is typically less expensive than PVC SDR35, but may not be appropriate for all RWH systems as it is not rated for UV exposure. It is important to note however, that even if rainwater is conveyed using pipe suitable for potable water, this does not imply that rainwater is potable or suitable for potable use.

Cold Weather Issues

Throughout much of Canada, temperatures often drop below freezing (0°C) during the winter months. During periods of extreme cold weather, rainwater that is outdoors or in an environment not temperature controlled (maintained above 0°C) is at risk of freezing. Rainwater can freeze in the conveyance network if it is not drained adequately or if it must travel through extended portions of the network that are not temperature controlled.

Rainwater Quality

When planning the rainwater catchment and conveyance network, the quality of rainwater entering the storage tank may be improved by excluding the catchment of rainwater from specific materials or sections of the catchment surface, such as sections which utilize a green roof or sections with overhanging foliage. If quality is of concern, but the amount of rainwater collected must be maximized by collecting from some of these surfaces, rainwater can be treated before use. Refer to *Chapter 3. Rainwater Quality & Treatment* for further details.

Rainwater quality can also be improved by preventing the entry of contaminants into the tank by means of the conveyance network. To prevent the entry of animals or insects into the tank, all sections of the conveyance network must be structurally sound and not have any holes or other points of entry other than those required for water flow. Particular attention should be paid to the transitions between components, especially the transition from the downspout to conveyance drainage pipe, which is usually located at ground level.

1.4 Design & Installation Guidelines

Design and installation guidelines:

> **Note**: refer to *Section 1.2 Applicable Codes, Standards, and Guidelines* for the specific provisions that apply when the term "in accordance with applicable provincial codes and regulations" is used.

1. When selecting the catchment(s) for collecting rainwater:
    a. Only roof surfaces are recommended;
    b. Collection from green roofs is not recommended;
    c. Avoid sections of the roof with overhanging foliage, or trim where possible;
    d. If rainwater collected from the catchment surface must be of very high quality, materials with NSF P151 certification can be selected.
2. To maximize the volume of rainwater collected by the RWH system:
    a. The catchment surface should be as large as possible;
    b. If a roof catchment material is to be selected and installed in conjunction with the RWH system, material with minimal collection losses, such as steel, should be selected (refer to Table A-1 for details);
    c. Convey rainwater using appropriately sized and sloped components, including gutters, downspouts, and/or conveyance drainage piping; and
    d. Where possible, multiple roof catchments can be connected to a central or 'communal' rainwater storage tank.
3. Gutters and downspouts:
    a. Gutter and downspout material:
        i. Aluminum or galvanized steel are recommended,
        ii. Copper, wood, vinyl, and plastic gutter and downspout materials are not recommended,
        iii. If rainwater conveyed through gutters and downspouts must be of very high quality, materials with NSF P151 certification can be selected.
    b. Gutter slope:
        i. Where possible, slope gutters in the direction of the location of the rainwater storage tank,
        ii. Ensure a minimum slope of 0.5-2% (the greater the slope the better) is maintained throughout the gutter length.
    c. Gutter size:
        i. In general, 125 mm [5 in.] K-style gutter is commonly used and should be suitable for most typical residential roof drainage areas and gutter lengths;
        ii. To determine the size of gutter required for a given roof drainage area:
            1. Consult the applicable provincial codes and regulations pertaining to the design rainfall intensity for the site location,
            2. Calculate the area of roof draining into the gutter:

$$\boldsymbol{Roof\ Drainage\ Area}\ (\mathbf{m^2}) = Length\ (\mathrm{m}) \times Width\ (\mathrm{m})$$

Equation 1-1

Where: Length = length of the gutter served by a downspout (m)
Width = distance from the eave to the ridge of the roof drainage area served (m)

1. Refer to Table 1-3 to determine the minimum size of gutter, required based upon the roof drainage area (m^2) and design rainfall intensity values determined above:

Table 1-3. Minimum gutter sizes for given roof drainage areas and rainfall intensities[4]

Minimum Required Gutter Size and Type	Maximum Roof Drainage Area Served per Downspout (m^2)[1,2]							
	Design Rainfall Intensity (15 Min rainfall, mm):							
	18.75	25	31.25	37.5	43.75	50	56.25	62.5
100 mm [4 in.] K-style	71	53	43	35	30	27	24	21
125 mm [5 in.] K-style	130	98	78	65	56	49	43	39
150 mm [6 in.] K-style	212	159	127	106	91	79	71	64

[1]Minimum required gutter size assumes that gutters have a minimum slope (≤ 6.25%). For greater gutter slopes, the table values may be multiplied by 1.1.
[2]Maximum roof drainage area assumed roof slopes ≤ 5:12. For steeper roof pitches, multiply the table values by 0.85.

ii. For other gutter types and/or larger roof drainage areas, consult the gutter manufacturer or contractor regarding the sizing of gutter.

b. Location and spacing of downspouts:
   i. Where possible, locate downspout(s) near the location of the rainwater storage tank,
   ii. Locating downspouts at inside building corners is not recommended;
   iii. Downspouts shall serve no more than 15 m [50 ft.] of gutter length.
c. Downspout size:
   i. In general, 50x75 mm [2x3 in] rectangular-type downspouts or 75x75 mm [3x3 in.] square-type downspouts are commonly used and should be suitable for most typical residential roof drainage areas and gutter lengths,
   ii. To determine the size of downspout required:
      1. Refer to Table 1-4 to determine the minimum size of downspout (either rectangular- or square type) based upon the size of gutter the downspout is serving:

[4] Adapted from Moisture Resistant Homes: A Best Practice Guide and Plan Review Tool for Builders and Designers. 2006. U.S. Department of Housing and Urban Development, Washington, DC

Table 1-4. Minimum downspout sizes for given size of gutter[5]

Gutter Size and Type	Minimum Downspout Size (mm [in])	
	Rectangular type	Square-type
100 mm [4 in.] K-style	50x75 [2x3]	75x75 [3x3]
125 mm [5 in.] K-style	50x75 [2x3]	75x75 [3x3]
150 mm [6 in.] K-style	75 x 100 [3x4]	100x100 [4x4]

iii. For other downspout types and/or larger gutter sizes, consult the gutter/downspout manufacturer or contractor regarding the sizing of downspout.

d. Gutter and downspout installation:
   i. Gutters should be custom-fabricated and installed such that there are no seams along the length of guttering,
   ii. Gutters shall be supported by hangers (hidden hanger or spike and ferrule) that are spaced at a maximum of 450 mm [18 in.],
   iii. Downspout offsets should not exceed 3.0 m [10 ft.].

e. Refer to *Appendix A* for an example of sizing gutters and downspouts.

2. Catchment area:
   a. In cases where an entire roof catchment or other catchment surface is utilized, catchment area can be determined using:

$$\boldsymbol{Catchment\ Area}\ (\mathbf{m^2}) = Length\ (\mathrm{m}) \times Width\ (\mathrm{m})$$

Equation 1-2

Where: Length = length of the catchment surface (m)
Width = width of the catchment surface (m)

   b. In cases where sections of one roof catchment or multiple catchment surfaces are utilized, the catchment area can be determined by summing the multiple smaller areas.

3. Plan the layout of the conveyance network:
   a. For rainwater tanks located above ground:
      i. Determine the location of the tank (refer to *Chapter 2. Rainwater Storage & Tank Sizing* for guidance),
      ii. Route downspout(s) and/or conveyance drainage piping to the tank.
   b. For rainwater tanks located below ground:
      i. Determine the location of the tank (refer to *Chapter 2. Rainwater Storage & Tank Sizing* for guidance),
      ii. Plan route of conveyance drainage piping from the downspout(s) to the tank,

[5] Adapted from Moisture Resistant Homes: A Best Practice Guide and Plan Review Tool for Builders and Designers. 2006. U.S. Department of Housing and Urban Development, Washington, DC

        iii. Ensure that there are no buried service lines (gas, electricity, water, stormwater, wastewater, phone, or cable lines) in the area where digging will take place to accommodate the buried conveyance drainage pipes by contacting the municipality and service providers,
        iv. For additional guidance on planning the layout of conveyance drainage piping for below ground tanks, refer to *Appendix A.*

4. Conveyance drainage pipes:
    a. Pipe material:
        i. PVC SDR35 pipe (recommended), or ABS pipe, where
        ii. Pipe selected must be approved by applicable provincial codes and industry standards (CSA, ASTM, etc.).
    b. Pipe size and slope:
        i. Ensure a minimum slope of 0.5-2% (the greater the slope the better) is maintained throughout the pipe length,
        ii. Consult the applicable provincial codes and regulations pertaining to conveyance drainage pipe sizing, and
        iii. For estimation purposes, consult Table A-1 and Table A-4 in *Appendix A*.
    c. Cleanouts:
        i. Cleanouts are required on conveyance drainage pipes to facilitate cleaning of the conveyance drainage pipes,
        ii. Consult the applicable provincial codes and regulations pertaining to size and spacing of cleanouts, manholes and location of cleanouts.
    d. Tank connection:
        i. Rainwater conveyance drainage piping should enter the tank at a height no lower than that of the overflow drainage piping, or ideally, at a height 50 mm [2 in.] above the bottom of the overflow drainage pipe(s) entering the tank.
5. Installation of conveyance drainage pipe:
    a. Above ground pipes shall be supported in accordance with applicable provincial codes and regulations;
    b. Below ground pipes shall be located in a properly excavated space, be supported and properly backfilled in accordance with applicable provincial codes and regulations;
    c. Pipe freeze protection:
        i. Ensure that all buried pipes are located below the frost penetration depth. Consult local building authorities regarding regulations or ‘rules of thumb’ for frost penetration depths. For estimation purposes, refer to *Appendix A*,
        ii. Provide insulation or heat tracing for pipes buried above the frost penetration depth or exposed above grade (refer to *Appendix A* for details regarding pipe insulation).
    d. Underground non-metallic pipes should be installed with ‘tracer tape’ (also referred to as ‘tracer wire’) at a height of 300 mm [12 in.] above the pipe for the purpose of locating as-installed piping.
    e. Consult the pipe manufacturer’s installation instructions regarding recommended pipe bedding, support and backfilling procedures.

6. Tank frost protection:
    a. Storage tanks located above ground at risk for freezing shall be protected by:
        i. A conveyance network bypass, where sections of downspout and/or pipe upstream of the tank shall be capable of being disconnected and/or re-routed to divert rainwater/snowmelt from entry into the tank during winter months,
        ii. A drain valve located at the bottom of the storage tank.
7. Ensure that there are no means of entry for small animals or insects into the rainwater storage tank from the conveyance network by:
    a. Properly installing all sections of the conveyance network, such that they do not have any holes or other points of entry other than those required for water flow; and
    b. Installing downspout-to-pipe transition fittings.
8. Install pre-storage treatment devices as required (refer to *Chapter 3. Rainwater Quality & Treatment* for details).

1.5 Management Guidelines

1. The catchment surface should be inspected once every six months, to:
    a. Identify any sources of contamination, including accumulated dirt and debris, presence of overhanging tree branches or other foliage, and/or signs of animal activity (i.e., bird droppings); and
    b. If contaminants are present, these should be removed by cleaning the catchment surface by garden hose or sweeping, and if applicable trimming overhanging tree branches/foliage.
2. The gutters and downspouts should be inspected once every six months, to:
    a. Remove any dirt and debris that have accumulated; and
    b. Repair and/or replace damaged components to ensure proper rainwater flow and prevent entry of birds, rodents or insects into the RWH system.
3. During periods of cold weather, the conveyance network should be inspected periodically for ice build-up:
    a. Inspect the components of the conveyance network that are easily accessible (roof inspection not recommended) for the presence of ice, and if present, monitor over time to determine if the ice is accumulating in the network;
    b. For buried pipelines, ice build-up may be identified by poor performance of the RWH system (low volumes of stored rainwater even during frequent freeze-thaw periods) and/or by rainwater backing up the preceding sections of the network.
4. If ice is accumulating in sections of the conveyance network, and if it poses a risk of blocking and/or causing damage to the network, the following steps are recommended:
    a. Winterize the conveyance network through some, or all, of the following:
        i. Install a heating system to maintain air temperatures above 0°C if a large portion of the conveyance network is located in cold indoor environments like garages,
        ii. Install heat trace wire around gutters and/or downspouts,
        iii. Excavate the conveyance drainage pipes and install rigid Styrofoam insulation or heat tracing.
    b. Alternatively, the RWH system can be decommissioned during the winter months (refer to *Section 2.5* of *Chapter 2. Rainwater Storage & Tank Sizing* for details).
5. While inspecting, cleaning, or repairing the catchment surface and parts of the conveyance network, follow all necessary safety precautions.

Chapter 2. Rainwater Storage & Tank Sizing

2.1 Introduction

The reservoir that is used to store rainwater harvested from roof catchments is often referred to as a rainwater storage tank, or sometimes referred to as a ‘rainwater cistern,’ or ‘holding tank.’ Rainwater storage tanks are available in variety of different materials – concrete, plastic, fibreglass, etc. – and can be installed either above- or below-ground, or alternatively, directly integrated within a building (such as built into a basement wall or foundation).

Figure 2-1. [LEFT] Pre-cast concrete tank (below ground application), [CENTRE] Plastic tank (above ground application) and [RIGHT] Cast in place concrete tank integrated within parking garage (integrated storage)[6]

The storage capacity of rainwater storage tanks can also vary – from several hundred litres for a typical rain barrel to thousands of litres of storage found in commercially available above- or below-ground holding tanks. In addition to acting as the primary storage reservoir, the rainwater storage tank can also be considered as the central hub of a RWH system. It is the central location for handling all of the rainwater going into (and coming out of) the RWH system and many important components, such as the pump and water level sensor, are often located directly within the tank itself.

Care must be taken during its selection, installation and maintenance to ensure the proper functioning and optimal performance of the RWH system. This chapter discusses the issues that must be considered when performing these tasks, and also provides guidance on how to maximize the collection efficiency of RWH systems while keeping the size (and cost) of rainwater tanks as small as possible.

[6] Image of cast in place tank © Toronto and Region Conservation Authority, Toronto, ON.

2.2 *Applicable Codes, Standards, and Guidelines*

Table 2-1 references specific codes and standards that are applicable to rainwater storage tanks.

Table 2-1. Applicable standards, codes and guidelines for rainwater storage tanks

Applicable Codes, Standards, and Guidelines	Selected Provisions & Design and Installation Implications
Ontario's Building Code O. Reg 350/06 (2006)	• **7.1.6.2. Accessibility** Specifies that all devices or pieces of equipment must be located such that they are readily accessible for use, cleaning and maintenance.
Confined Spaces O. Reg 632/05 (2009)	Where entry into a rainwater tank is needed to install components, precautions outlined in Ontario Regulation 632/05 Confined Spaces must be followed.
Ontario's Building Code O. Reg 350/06 (2006)	• **8.2.1.5. Clearance Distances for Class 1, 2 and 3 Sewage Systems** Specifies minimum clearances of greywater systems from wells, property lines, etc. These clearances should provide guidance on the separation distances for rainwater storage tanks.
CSA Standard B128.1 (2006)	• **7.0 Storage Tanks** Provides specifications for the design and installation of rainwater storage tanks, including: access openings, piping connections, overflow, drainage and venting. *Note: Not legally binding unless adopted in future editions of the OBC.*
NSF/ANSI Standard 61 (2008)	Selection of a plastic tank with NSF/ANSI Standard 61 certification is will not impart unsafe levels of contaminants in drinking water. Recommended where high quality rainwater is needed for the intended use. Note: *Not legally binding unless adopted in future editions of the OBC.*

Mandatory Documents   Supplementary Documents

2.3 Issues for Consideration

General

As the central hub for RWH systems, rainwater storage tanks are directly connected to a number of pipes and also house some components internally. These components may include some, or all, of the following items shown in Figure 2-2.

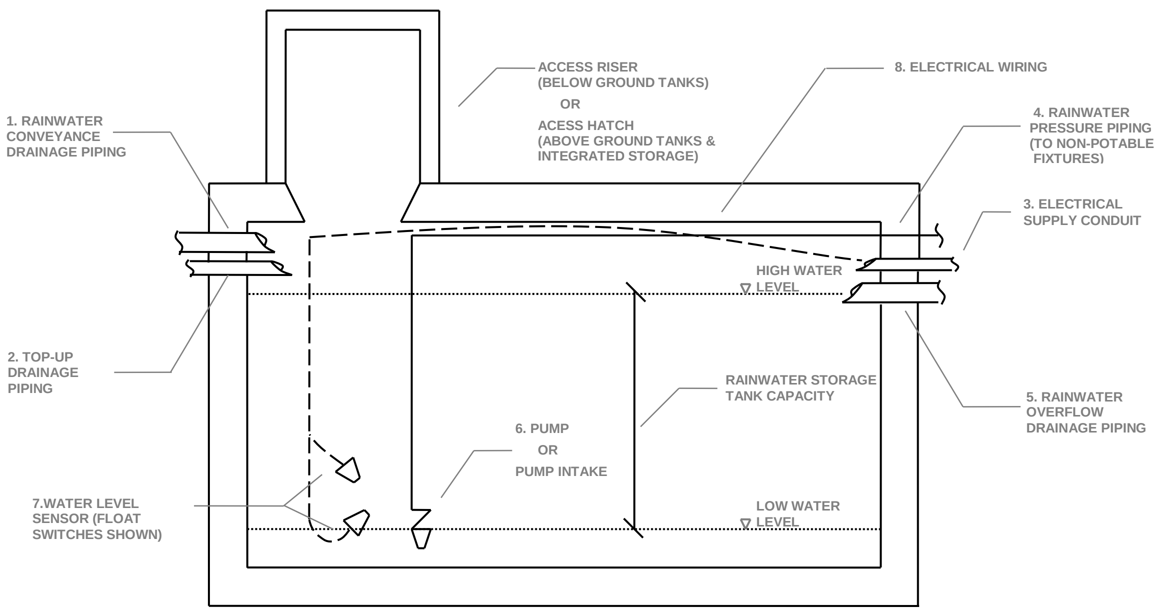

Figure 2-2. Rainwater storage tank schematic

Tank Location

The optimum location of a tank on a given site depends upon the required fall for the gravity flow conveyance network (as discussed in *Chapter 1: Rainwater Catchment & Conveyance*), as well as a broader range of issues, including:

1. Placement of tank – above- or below-ground, or integrated within building,
2. Desired/required rainwater storage tank capacity,
3. Regional climate – freezing issues,
4. Site conditions – site grading, accessibility, and space availability,
5. Proximity to the following:
    a. Catchment area,
    b. Overflow discharge location,
    c. Control components of pump and pressure system,
    d. Other site services (i.e.,. gas, electricity, water, stormwater, wastewater, phone, or cable lines).

Following consideration of each of these issues, it is likely that trade-offs must be made – for instance, the optimum tank storage capacity may be too large to be accommodated at the site, or the optimum location for the tank may be in an area that is difficult to access. Some guidance with respect to these issues is provided in the following sections.

Tank Placement

Table 2-2 discusses some of the advantages and disadvantages associated with the different placement options with regards to rainwater storage.

Table 2-2. Advantages and disadvantages of different tank locations

Tank Placement	Advantages	Disadvantages
Above-ground	• Don't have site excavation costs associated with below-ground storage	• Rainwater may freeze in tank unless located in temperature controlled environment
Below-ground storage	• Storage tank can be placed below frost penetration depth, permitting year-round operation • Does not take up yard space	• Location must be free of buried service lines and accessible by excavation machinery • Excavation requires additional site work which increases cost of RWH system
Integrated storage	• Little or no excavation cost • Storage tank capacity can be customized for each site • Permits year-round operation	• Engineers must design storage reservoir such that it is structurally sound and does not leak into the building

Tank Capacity

In general, the larger the tank, the greater the volume of rainwater that can be collected and stored during rainfall events (collection efficiency). However, this is true only up to a certain point – after which other factors, such as local rainfall patterns, roof catchment area and rainwater demand, will limit the amount of rainfall that can be collected and utilized by the system. Thus, for a RWH system with a given roof catchment area, rainwater demands and local rainfall patterns, the storage capacity of the tank can be described as either:

1. **Too small** –Much of the collected rainwater overflows during rainfall events. Significant improvements in collection efficiency can be achieved from minor increments in storage volume.
2. **Optimum range** – Rainwater tanks in this range provide the best balance between collection efficiency of the RWH system and minimizing its size and cost.
3. **Too large** – Rainwater tanks in this range rarely fill to capacity. A smaller tank can be utilized without a significant drop in the collection efficiency of the RWH system. An over-sized rainwater storage tank, however, may be desirable if stormwater management is a strong driver for installing a RWH system.

To determine the appropriate rainwater storage tank capacity, two methods are available:

Rainwater Harvesting Design Tool – This is a Microsoft Excel-based program that can be used to determine the optimal storage tank capacity given site-specific details including city, catchment area and material, and rainwater demands. For further details regarding this companion to the Ontario Guidelines for Residential Rainwater Harvesting Systems, refer to *Appendix B.*

Rainwater Storage Tank Sizing Tables – Tables of optimal rainwater tank capacities have been generated using the Rainwater Harvesting Design Tool for the city of Toronto, given a variety of roof catchment areas and rainwater demands. This table is provided in *Appendix B.*

Note that when selecting a tank size, consideration must be given to the unused volume at the bottom and top of the tank (sometimes referred to as 'dead space'), which reduces the effective storage volume. Refer to *Chapter 4. Make-up Water System and Backflow Prevention* and *Chapter 5. Pump and Pressurized Distribution System* for information regarding dead space at the bottom of the tank.

Cold Weather Issues

Throughout much of Canada, temperatures often drop below freezing (0°C) during the winter months. Rainwater stored outdoors or in an environment not temperature controlled (maintained above 0°C) is at risk of freezing, either in the storage tank itself, in the pump pressure piping, or both. Water freezing in either location may cause short term blockages and service disruptions, or in the long term, the RHW system may become damaged through the expansion of ice in the system. To minimize these risks, the following options are available:

1. **Winter decommissioning** – If an outdoor above-ground tank is used to store rainwater (or other setup in a non-temperature controlled setting), the tank, pump and pressurized lines shall be drained of all rainwater prior to the onset of cold weather and use of the system shall be discontinued during the winter months.
2. **Winterize RWH system** – A RWH system can be utilized year-round in cold climates provided the tank is:
    a. Located in a temperature-controlled environment such as a heated garage or basement in the case of above-ground or integrated rainwater storage; or

b. Located in a below-ground tank that is buried below the local frost penetration depth.

The first option is generally the simplest and least costly system to design and install. These benefits, however, are largely offset by the significant reduction in rainwater that can be collected and used throughout a given year, as well as by the potential damage to system components if decommissioning occurs too late or not at all. The second option, to winterize the system, is more complicated and more costly, however it is preferred since it enables the RWH system to operate throughout the entire year and ensures system components are protected from frost damage.

Tank Material

In Canada, materials such as concrete, plastic, and fiberglass are commonly used in the construction of storage reservoirs. The selection of one of these materials for a rainwater storage tank will largely depend upon local availability, as well as on cost, tank placement (above- or below-ground or integrated), storage requirements, site accessibility, and/or engineering specifications. In recent installations, above-ground tanks are often plastic while integrated tanks are usually cast-in-place concrete. Below-ground tanks are usually pre-cast concrete or plastic. In general, greater economies of scale are seen for concrete tanks than for plastic tanks, making concrete a more desirable material for very large systems. Engineering specifications such as maximum rated burial depth or minimum required water level vary for different tank materials and designs. Installation and operational specifications can be sought from manufacturers.

Another consideration is the potential for chemicals to leach from the tank into the stored rainwater; however, this is primarily a concern if rainwater must be of very high quality for one or more of the connected rainwater fixtures.

2.4 Design & Installation Guidelines

Design and installation guidelines:

> **Note**: refer to *Section 2.2 Applicable Codes, Standards, and Guidelines* for the specific provisions that apply when the term "in accordance with applicable provincial codes and regulations" is used.

1. Determine the rainwater storage tank capacity:
    a. If the rainwater storage tank will be used for stormwater retention and/or as part of a stormwater management system, the tank shall be sized as required by local authorities (refer to *Chapter 6. Overflow Provisions & Stormwater Management* for details);
    b. For storage tanks used for rainwater harvesting purposes:
        i. Use the Rainwater Harvesting System Design Tool (refer to *Appendix B* for instructions on accessing the Design Tool), or
        ii. Use the method provided in the *Rainwater Storage Tank Sizing Table* section of *Appendix B*.
    c. If sizing the tank without reference to the Design Tool or Tank Sizing Table, consider:
        i. The unused volume (typically referred to as the 'dead space') when selecting tank size. If unknown, assume 20% of tank capacity will be dead space,
        ii. The collection losses from pre-storage treatment devices (refer to *Chapter 3. Rainwater Quality & Treatment* for details).
2. Determine the type of material utilized for the rainwater tank, based on:
    a. Placement (above- or below-ground, or integrated storage);
    b. Storage volume requirements;
    c. Engineering specifications (see *Section 2.2 Applicable Codes, Standards, and Guidelines* for applicable standards and consult with manufacturers for further specifications); and
    d. Connected rainwater fixtures and desired quality. (See *Section 3.2 Applicable Codes, Standards, and Guidelines* for applicable standards).
3. Determine the location of the rainwater storage tank:
    a. For all rainwater storage tank locations:
        i. Ensure the location allows for:
            1. Proper drainage of rainwater through the conveyance network (refer to *Chapter 1. Rainwater Catchment & Conveyance* for details),
            2. Proper drainage of make-up water through top-up drainage piping (refer to *Chapter 4. Make-up Water System and Backflow Prevention* for details),
            3. Proper drainage of rainwater from the storage tank to an appropriate stormwater discharge location (refer to *Chapter 6. Overflow Provisions & Stormwater Management* for details).

b. For below ground storage tanks:
    i. Identify the area(s) where the tank can be located:
        1. Ensure the location is free from buried service lines. Contact service providers to determine the location of buried service lines (gas, electricity, water, stormwater, wastewater, phone, or cable lines),
        2. Ensure the location is permitted by applicable provincial codes and regulations based upon the minimum clearance requirements for buried tanks,
        3. Ensure the location is accessible for excavation equipment and the tank delivery vehicle. Consult the excavation contractor and tank supplier for exact requirements.
    ii. Tank freeze protection:
        1. Locate the tank such that the high water level in the tank is at a depth below the frost penetration depth (consult the tank manufacturer regarding the rated burial depth of the tank),
        2. Consult applicable provincial codes and regulations and/or local building authorities to determine local frost penetration depth (refer to *Appendix A* for an estimation of frost depth),
        3. If the tank cannot be placed below frost depth, insulate with rigid Styrofoam, installed on the tank roof and extended out beyond the tank walls (refer to *Appendix A* for guidelines regarding thickness of foam insulation).

c. For above ground storage tanks:
    i. Identify the area(s) where the tank can be located:
        1. Ensure the location is permitted by applicable provincial codes and regulations and municipal zoning bylaws. Consult local building authorities for details,
        2. Ensure the location has sufficient space for access above and around the tanks for inspection and maintenance.
    ii. Tank freeze protection:
        1. If the tank is not located in a temperature-controlled environment and is at risk for freezing, winterizing or decommissioning must be performed in accordance with the guidelines below.

d. For rainwater storage tanks located within a building and/or integrated within a building:
    i. Identify the area(s) where the tank can be located:
        1. Ensure the location is permitted by applicable provincial codes and regulations and municipal zoning bylaws. Consult local building authorities for details,
        2. Ensure the location has sufficient space for the required storage volume,
        3. Ensure the location has sufficient space for access above and around the tanks for inspection and maintenance,

        4. Ensure provisions (such as floor drains and/or sump pump) are in place to handle potential leaks and overflows from the storage tank,
        5. Consult a structural engineer regarding the design and location of all integrated tanks, as well as indoor tanks located anywhere other than the basement or garage.
    ii. Tank freezing protection:
        1. Locate the tank in a temperature-controlled environment such as a heated garage or basement to prevent tank freezing,
        2. If the tank is not located in a temperature-controlled environment and is at risk for freezing, winterizing or decommissioning must be performed in accordance with the guidelines below.

4. Tank frost protection:
    a. If the tank is not located in a temperature-controlled environment and is at risk for freezing, winterizing or decommissioning must be performed:
        i. Winterizing:
            1. Provide a heating system to maintain air temperatures above 0°C (if tank is located indoors),
            2. Provide a water heating system directly inside the rainwater tank,
            3. Insulate the rainwater storage tank.
        ii. Decommissioning:
            1. Prior to the onset of freezing temperatures, the rainwater stored in the rainwater tank must be drained,
            2. Provisions shall be made to prevent the accumulation of rainwater and/or snowmelt into the tank during winter months by means of a tank bypass or tank drain valve (refer to *Section 1.4 Design & Installation Guidelines* for further details).
5. Tank access and openings [7]:
    a. Tanks shall be provided with an access opening;
    b. Access openings shall be a minimum of 450 mm [18 in.] to facilitate installation, inspection and maintenance of components within the rainwater storage tank;
    c. Access openings shall have drip-proof, non-corrosive covers;
    d. Openings that are larger than 100 mm [4 in.] shall have lockable covers;
    e. Consult applicable provincial codes and standards regarding tank access and openings.
6. Tank venting:
    a. For below ground rainwater storage tanks:
        i. In general, venting of the tank through the rainwater conveyance drainage piping and overflow drainage piping connected to the tank(s) is considered to be sufficient for typical single family residential dwelling,
        ii. For other dwellings, or in cases where venting by means of conveyance drainage piping and overflow drainage piping connections is considered insufficient, a vent shall be installed on each tank, where:

[7] Adapted from CAN/CSA-B128.1-06 Design and installation of non-potable water systems. 2006. CSA International, Mississauga, ON. Refer to CSA B128.1 for further details.

1. The vent pipe shall extend from the top of tank to a minimum height of 150 mm [6 in.] above grade,
2. The vent pipe shall be of a sufficient size to permit the flow of air while the tank is filling, and shall be no less than 75 mm [3 in.] in size,
3. Vent shall terminate in a gooseneck fitting with a screen to prevent the entry of birds, rodents and insects.

b. For rainwater storage tanks located indoors and/or integrated within buildings:
   i. Rooms containing open tanks shall be vented to the outside of the building to prevent the accumulation of humidity or noxious gases.

7. Installation of storage tanks:
   a. Below ground tanks shall be placed in a properly excavated space, be supported on a tank bedding and be properly backfilled in accordance with applicable codes and standards;
   b. Integrated storage tanks must be constructed and/or installed in accordance with the designer's instructions and good engineering practice;
   c. Consult the tank manufacturer's installation instructions regarding recommended tank bedding, support and backfilling procedures;
   d. Connect the rainwater conveyance drainage pipe(s), overflow drainage pipe(s), rainwater pressure pipe(s) and electrical conduit(s) to the tank, ensuring that the connections are properly sealed and watertight.
8. Installation of components within the rainwater storage tank:
   a. Components installed within the tank typically include:
      i. A pump or pump intake (refer to *Chapter 5. Pump and Pressurized Distribution System* for details),
      ii. Water level sensors and/or other types of control equipment,
      iii. Electrical wiring for the pump and control equipment (refer to *Chapter 4. Make-up Water System and Backflow Prevention* for details).
   b. Entry into the rainwater storage tank, for the purposes of installing components within the tank is not recommended;
   c. If entry inside the rainwater storage tank is required, it shall be performed in accordance with Ontario Regulation 632/05 Confined Spaces due to the significant dangers involved when working within a confined space;
   d. To reduce and/or eliminate the need to perform work inside the storage tank:
      i. Wherever possible, install internal components using the access port, without entering the tank, or
      ii. Have RWH components installed by tank manufacturer, using personnel trained in confined spaces.
   e. Install components such that they are accessible for inspection and maintenance, without entry into tank;
   f. Components installed in the tank should be suited for a wet environment.

2.5 Management Guidelines

1. Rainwater tanks should be inspected at least once every year for the following:
   a. Leaks:
      i. For below-ground storage tanks, leaks may be identified through poor performance of the RWH system (i.e., the water make-up system operates often), from moist soil conditions surrounding the tank and/or excessive settling of the tank in the excavated space,
      ii. For above-ground storage tanks and integrated storage, leaks can be identified visually by examining the area surrounding the tanks, or through poor system performance or soil moisture (if applicable).
   b. Accumulation of debris:
      i. Sediment may accumulate on the bottom of the tank and, depending on the treatment provided, appear at the point of use. In such cases, the location (height) of the pump intake may need adjustment. Adjust the location of the pump intake such that it is located 100-150 mm [4-6 in.] above the bottom of the tank,
      ii. If sediment is still detected at the point of use, pre-storage and/or post-storage treatment devices may need to be installed (or cleaned/maintained) to improve rainwater quality (refer to *Chapter 3. Rainwater Quality & Treatment* for details),
      iii. In some cases, it may be necessary to remove the accumulated sediment on the bottom of the tank. Place a pump capable of handling large debris and/or solids (i.e., a suitable sump pump or effluent pump) at the bottom of the tank to pump out the sediment layer. (Note: removal of sediment and/or tank cleaning is not generally recommended on an annual basis, as this can destroy beneficial 'biofilms' in the tank. These biofims may contribute to improved stored rainwater quality[8]).
   c. Fault with pump, water level sensors or other control equipment:
      i. Refer to *Chapter 4. Make-up Water System and Backflow Prevention* and *Chapter 5. Pump and Pressurized Distribution System* for maintenance details.
   d. While inspecting, cleaning, or repairing the tank follow all necessary safety precautions, such as those listed in *Section 2.2 Applicable Codes, Standards, and Guidelines*.
2. If tank is susceptible to freezing (i.e., outdoor above ground), either winterize or decommission the system prior to the onset of freezing temperatures:
   a. Winterizing:
      i. Install a heating system to maintain air temperatures above 0°C (if tank is indoors), and/or
      ii. Install a water heating system directly inside the rainwater tank, and/or
      iii. Install heat trace wire around pipes, valves and/or pump, and/or

[8] Key Messages from a Decade of Water Quality Research into Roof Collected Rainwater Supplies. 2006. Coombes, P.J., Dunstan, H., Spinks, A., Evans, C., Harrison, T. In: Proceedings of 1st National HYDROPOLIS Conference.

    iv. Install insulation on the rainwater tank, around pipes, valves and/or pump.

b. Decommissioning:
    i. Drain all of the rainwater stored in the tank and the rainwater pressure piping,
    ii. Shut off the water supply to the water make-up system (if present) to prevent the tank from refilling,
    iii. Disconnect electrical supply to the pump and control equipment,
    iv. Disconnect downspouts from the conveyance network and have them discharge to grade or other suitable location, and
    v. Disconnect fixtures from rainwater supply and connect to the potable water system.

Chapter 3. Rainwater Quality & Treatment

3.1 Introduction

As precipitation falling from the sky, rainwater is naturally of very high quality. Once this precipitation reaches the earth, however, rainwater comes into contact with a variety of surfaces – grasses and landscapes, bodies of water, and anthropogenic surfaces such as roofs and parking lots – that can impart contaminants to the rainwater runoff. Contaminants can also be introduced into rainwater from environmental conditions such as the presence of air pollutants from industry and major roadways, and from plants or animal activity.

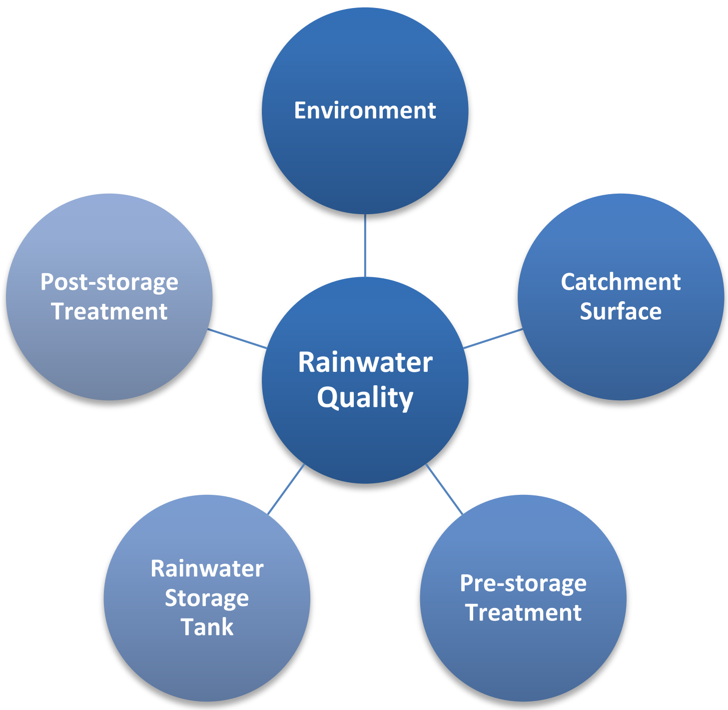

Figure 3-1. Factors that can affect rainwater quality

The presence of these contaminants can affect the physical, chemical and/or biological properties of water, and if present in sufficient quantities, they can affect the aesthetic quality of water (its colour, taste, and odour) and/or produce negative human health impacts from its use. For these reasons, rainwater quality (a measure of its physical, chemical and biological characteristics) is one of the key factors that determine its suitability for a particular use.

This chapter discusses the factors that can affect rainwater quality and provides suggestions on how these risk factors can be mitigated through the appropriate design and installation of rainwater harvesting systems and through the application of rainwater treatment.

3.2 Applicable Codes, Standards, and Guidelines

Table 3-1 references specific codes and standards that are applicable to the quality of harvested rainwater and required treatment.

Table 3-1. Applicable standards, codes and guidelines for rainwater quality and treatment

Applicable Codes, Standards, and Guidelines	Selected Provisions & Design and Installation Implications
Ontario's Building Code O. Reg 350/06 (2006)	• **7.1.5.3.(2) Water Distribution Systems** Specifies that rainwater (referred to as "storm sewage" in the OBC) or greywater that is free of solids may be used for the flushing of water closets, urinals or the priming of traps. *Note: The OBC does not specify what degree of treatment is required for rainwater/non-potable water to be "free of solids".*
CSA Standard B128.1 (2006)	• **8.0 Treatment** Specifies that water supplied by a RWH system must be treated to meet the water quality standards specified by public health or other regulatory authorities. *Note: Not legally binding unless adopted in future editions of the OBC.*
NSF Protocol P151 (1995)	Selection of roofing materials, coatings, paints, and gutters with NSF P151 certification will not impart levels of contaminants greater than those specified in the U.S. EPA's Drinking Water Regulations. Recommended where high quality rainwater is needed for the intended use. *Note: Not legally binding unless adopted in future editions of the OBC.*
NSF/ANSI Standard 61 (2008)	Selection of a plastic tank with NSF/ANSI Standard 61 certification is will not impart unsafe levels of contaminants in drinking water. Recommended where high quality rainwater is needed for the intended use. *Note: Not legally binding unless adopted in future editions of the OBC.*

Mandatory Documents   Supplementary Documents

3.3 Issues for Consideration

Rainwater Quality & Treatment Guidelines

The 2006 edition of Ontario's Building Code specifies, in Sentence 7.1.5.3.(2) of the Code, that rainwater may be used for toilet and urinal flushing providing that the rainwater is "free of solids"[9] . The 2006 edition of Ontario's Building Code, however, does not specify the degree of treatment required for rainwater to be considered "free of solids." Thus, the quality of rainwater and the need for treatment must be evaluated in the context of connected fixtures. Connected fixtures where there is minimal contact with the rainwater do not require the same quality of water as applications where users come into direct contact with the water. Treatment needs should be determined on a case by case basis by local building or health authorities, considering the recommendations of designers and preferences of end users.

Factors Affecting Rainwater Quality

Catchment Surface

Contaminants can be imparted to runoff from the catchment surface in two ways, either by washing off contaminants that have collected on the surface between rainfall events, or through the leaching of chemicals and/or metals from the catchment material.

Storage Material

Like the catchment surface, chemicals and/or metals can leach from the rainwater storage tank material(s) or from the various components located in the tank. The rainwater storage tank can also have beneficial impacts on rainwater quality by providing a reservoir where suspended dirt and debris can settle to the bottom of the tank.

Environment

Environmental conditions are largely out of the hands of the designer and/or user of rainwater harvesting systems. Environmental sources of contamination include anthropogenic sources of air pollution like industry and major roadways. Natural sources of contamination include nearby trees and plants (which deposit leaves, pollen, etc.) and the activity of animals (birds, squirrels which deposit waste, etc.) on the catchment surface.

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[9] Ontario's Building Code. 2006. Ministry of Municipal Affairs and Housing, Toronto, ON.

Rainwater Overflows

Contaminants can also be introduced into the rainwater storage tank through the overflow-handling method utilized by the rainwater harvesting system (see *Chapter 6. Overflow Provisions & Stormwater Management* for details). If overflows are directed to a municipal storm sewer or an on-site soakaway pit, there is the potential during intense rainfall events for these systems to backflow into the tank, contaminating it with poor quality water. These overflow-handling systems must be designed properly, and preventative measures put in place, to minimize the possibility of storage tank contamination.

Treatment Options

Treatment can be applied to improve rainwater quality and can take place:

1. Before it is stored in the rainwater storage tank (pre-storage treatment), and/or
2. After it is stored in the rainwater storage tank (post-storage treatment)

Pre-storage treatment devices must be incorporated as part of the conveyance network and rely on gravity flow to facilitate the treatment process. Alternatively, post-storage treatment devices tend to be more rigorous than pre-storage treatment and often require pressurized flow and/or electricity to aid in the treatment process. The advantages and disadvantages associated with these treatment approaches are summarized in Table 3-2.

Table 3-2. Comparison of advantages and disadvantages associated with Pre- and Post-storage treatment

Treatment Location	Advantages	Disadvantages
Pre-storage treatment	• Simple in design; operates using gravity flow (no electricity or high pressure requirements) • Prevents large particles from accumulating in the storage tank • Reduces requirements for post-storage treatment devices (or can preclude their use altogether)	• Susceptible to freezing • Requires regular cleaning and maintenance. Poorly-maintained devices may prevent rainwater from being conveyed to tank or may permit untreated rainwater to enter the tank • Multiple collection points may require a number of localized pre-treatment devices, increasing cost
Post-storage treatment	• Very high quality of water can be achieved • Located inside building, so no freezing risks • Can be used to treat more complex quality issues (i.e., pine needles in tank that create tannic acids)	• May require maintenance and replacement of filters, chemicals, or other materials • End quality depends on incoming rainwater quality and maintenance of pre-storage treatment devices • Generally more expensive than pre-storage treatment

Pre-storage Treatment Devices

Although there are a variety of means of treating rainwater prior to storage, methods tend to use one of three techniques: first-flush diversion, filtration, or settling.

First flush diversion involves diverting the first portion of runoff (collected from the catchment surface) away from the storage tank. One of the many means by which this diversion can take place is depicted in Figure 3-2. This technique improves stored rainwater quality by preventing the entry of the dirt and debris that collect on the catchment surface between rainfall events – the majority of which are contained in the first portion of runoff (first-flush).

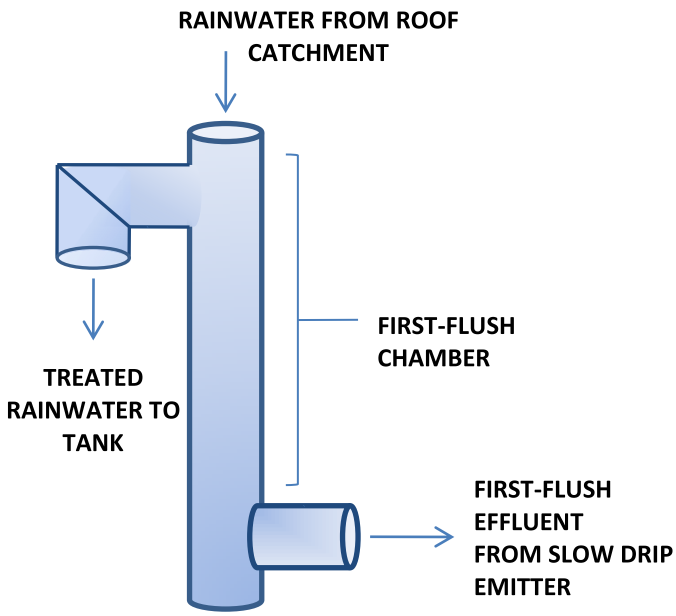


Figure 3-2. Schematic indicating the operation of a first-flush diverter

The second method, filtration, involves screening out leaves and large debris from runoff, preventing their entry into the rainwater storage tank. Filtration can take place at or near the catchment surface in the form of screens placed over gutters (referred to as “gutter guards”) or screens placed over rain leaders on flat roofed buildings (common on commercial buildings). Filtration can also take place on downspouts, or be integrated into other parts of the conveyance network. Examples of commercial filtration devices are shown in Figure 3-3.

Figure 3-3: Pre-storage filtration options: [LEFT] Leaf Eater®, [CENTRE] Alu-Rex Fixa-Tech®, [RIGHT] 3P VF1 Filter[10,11,12]

Another pre-storage treatment method is a settling chamber within a rainwater storage tank, or a dedicated settling tank. Rainwater from the roof catchment is first conveyed to the settling tank or settling chamber, where the dirt and debris suspended in the rainwater can settle out and collect as sediment at the bottom of the tank or chamber. The treated or 'clarified' water is then conveyed to the rainwater storage tank, or storage chamber of the tank. A two-compartment rainwater storage tank with a settling chamber is depicted in Figure 3-4.

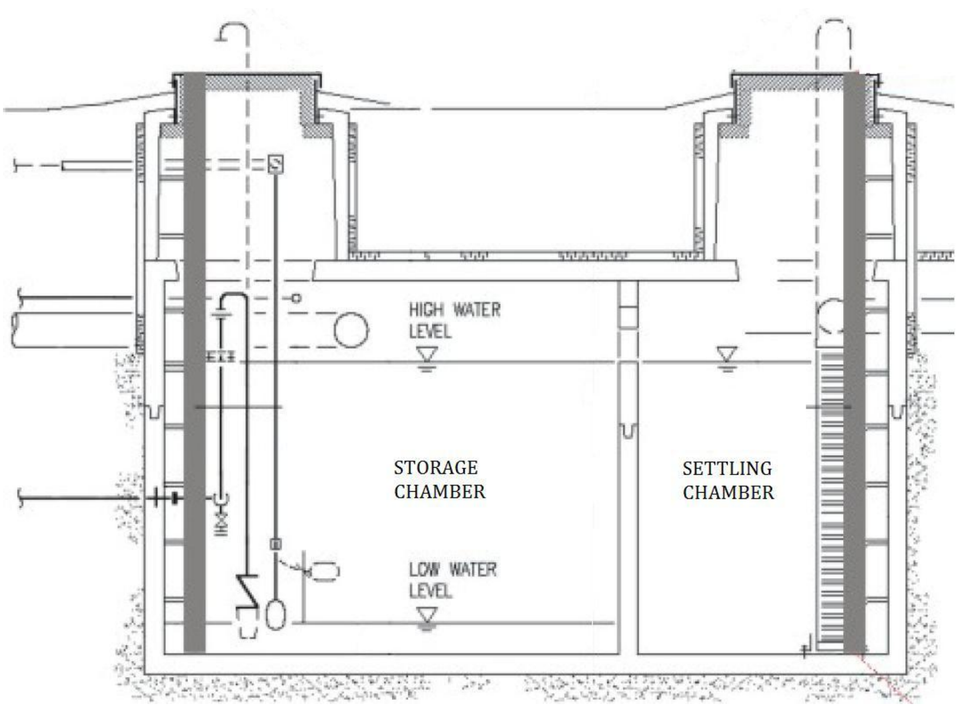


Figure 3-4. Rainwater storage tank with integrated settling and storage chambers[13]

[10] Image of Leaf Eater ® © Rain Harvesting Pty Ltd, Brisbane, Australia.
[11] Image of Alu-Rex Fixa-Tech® © Alu-Rex Inc., Charny, QB.
[12] Image of 3P VF1 Filter © 3P Technik Filtersysteme GmbH, Donzdorf, Germany.
[13] Image of tank with settling chamber © Toronto and Region Conservation Authority, Toronto, ON.

Post-storage Treatment Devices

Post-storage treatment includes filtration, disinfection, and/or treatment for aesthetic issues like colour, taste, or odour. Like pre-storage treatment, there are a number of different treatment devices available to perform these tasks. A description of these techniques, their applications and a list of available devices/options are provided in Table 3-3. A common form of post-storage treatment is 5 micron particle filtration, followed by and ultraviolet (UV) disinfection.

Table 3-3. Summary of post-storage treatment options

Treatment Method	Details	Treatment Devices/Options Available[1]
Filtration	Filtration removes suspended particles from water by passing it through a permeable material. *Water quality issues targeted:* • *Turbidity* • *Total suspended solids*	• Particle filtration (i.e., bag/sock or cartridge filter) • Slow sand filtration • Membrane filtration
Disinfection[2]	Disinfection removes or inactivates microorganisms by chemical or physical means. *Water quality issues targeted:* • *Microbiological contaminants (viruses, bacteria and protozoa)*	• Ultraviolet (UV) • Chlorine • Ozonation • Slow sand filter • Membrane filtration • Thermal treatment
Aesthetic issue treatment	Aesthetic issue treatment removes constituents from water that contribute towards colour, taste, or odour issues. *Water quality issues targeted:* • *Hydrogen sulphide* • *Organic matter* • *Manganese* • *Iron*	• Activated carbon • Ozonation • Slow sand filter • Reverse Osmosis • Membrane filtration with chemical addition

[1] Other treatment options may be available.

[2] All methods will require some level of on-line monitoring to ensure disinfection is reaching appropriate levels.

Treatment Device Selection

When determining the treatment device(s) required for a rainwater harvesting system, the following questions should be considered:

1. What quality requirements do applicable provincial, territorial and/or national codes and regulations specify for the uses under consideration?
2. What applications will the rainwater be used for?
3. Can the rainwater harvesting system supply sufficient quantities of rainwater to meet the desired uses?
4. Can treatment requirements be achieved through the proper design, installation and maintenance of the rainwater harvesting system?
5. What are the personal preferences of those using the rainwater and those who are managing the rainwater harvesting system?
6. What treatment devices are locally available?
7. Are there methods of segregating the rainwater usage in the house or building (i.e., supplying rainwater of varying qualities to different fixtures)?
8. What is the waste stream that is going to be generated through treatment? How will it be disposed?
9. What are the capital, operations and maintenance costs associated with the treatment device(s)?
10. Who will be responsible for the management of the rainwater harvesting system, and treatment system specifically? (i.e., who will ensure that maintenance is performed, provide training to maintenance personnel, and pay for the replacement of filters or other components?)

Recommendations on how to address these questions and select the method of treatment are provided in *Section 3.4 Design & Installation Guidelines*.

Performance Issues with Treatment Devices

Losses

Like the roof catchment, pre-storage treatment devices typically reduce the collection efficiency of a rainwater harvesting system. These losses can be quantified using the same measures as were used for the catchment surface – an initial rainfall loss factor and a continuous loss factor. If a pre-storage treatment device is to be incorporated into a rainwater harvesting system, these losses should be considered in addition to catchment surface losses when sizing the storage tank (refer to *Chapter 2. Rainwater Storage & Tank Sizing* for details). In general, initial losses are higher for first-flush devices than for filtration devices, while continuous losses are higher for filtration devices than for first-flush devices. Exact losses depend on system design and can be supplied by the manufacturer or supplier.

Collection efficiency losses are not typically found with post-storage treatment devices, although some are associated with a loss in system pressure. These losses, however, are small and can be considered when selecting the pump for the pressure system, or often, ignored altogether (for further details refer to *Chapter 5. Pump and Pressurized Distribution System*).

Cold Weather Issues

Cold weather issues can develop with pre-storage treatment devices since these are often integrated with the outdoor parts of the conveyance network. For example, if ice accumulates in the pre-storage treatment device, it may prevent the flow of snowmelt from the catchment surface during freeze-thaw periods. This ice build-up could eventually damage the pre-treatment device itself, or damage parts of the conveyance network. Because of these issues, the selection and proper maintenance of a pre-storage treatment device appropriate for a cold weather climate is necessary to ensure the optimal performance of the RWH system during the winter months.

3.4 Design & Installation Guidelines

Design and installation guidelines:

> **Note**: refer to *Section 3.2 Applicable Codes, Standards, and Guidelines* for the specific provisions that apply when the term "in accordance with applicable provincial codes and regulations" is used.

1. Identify factors that impact the quality of rainwater in the rainwater harvesting system, and can be mitigated through proper design and installation (see Table 3-4).

Table 3-4. Factors affecting rainwater quality and recommendations for mitigating rainwater contamination through design and installation best practices

Component of RWH System	Risk Factors	Design & Installation Best Practices
Catchment surface	1. Overhanging tree branches and animal activity 2. Leaching of chemicals and/or metals from catchment material 3. Grease and lint on catchment surface from kitchen cooktop vent and drier vent, respectively 4. Proximity to sources of air pollution (industry, major roadways, etc.)	1. Trim overhanging tree branches 2. Collect runoff from surfaces with NSF Protocol P151 certification 3. Direct drier and kitchen cooktop vents under gutters 4. Do not collect runoff from sections of catchment area at risk for poor quality
Conveyance network	1. Entry of potentially poor quality groundwater/surface water from poorly sealed joins 2. Entry of animals, rodents and/or insects from poorly sealed joints	1. Ensure underground pipe connections and fittings are secure 2. Utilize downspout-to-PVC pipe adapters
Rainwater storage tank	1. Sediment settled on bottom of tank 2. Ingress of insects, rodents or debris 3. Algae growth in tank 4. Leaching of chemicals and/or metals from tank material or components located inside tank	1. Locate pump intake a suitable distance above tank floor 2. Ensure tank hatch is properly covered and vents have screens 3. Prevent entry of direct sunlight into tank 4. Store rainwater in tank with NSF/ANSI Standard 61 certification
Overflow system	1. Backflow of storm sewage during extreme rainfall events (if overflow is connected to stormsewer)	1. Ensure overflow system is adequately designed for intense rainfall events and utilize backwater valve on overflow drainage piping

2. Determine rainwater quality and treatment requirements:
    a. In the Province of Ontario, rainwater may be used for:
        i. Toilet and urinal flushing, and
        ii. Sub-surface irrigation and below ground irrigation.
    b. Consult the applicable provincial codes and regulations to verify the fixtures for which connection to rainwater is permitted;
    c. Consult the applicable provincial codes and regulations and local authorities regarding quality and treatment requirements for the permitted rainwater fixtures;
    d. Treatment recommendations (provided for guidance purposes only):
        i. For typical single family residential dwellings consult the recommendations in Table 3-5.

Table 3-5. Treatment recommendations for typical single family residential dwellings

Rainwater Fixtures	Recommended Degree of Treatment[1]
Toilet and urinal flushing	• Treatment by pre-storage treatment device in addition to the adoption of best practices outlined in Table 3-4.
Sub-surface irrigation and below-ground irrigation systems	• Treatment by pre-storage treatment device in addition to the adoption of best practices outlined in Table 3-4. • Treatment by post-storage filtration device(s) as required by irrigation system manufacturer/contractor.
Laundry	• Treatment by pre-storage treatment device in addition to adoption of best practices outlined in Table 3-4. • Treatment by post-storage treatment device(s) that shall provide filtration and disinfection (using the methods outlined in Table 3-3, or equivalent). *Recommended typical treatment: 5 micron particle filtration followed by ultraviolet (UV) disinfection.*

[1]Note: Recommendations only. Consult applicable provincial codes and regulations as well as local authorities regarding permitted fixtures, quality targets and required treatment devices.

3. Select and install pre-storage treatment devices:
    a. Pre-storage treatment devices must be sized to handle the peak runoff from the catchment surface (refer to *Section 1.4 Design & Installation Guidelines* for further details regarding design rainfall intensity);
    b. Filter frost protection:
        i. Locate the treatment device in a temperature-controlled environment (maintained above 0°C), or
        ii. Locate the treatment device below the frost penetration depth, or where burial below the frost penetration depth is not possible, locate the device

below ground with appropriate insulation (refer to *Appendix A* for details), or

iii. Decommission/disconnect the treatment device from the conveyance network and drain the device prior to the onset of cold weather (refer to *Section 2.4 Design & Installation Guidelines* for details).

c. First-flush diverters:

i. Size the first-flush chamber based on the desired amount of runoff (typical diversion height is 0.5-1.5 mm) to divert from the storage tank, using the following formulas:

$$\boldsymbol{Diversion\ Volume\ (L)} = Diversion\ Height\ (mm) \times Catchment\ Area\ (m^2)$$

Equation 3-1

$$\boldsymbol{Height\ of\ First\ Flush\ Chamber\ (mm)} = \frac{4\ \times Diversion\ Volume\ (L) \times 1000}{3.14\ \times [Pipe\ Diameter\ (mm)]^2}$$

Equation 3-2

ii. Estimate the collection losses:

1. Initial loss factor – Equal to the Diversion height (mm),
2. Continuous loss factor – Depends on the rate of flow through the slow drip emitter. A 5% continuous loss can be assumed, or the continuous loss can be directly measured during a rainfall event.

d. Settling tank or a settling chamber:

i. Size the settling tank or settling chamber based on the temporary storage of a prescribed volume of runoff,

1. Where the prescribed volume can be based on rainwater height (i.e., 5 mm of rain)[14] , as given by:

$$\boldsymbol{Settling\ Tank\ Volume\ (L)} = Rainwater\ Height\ (mm) \times Catchment\ Area\ (m^2)$$

Equation 3-3

2. Where the prescribed volume can be based on a percentage of the capacity of the rainwater storage tank (i.e., settling chambers within two-compartment tanks typically have 1/3 the capacity of the storage chamber).

e. Pre-storage treatment filtration devices:

i. The following components may be included as part of the filtering system:

1. High quality gutter guards, available from gutter contractors,
2. Leaf screens placed on the downspout, available from gutter contractors, and/or
3. Commercially supplied rainwater filter installed in-line with conveyance drainage pipe or inside tank.

[14] Adapted from Performance Evaluation of a Rainwater Harvesting System. Interim report 2008. Toronto and Region Conservation Authority, Toronto, ON.

ii. Estimate the collection losses:
    1. Initial loss factor – Reported by the supplier, or can be assumed to be negligible (0 mm),
    2. Continuous loss factor – Reported by the supplier, or can be conservatively estimated at 20%.

f. Pre-storage treatment devices shall be installed in accordance with applicable provincial codes and standards and manufacturer's instructions;
g. Pre-storage treatment devices shall be installed such that they are readily accessible. Access openings to facilitate entry into the device and/or tank shall be in accordance with the guidelines in *Section 2.4 Design & Installation Guidelines*.

4. When selecting and installing post-storage treatment device(s):
    a. Pre-storage treatment device(s) should also be utilized to minimize wear on post-storage treatment devices;
    b. Post-storage treatment device(s) must be sized in accordance with the maximum flow rate of the pressure system and manufacturer's requirements;
    c. Post-storage treatment devices shall be installed in accordance with applicable provincial codes and standards and manufacturer's instructions;
    d. Post-storage treatment devices shall be installed such that they are readily accessible.

3.5 Management Guidelines

1. Identify the factors that can impact the quality of rainwater in the RWH system, and take steps to mitigate the risks posed by these factors by implementing the following maintenance activities:
    a. Consult the maintenance best practices provided in Table 3-6.

Table 3-6. Factors affecting rainwater quality and recommendations for mitigating rainwater contamination through maintenance best practices[15]

Component of RWH System	Risk Factors	Maintenance Best Practices
Catchment surface	1. Proximity to sources of air pollution (industry, major roadways, etc.) 2. Overhanging tree branches 3. Animal activity 4. Leaching of chemicals and/or metals from catchment material	At least once every 6 months: • Inspect catchment surface for sources of contamination (accumulated debris, leaves, pine needles, etc.) and clean area • Trim overhanging tree branches
Conveyance network	1. Entry of potentially poor quality groundwater/surface water from poorly sealed joins 2. Entry of animals, rodents and/or insects from poorly sealed joins	At least once every 6 months: • Inspect gutters for sources of contamination (accumulated debris, leaves, pine needles, etc.) and clean gutters as required • Inspect area(s) where downspouts connect to conveyance network to ensure fittings are secure • Inspect pre-storage treatment device(s) connected with conveyance network and clean devices as required
Rainwater storage tank	1. Leaching of chemicals and/or metals from rainwater tank storage material 2. Leaching of chemicals and/or metals from components located within rainwater tank 3. Pump intake located at bottom of tank where it can draw in sediment	At least once annually: • Inspect components inside tank for signs of corrosion and/or degradation and replace components as necessary • Monitor rainwater quality at point-of-use for indication of sediment accumulation in tank.

    b. Consider other site specific risk factor(s) and adapt the maintenance of the RWH system as appropriate to mitigate the risks posed to rainwater quality.

[15] Adapted from CSA B128.1-06/B128.2-06. Design and installation of non-potable water systems/Maintenance and field testing of non-potable water systems. 2006. CSA International, Toronto, ON.

2. Pre-storage treatment device(s) should be inspected at least twice per year, or more frequently as required by manufacturer’s instructions and site conditions:
    a. Observe rainwater passing through the device(s) during a rainfall event, or simulate a rainfall event by discharging water from a hose onto the catchment surface. Look for potential problems such as:
        i. Accumulated dirt and debris blocking flow through filter,
        ii. Loose fittings or other problems with the treatment device(s) such that rainwater is passing through without treatment taking place, or
        iii. Other problems with the treatment device(s).
    b. Clean the filtration device(s) according to the manufacturer’s maintenance instructions, repair as required.
3. If pre-storage treatment devices need to be decommissioned during the winter:
    a. Drain all of the rainwater accumulated in the treatment device;
    b. Disconnect the treatment device(s) from the conveyance network; and/or
    c. Install pipe, downspout or other material to bypass the pre-storage treatment device(s) and direct untreated water to the tank.
4. Post-storage treatment device(s) should be inspected at least quarterly, or more frequently depending upon manufacturer’s instructions and site conditions:
    a. Observe the device(s) as water flows through the pressure system, looking for problems such as:
        i. Water leaking from treatment device(s),
        ii. Warning/indicator lights on treatment device(s) indicating fault with device and/or required replacement of components.
    b. Maintain post-storage treatment devices as necessary through the regular cleaning of filtration device(s) and/or replacement of filter media, lamps, or other components as specified by the product manufacturer(s).
5. While inspecting, cleaning, or repairing the pre-storage treatment and/or post-storage treatment device(s) or other component of the rainwater harvesting system follow all necessary safety precautions.

Chapter 4. Make-up Water System and Backflow Prevention

4.1 Introduction

Regardless of the size of the rainwater storage tank or size of the catchment area, there will occasionally be times when there is insufficient rainfall to meet the demands placed on the RWH system, and the storage tank will run dry. RWH systems need to have a system in place to recognize when there is insufficient rainwater and perform an action such as triggering a warning light or switching to an alternative supply of water. This system is often referred to as a "make-up" or "back-up" system.

The primary concern with a make-up system is that it requires water of high quality (from a municipality or private water source) to be brought into close proximity with rainwater, typically of poorer quality. In such situations, there is a risk of a cross-connection. If a connection is made between the RWH system and a municipal water system, there is a risk that the rainwater can be drawn into the potable water system through the process of backflow.

Given these concerns surrounding cross-connections and backflow, care must be taken when implementing and managing a make-up water system. This chapter provides an overview of the various components that comprise a make-up system and gives guidance on how to assess and then mitigate the risks associated with cross-connection and backflow.

Note: Proper design, installation and management must also be extended to the entire rainwater pressure system, since a cross-connection can potentially exist at any point in the system. Refer to *Chapter 5. Pump and Pressurized Distribution System* for further details.

4.2 Applicable Codes, Standards, and Guidelines

Table 4-1 references specific codes and standards that are applicable to make-up water systems and backflow prevention.

Table 4-1. Applicable standards, codes and guidelines for make-up water systems and backflow prevention

Applicable Codes, Standards, and Guidelines	Selected Provisions & Design and Installation Implications
Ontario's Building Code O. Reg 350/06 (2006)	• **7.2.10.15. Water Hammer Arresters** • **7.6.1.16. Thermal Expansion** • **7.6.2.1. Connection of Systems** • **7.6.2.2. Back-Siphonage** • **7.6.2.4.(5), (8), and (9) Backflow from Fire Protection Systems** • **7.6.2.9. Air Gap** • **7.7.1.1. Non-Potable Connection** Article 7.7.1.1. specifies that a rainwater harvesting system (non-potable water system) shall not be connected to a potable water system. The potable water system shall be protected by means of an air gap (7.6.2.9.) for top-up systems, and that all connections to potable water systems shall be designed and installed to provide protection from contamination (as per Articles 7.6.2.1. and 7.6.2.2.). This requires that rainwater harvesting systems be installed with backflow prevention devices as outlined by the Ontario's Building Code (Sentences 7.6.2.4.(5), (8), and (9)) and CAN/CSA-B64.10 (see below for details). When backflow prevention devices are installed, thermal expansion tanks must also be installed as per 7.6.1.16. When a solenoid valve is installed for a top-up system, a water hammer arrester may be required in accordance Article 7.2.10.15.
CAN/CSA B64.10 (2001)	• **Appendix B, Table B1** • **4.3.4.2 Premise isolation** Specifies that where a potential connection exists between the rainwater harvesting system (non-potable water system) and potable water system, it must be protected by means of an air gap or reduced pressure (RP) backflow prevention device. Buildings with a rainwater harvesting system (rated as a severe hazard classification) must have premise isolation by means of a reduced pressure (RP) backflow preventer. *Note: CSA B64.10 permits cross connections where adequate backflow prevention measures are taken, however, Article 7.7.1.1. of the OBC prohibits such connections, and in cases of conflict with a referenced document the OBC provision governs.*

Mandatory Documents   Supplementary Documents

Applicable Codes, Standards, and Guidelines	Selected Provisions & Design and Installation Implications
Ontario Electrical Safety Code O. Reg. 164/99 (current edition)	**All electrical equipment must be approved and installed to according to the requirements of the current edition Ontario Electrical Safety Code**
CSA Standard B128.1 (2006)	• **6.0 Backflow prevention** • **11.2 Cross-connection testing** Specifies that backflow prevention devices shall comply with CAN/CSA-B64.10 and the applicable provincial or territorial building code. Section 11.2 provides guidelines for testing cross-connections after installation. *Note: Not legally binding unless adopted in future editions of the OBC.*
CAN/CSA Standard B64.10 (2007)	• **Appendix B, Table B1** • **5.3.4 Premise isolation** Specifies that a dual check valve (DuC) shall be used to isolate a residential premise with access to an auxiliary water supply (the RWH system), if there is no direct connection between the auxiliary water supply and the potable supply. *Note: Not legally binding. OBC (2006 ed.) references CAN/CSA B64.10 (2001 ed.). The next edition of the OBC (2010) may reference the 2007 edition of B64.10.*

Mandatory Documents

Supplementary Documents

4.3 Issues for Consideration

Types of Make-up Water Systems

To ensure that rainwater demands are met during times when there is insufficient rainfall and the tank runs dry, there are two general options available:

1. **Top-up** – The rainwater storage tank can be partially filled, either manually or automatically, with make-up supplies of water from municipal (potable), or private water sources;
2. **Bypass** – The rainwater supply from the pressure system can be shut-off, either manually or automatically, and water from municipal or private sources can be directed through the rainwater pressure piping.

Of these options, only top-up systems are permitted by the 2006 edition of Ontario's Building Code. The bypass method contravenes Subsection 7.7.1, of the Code which states that "a non-potable water system shall not be connected to a potable water system."[16] As such, this chapter focuses on top-up based make-up systems. The advantages and disadvantages associated with the manual and automatic top-up systems are discussed in Table 4-2.

Table 4-2. Advantages and disadvantages associated with top-up methods

Water Make-up Method	Advantages	Disadvantages[1]
Manual top-up	• Simplest method to design and install due to reduced control equipment requirements • Lowest cost alternative	• May result in service interruptions (i.e., no water for flushing toilets) if tank not topped-up prior to going dry • Requires homeowner to monitor volume of stored rainwater in tank and top-up pre-emptively if low
Automatic top-up	• Reduces the number of service interruptions by automatically filling tank prior to it running dry • Make-up system operates without the need for monitoring or intervention by the homeowner	• Improper design or installation of control equipment may cause insufficient or excessive top-up volumes to be dispensed by the make-up system • Service interruption during power failure

[1] Note: Improper design, installation and/or management of all make-up systems may result in risk of cross-connection with the potable water supply.

[16] Ontario's Building Code. 2006. Ministry of Municipal Affairs and Housing, Toronto, ON.

For the majority of residential applications, it is recommended that the automatic top-up be selected as it minimizes service interruptions and is the least onerous for the home-owner. An automatic top-up system is depicted in Figure 4-1 and the various components are described below.

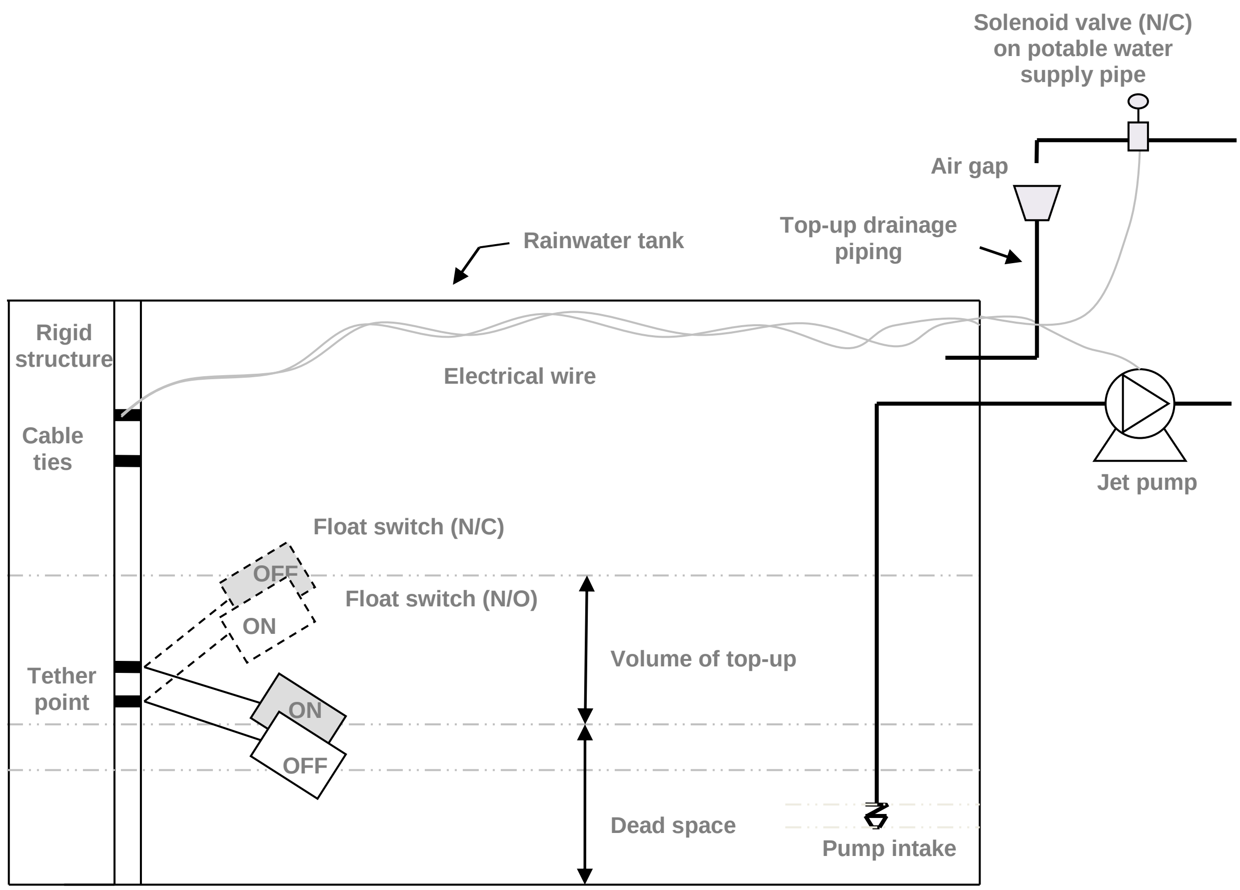


Figure 4-1. Components of an automatic top-up system

Control Equipment

The control equipment used to construct a make-up water system are listed in Table 4-3.

Table 4-3. Control equipment for make-up water systems

Control Equipment	Description	Devices/ Options Available
Water level sensor	• A device inside the tank that is used to sense the level of water • Can control (turn on or off) warning lights, solenoid valves and/or pumps, based on water level	• Float switch • Ultrasonic level sensor • Liquid level switch (Float switch is typically used for residential applications).
Shut-off valve	• A device that is manually opened (or closed) to permit (or prevent) the flow of water • Integrated into the RWH pressure system to manage flow of water and isolate components of the make-up system (i.e., solenoid valves and backflow preventers)	• Types: ball valve, gate valve The shut-off valve(s) selected must be approved for handling water that is under pressure.
Solenoid valve (automated shut-off valve)	• A valve that actuates (opens or closes) automatically when electricity is applied to it • Connected with water level sensor to activate make-up water system	• Come in a variety of configurations The solenoid valves selected must be approved for handling water that is under pressure.

When selecting control equipment for the make-up system, the following issues must be considered.

Sizing

All control equipment must be appropriately sized. Of particular concern for top-up based systems is the sizing of the top-up drainage piping. This pipe must be sized according to gravity flow, not pressurized flow, to prevent water backing up the pipe. In addition, all valves and backflow preventers must also be sized to be the same diameter as the diameter of the pipe(s) to which they are connected.

Electrical

Many of the make-up water system control components require an electrical supply to operate. When designing the electrical system for the RWH system, the following must be taken into consideration:

1. The operating voltage (120 or 240V) of the pump, solenoid valve and other relevant components;
2. The power requirements (in Watts or Horsepower) of the pump, solenoid valve and other relevant components;
3. Power rating for float switches and electrical wiring;
4. All equipment must be certified and installed in accordance with the current edition of the Ontario Electrical Safety Code.

Many water level sensors (such as float switches) must be rated to handle the power of the device they are controlling. For instance, if a float switch controls a solenoid valve or pump, it must be rated to handle the power needed to operate the valve or pump.

Operating State of Float Switches and Solenoid Valves

Both float switches and solenoid valves act similar to a typical light switch (i.e., on or off, open or closed) however, they differ in that these actions can take place either when power is supplied or when the power supply is disconnected. To differentiate between these two operating conditions, the terms "normally open" (N/O) and "normally closed" (N/C) are used, as described in Table 4-4.

Table 4-4. Differences between Normally Closed and Normally Open float switches and solenoid valves

Control Equipment	Normally Closed (N/C)	Normally Open (N/O)
Float switch	Permits power supply (turns things "*on*") when the switch is in the "*down*" position (when there is a high water level in the tank)	Permits power supply (turns things "*on*") when the switch is in the "*up*" position (when the water level is below the float switch)
Solenoid valve	When power is supplied, the valve is in an "*open*" state and permits the flow of water. Valve closes when power supply is discontinued.	When power is supplied, the valve is in a "*closed*" state and prevents the flow of water. Valve opens when power supply is discontinued.

Float switches detect the level of rainwater in the tank and automatically trigger an action when levels drop below or above a predetermined set point. This may include opening a valve, activating a warning light or shutting off a pump. Float switches must be installed directly inside the storage tank, with the electrical cord tied to a rigid material such as a pipe so that the float can pivot up or down from a "tether point" (refer to Figure 4-1).

In a top-up system, a N/C switch is used in conjunction with a N/C solenoid valve. When in the down position, the float switch electrifies the solenoid valve, causing it to open and top-up the tank with water from the potable water system. The volume of make-up water used is dependent upon the "tether length" of the float switch (illustrated in Figure 4-1), with longer tether lengths requiring greater make-up volumes before the use of rainwater resumes. The tether point sets the height (liquid level) at which this process takes place, with higher tether points initiating this process earlier (and leaving more unused rainwater, or "dead space," at the bottom of the tank). To maximize rainwater use, the tether length should be as short as possible and the tether point should be as low as possible, while providing enough water for the pump.

This system theoretically provides dry run protection because the pump intake is located below the low water level (down position of the switch). Dry running occurs when the pump attempts to operate when there is insufficient rainwater in the tank and can cause the pump to overheat and become damaged. However, if the float switch controlling the solenoid valve fails, or if insufficient make-up water is available, dry running may still occur. A second float switch (N/O) should be connected to the pump, and located below the N/C float switch, to shut off the pump and ensure dry run protection in these cases. Similarly, a N/O switch should be used to shut off the pump where a manual top-up system is in place as there is the likelihood that the storage tank will run dry before make-up water is supplied.

Some pumps may have built in dry run protection, however, this protection is not appropriate for RWH systems if it is based on a timer and not water levels.

Cross-connections, Backflow Prevention and Premise Isolation

With RWH systems, the risk of cross-connection is highest at the make-up system, as it requires that water from a potable water system be brought into close proximity with non-potable rainwater.

A cross-connection is defined as "any actual or *potential* connection between a potable water system and any source of pollution or contamination"[17] (emphasis added). If a connection is made between the rainwater pressure piping and the potable water system, backflow[18] may occur, if pressure in the rainwater pressure piping is too high and/or the pressure in the potable water system is too low. Rainwater may unintentionally be drawn into the potable water supply of the house or building, or drawn into the entire water supply system of a municipality and be used to meet potable water applications.

Because of these risks, both to the individuals in the home or building, and the residents of the municipality, backflow prevention measures are applied on two distinct levels:

[17] CAN/CSA-B64.10-07/B64.10.1-07. Selection and Installation of Backflow Preventers/Maintenance and Field Testing of Backflow Preventers. 2007. CSA International, Toronto, ON.

[18] Backflow is defined as "a flowing back or reversal of the normal direction of flow". CAN/CSA-B64.10-07/B64.10.1-07. Selection and Installation of Backflow Preventers/Maintenance and Field Testing of Backflow Preventers. 2007. CSA International, Toronto, ON.

1. **Zone protection** – Backflow prevention device is installed at the point of an actual cross-connection to protect residents of the building from backflow; and
2. **Premise isolation** – Backflow prevention device is installed on the potable water piping entering a building, in case zone protection fails or in case of a future unintentional or clandestine cross-connection. Serves to protect users of the municipal system from backflow.

In the case of RWH systems, zone protection is required for the make-up system and premise isolation is required for the building. Numerous devices exist to provide backflow prevention. The 2006 edition of Ontario's Building Code prohibits any direct connection between a potable and non-potable system and therefore an air gap is required for zone protection of the top-up system. Following CAN/CSA-B64.10-07, premise isolation may be provided by a dual check valve, if there is no direct connection between the RWH system and the potable water system. All applicable provincial codes and regulations as well as municipal bylaws must be consulted to determine what degree of backflow prevention is required (refer to *Section 4.2 Applicable Codes, Standards, and Guidelines* for details).

In addition to these backflow prevention measures, other requirements to reduce the potential for cross-connections include the separation of potable and non-potable pipes and the labelling of non-potable plumbing pipes (refer to *Chapter 5 Pump and Pressurized Distribution System* for details).

Air Gap

The typical method of backflow prevention used for top-up systems is the air gap. An air gap is one of the simplest methods of preventing backflow, and involves a physical separation between two sections of pipe that is open to the atmosphere (shown in Figure 4-1 and Figure 4-2).

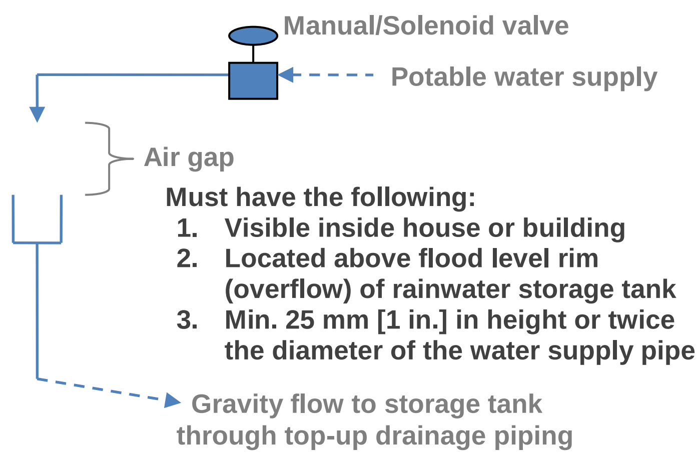


Figure 4-2. Schematic drawing of a top-up system with an air gap[19]

[19] Adapted from Ontario's Building Code. 2006. Ministry for Municipal Affairs and Housing, Toronto, ON.

This physical break prevents the backflow of water since even if rainwater backed up from the tank to the gap, it would spill from the gap and not come into contact with the potable water supply. The air gap must be located higher than the overflow drainage piping from the tank and the overflow drainage piping must remain free of blockage so that excess rainwater flows to the overflow system and does not back up and overflow at the air gap.

4.4 Design & Installation Guidelines

Design and installation guidelines:

Note: refer to *Section 4.2 Applicable Codes, Standards, and Guidelines* for the specific provisions that apply when the term "in accordance with applicable provincial codes and regulations" is used.

1. Determine the type of make-up system:
    a. Automatic top-up system (recommended);
    b. Manual top-up system;
    c. No make-up system (not recommended).
2. Plan the layout of the top-up system:
    a. A top-up system is generally comprised of the following:
        i. Water level sensor(s) located in the rainwater storage tank,
        ii. A solenoid valve located on the potable water supply pipe,
        iii. An air gap,
        iv. Top-up drainage piping conveying make-up water to the rainwater storage tank, and
        v. Electrical conduit(s), containing wiring from the water level sensor(s) and pump.
    b. Determine the location of the solenoid valve and air gap in accordance with the guidelines provided below;
    c. Plan route of top-up drainage piping from the air gap to the tank (refer to Section *1.4 Design & Installation Guidelines* for guidelines and applicable provincial codes and regulations regarding drainage piping);
    d. Plan route of electrical conduit(s) from the location of the solenoid valve and power supply to the tank (refer to *Section 1.4 Design & Installation Guidelines* for piping installation guidelines);
    e. Ensure that there are no buried service lines (gas, electricity, water, stormwater, wastewater, phone, or cable lines) in the area where digging will take place to accommodate the buried top-up drainage piping and/or electrical conduit by contacting the municipality and service providers.
3. Water level sensors:
    a. Select the appropriate water level sensor(s) for the RWH system (float switch, ultrasonic level sensor, or other);
    b. Float switches:
        i. Select the type of float switch:
            1. Solenoid valve actuation is typically provided by a N/C float switch, for top-up systems,
            2. Pump dry run protection is typically provided by a N/O float switch.
        ii. Electrical requirements:
            1. The voltage rating of the float switch must match that of the device it controls (120 V or 240 V),
            2. The power rating (Watts [W] or Horsepower [HP]) of the float switch must be sufficient to carry the total load of the device it

controls, or alternatively, float switches may be low voltage and used to activate the pump through relays in a control panel,
3. Spliced electrical wiring must be water tight and be of sufficient electrical rating as determined by the loads handled by the float switch and the total length of wiring,
4. All electrical connections for float switches must be made by a licensed electrician in accordance with the manufacturer's instructions.

c. Float switch installation:
   i. The float switch shall be tethered to a rigid freestanding object, such as a vertical section of pipe or the pump, that:
      1. Permits the float switch to rise and fall without any obstructions,
      2. Is located in area where it is easily accessible and can be withdrawn from the tank without requiring entry into the tank.
   ii. To set the operating parameters of the float switch:
      1. To maximize rainwater collection, the tether length should be as short as possible: 75 mm [3 in.]. Refer to the manufacturer's installation instructions for details,
      2. To maximize rainwater collection, the tether point should be as low as possible (such that the float is 50 mm [2 in.] above the pump intake when in the down position),
      3. If utilizing a dual float switch configuration, the float switch controlling the solenoid valve should be located a minimum of 75 mm [3 in.] above the float switch controlling the pump.
d. Other water level sensors shall be selected and installed in accordance with applicable provincial codes and regulations, where all electrical connections must be made by a licensed electrician in accordance with the manufacturer's instructions.

4. Solenoid valves and shut-off valves:
   a. Select the type and size of solenoid valve and/or shut-off valve:
      i. All valves must be suitable for potable water and pressure applications,
      ii. Valve openings must be no less than the size of the piping where they are located,
      iii. Top-up systems typically use a N/C solenoid valve,
      iv. Solenoid valves with a 'slow close' or 'soft close' are recommended.
   b. Electrical requirements:
      i. Solenoid valves must be wired into a power supply in conjunction with a water level sensor;
   c. Solenoid valve and shut-off valve installation:
      i. Solenoid valves or shut-off valves used as part of a top-up system shall be installed on the potable water supply pipe upstream of the air gap,
      ii. Solenoid valves must be installed by a licensed plumber and electrician in accordance with the manufacturer's installation instructions.
   d. Water hammer protection:
      i. If a 'slow close' or 'soft close' solenoid valve is not utilized a water hammer arrester shall be installed on the potable water supply piping

upstream of the solenoid valve in accordance with applicable provincial codes and regulations.

5. Air gap:
    a. An air gap is required as part of a top-up system for the purpose backflow prevention (zone protection);
    b. Air gaps shall be designed and installed in accordance with applicable provincial codes and regulations. For guidance purposes only, the following guidelines are provided:
        i. The gap must be unobstructed – mechanical supports fixing the potable water supply pipe to the top-up drainage pipe, or other components located at or between the potable water supply pipe and top-up drainage pipe is not permitted,
        ii. The air gap must be located in an area where it can be observed and inspected,
        iii. The air gap must be installed at a height above the flood level rim (overflow) of the rainwater storage tank. If not, there is a risk that rainwater will back up the top-up drainage pipe and overflow from the air gap,
        iv. The air gap height must be at least 25 mm [1 in.] or twice the diameter of the water supply pipe.
    c. Splash and water damage prevention:
        i. To prevent make-up water from splashing at the air gap, install the following:
            1. Flow restrictor, installed upstream of the solenoid valve, and/or
            2. Aerator, installed where the potable water supply pipe terminates, and/or
            3. Extended length of vertical pipe with the end of the pipe cut at a angle no less than 45° (to produce laminar flow), installed where the potable water supply pipe terminates above the air gap.
        ii. To prevent water damage to rooms where the air gap is located:
            1. Locate air gaps near a floor drain,
            2. Install an overflow on the top-up drainage pipe, located downstream of the air gap to direct excess make-up water to the sanitary sewer (where permitted by local authorities),
            3. Appropriately size and slope the top-up drainage piping.
    d. Make-up water flow rate:
        i. To ensure RWH system operation during top-up, the following measures are recommended:
            1. The flow rate of make-up water should be equivalent to that of the maximum flow rate of the rainwater supply pump, or
            2. The water level sensor(s) shall be configured to provide a sufficient reserve volume in the rainwater storage tank (i.e., where said reserve volume shall be equivalent to that of the average daily rainwater demand for the RWH system).

6. Top-up drainage pipes:
    a. Pipe material:
        i. ABS pipe (recommended), where
        ii. Pipe selected must be approved by the applicable provincial codes and regulations, and industry standards (CSA, ASTM, etc.).
    b. Pipe size and slope:
        i. Top-up drainage piping shall be sized to handle the maximum flow rate of make-up water discharged at the air gap,
        ii. For a typical single family residential dwelling (provided for guidance purposes only):
            1. Top-up drainage piping shall be no less than 50 mm [2 in.] in size when served by a potable water supply pipe no more than 18 mm [3/4 in.] in size.
        iii. Ensure a minimum slope of 0.5-2% (the greater the slope the better) is maintained throughout the pipe length.
    c. Consult the applicable provincial codes and regulations pertaining to the installation of drainage piping (refer to *Section 1.2 Applicable Codes, Standards, and Guidelines* for details).
7. Point of use cross-connections and zone protection:
    a. Additional backflow protection is required where there is a potential cross-connection between the rainwater pressure piping and the potable water system;
    b. Consult with local authorities for case-by-case requirements;
    c. For guidance purposes only, refer to Table 4-5 for point of use protection recommendations.

Table 4-5. Recommended zone protection measures based on rainwater fixtures

Rainwater Fixtures	Recommended Backflow Prevention Measures[1]
Toilet and urinal flushing	• Additional backflow prevention measures not necessary.
Laundry[2] (cold and dedicated hot rainwater service)	• If rainwater is used to supply both cold and hot water (through dedicated rainwater hot water system), no additional backflow prevention measures are necessary.
Laundry[2] (cold rainwater service only)	• If rainwater is used to supply only cold water and hot water is from a potable water supply: ▪ A reduced pressure backflow preventer (RPBP) must be installed on the hot water supply pipe upstream of the connection to the washing machine, *or* ▪ The hot water supply pipe must be permanently disconnected from the washing machine.

[1] Recommendations only. Consult applicable building codes and local authorities regarding backflow prevention requirements.

[2] The use of rainwater for laundry and/or hot water rainwater use are not permitted by the 2006 edition of Ontario's Building Code.

8. Premise isolation:
    a. Backflow preventers must be installed for the purpose of premise isolation. The following guidelines are based on CAN/CSA-B64.10-07; however, this edition is not yet adopted in the 2006 edition of Ontario's Building Code (refer to *Section 4.2 Applicable Codes, Standards, and Guidelines* for further details);
    b. Backflow preventer selection:
        i. Residential premises with access to an auxiliary water supply (not directly connected) must be isolated from the potable water supply by a dual check valve (DuC) backflow preventer,
        ii. All other premises with access to an auxilriary water supply (including residential premises with a direct connection) must be isolated from the potable water supply by a reduced pressure (RP) backflow preventer. A double check valve assembly (DCVA) may be permitted, consult municipal bylaws and local building officials.
    c. Protection against thermal expansion:
        i. If a backflow preventer is installed for premise isolation, the building potable water supply piping must be protected from thermal expansion by installation of an appropriately sized diaphragm expansion tank, selected and installed in accordance with applicable provincial codes and regulations.
    d. Backflow preventer testing and maintenance:
        i. Backflow preventers shall be tested and maintained in accordance with CAN/CSA-B64.10.1-07 Maintenance and Field Testing of Backflow Preventers.
9. Electrical wiring:
    a. All electrical wiring must be installed in accordance with the applicable provincial codes and regulations, including the current edition of the Ontario Electrical Safety Code.
10. Electrical conduit and rainwater service conduit:
    a. Wiring located underground shall be provided with mechanical protection by means of an electrical conduit, or other approved means;
    b. To facilitate repair and/or replacement of underground rainwater pressure piping, piping should be installed inside a rainwater service conduit, where the conduit material can be flexible drainage tubing (typically referred to as "Big 'O' " tubing) or other suitable material.

4.5 Management Guidelines

1. Following the installation of the RWH system, if the make-up system does not operate, or if it operates under conditions when it should not (i.e., tops-up the tank when there is a sufficient quantity of rainwater in the tank):
    a. Ensure that the proper control equipment were selected and arranged in accordance with the provided Design & Installation Guidelines;
    b. Visually examine the RWH system, in particular:
        i. Examine the volume of rainwater in the storage tank. If there is sufficient rainwater in the tank, the make-up system should not operate and the fact that it is "off" may indicate that it is functioning as intended,
        ii. Examine the electrical supply to the rainwater pump, solenoid valve(s), and water level sensor(s) to verify that electricity is being supplied to all equipment,
        iii. Examine the potable water supply pipe to verify that water flow is not being restricted by closed shut-off valve(s).
    c. If the above steps do not resolve the problems with the make-up system, its performance must be verified by performing the following steps *(Note: this method assumes that a float switch is the water level sensor utilized, and must be modified for other types of water level sensors using the manufacturer's supplied troubleshooting instructions)*:
        i. Float switch performance:
            1. Visually examine the float switch(es) in the rainwater tank to ensure that:
                a. They are properly tethered at the appropriate height and can freely move up and down,
                b. They are not tangled with the pump or other components located in the tank,
                c. Any electrical splicing of the float switch wire is intact.
            2. Adjust and untangle the float switches if required,
            3. Remove the float switch(es) and the structure to which they are tethered from the rainwater tank, in order to test their performance,
            4. If two float switches are present, the float switch at the lowest elevation should control the rainwater pump (preventing dry running) and the other switch, at a higher elevation, should control solenoid valve(s) for a make-up system,
            5. Simulate a low level event by holding the top float switch in the down position,
            6. For top-up systems, the flow of make-up water should start, which can be observed through an air gap or from the storage tank lid/access hatch,
            7. Next, simulate a high level event by holding the top float switch in the up position,

8. For top-up systems, the flow of make-up water should stop (as observed through an air gap or from the discontinuation of flow into the storage tank),
9. If another float switch is present in the tank, one which should control the pump in the event of low tank levels, this float switch should also be tested using the above method,
10. If the make-up system is operating under the opposite conditions as intended, then the problem lies in the type of float switches selected. If a N/O float switch is currently installed, then it must be replaced for a N/C float switch, and a N/C float switch must be replaced with a N/O float switch,
11. If no actions are observed under either float switch up or down scenarios, have the RWH system inspected by a licensed plumber and/or electrician.

ii. Solenoid valve performance:
   1. Visually examine the solenoid valve(s) on the potable water supply pipe and/or rainwater pressure piping. Ensure that each valve is connected to a power supply (i.e., electrical panel) and all manual shut-off valves located upstream of the solenoid valves are in the open position,
   2. Determine if the solenoid valve(s) are operating following the float switch performance guidelines provided above. If make-up water flow cannot be easily observed, verify whether the solenoid valve(s) are operating by listening for a buzzing sound and/or checking the temperature of the solenoid valve coil,
   3. If the solenoid valves do not appear to be operating, have the RWH system inspected by a licensed plumber and/or electrician.

iii. Top-up drainage pipe performance:
   1. Determine if the problem lies with top-up drainage piping by visually inspect the flow of water through the gap while performing the float switch performance evaluation (provided above) and/or simulating a top-up process by manually pouring water into the top-up drainage pipe through the air gap,
   2. During the top-up process, if water overflows from the air gap, this may indicate some or all of the following problems:
      a. The top-up drainage piping is undersized and/or the flow rate of make-up water is too high,
      b. There is a blockage or obstruction in the top-up drainage piping,
      c. If the system is operating under cold weather conditions, then water in the top-up drainage pipe may have frozen,
   3. To address these issues, first attempt to decrease the flow rate of make-up water into the top-up drainage pipe, and observe the make-up process to see if this corrects the problem. If this problem arose during a period of extreme cold weather, it may be necessary to winterize or decommission the RWH system (refer to

the instructions in *Chapter 2. Rainwater Storage & Tank Sizing* for details) then monitor the performance of the make-up system after warmer temperatures are present,

4. If the above recommendations do not resolve the problem, the make-up system and top-up drainage piping may need to be examined and/or scoped by a licensed plumber to determine if any obstructions are in the pipe.

2. Backflow preventer testing and maintenance:
   a. Backflow preventers shall be tested and maintained in accordance with CAN/CSA-B64.10.1-07 Maintenance and Field Testing of Backflow Preventers.
3. If the make-up system is operating properly, it is recommended that it still be inspected once every six months to:
   a. Verify that the float switch wires are not tangled with other float switches, the pump or other objects in the tank;
   b. Remove any dirt and/or debris that have accumulated on the float switch(es), if present;
   c. Observe the make-up system while operating to ensure that water is not overflowing from the top-up drainage pipe at the air gap and is not discharging from the backflow preventer(s). If any water leaking or discharging is observed, refer to the troubleshooting instructions above.
4. While inspecting, cleaning, or repairing the make-up system follow all necessary safety precautions, such as disconnecting the power supply when necessary.

Chapter 5. Pump and Pressurized Distribution System

5.1 Introduction

To supply rainwater to permitted fixtures a pump and pressurized distribution system is often required. Water is pumped from the rainwater tank, pressurized it, and delivered it to fixtures located at higher elevations in the building. The system is comprised of a pump, a 'pressure tank' (a tank used to store pressurized water), a pressure switch or constant pressure components, independent plumbing lines and various other plumbing components.

To ensure the proper operation of these systems, care must be taken when selecting the type and size of the pump and associated pressure tank. The pressure system must be capable of supplying water at a sufficient rate, and at a sufficient pressure to all the fixtures it is connected to, even those located the furthest distance from the pump. In addition, it must be designed and installed to minimize the risk of a cross-connection and potential backflow (refer to *Chapter 4. Make-up Water System and Backflow Prevention* for further details). Homeowner maintenance is also critical, as homeowners must periodically inspect the system and be capable of troubleshooting the system if an issue with the pump does occur.

5.2 Applicable Codes, Standards, and Guidelines

Table 5-1 references specific codes and standards that are applicable to pressure systems.

Table 5-1. Applicable standards, codes and guidelines for pump and pressure distribution systems

Applicable Codes, Standards, and Guidelines	Selected Provisions & Design and Installation Implications
Ontario's Building Code (O. Reg 350/06)	• **7.1.5.3.(2) Water Distribution Systems** • **7.2.5.5. Polyethylene Pipe and Fittings** • **7.2.5.7. Crosslinked Polyethylene Pipe and Fittings** • **7.2.5.8. PVC Pipe and Fittings** • **7.2.5.9. CPVC Pipe, Fittings and Solvent Cements** • **7.2.7.1. Copper and Brass Pipe** • **7.2.7.4. Copper Tube** • **7.3.4.5. Support for Horizontal Piping** • **7.6.3. Size and Capacity of Pipes** • **7.7.1.1. Non-Potable Connection** • **7.7.2.1. Markings Required** • **7.7.3.2. Outlets** Sentence 7.1.5.3.(2) specifies that rainwater (referred to as "storm sewage" in the OBC) or greywater that is free of solids may be used for the flushing of water closets, urinals or the priming of traps. Articles 7.2.5.5., 7.2.5.7., 7.2.5.8., 7.2.5.9., 7.2.7.1. and 7.2.7.4. specify approved pipe materials used for pressure applications. Article 7.3.4.5. provides specifications for the support of piping. Article 7.7.1.1. prohibits connections between potable and non-potable water systems. Article 7.7.3.2. specifies that rainwater shall not discharge into a sink or lavatory, a fixture into which an outlet from a potable water system is discharged, or a fixture that is used for the preparation, handling or dispensing of food, drink or products that are intended for human consumption. Subsection 7.6.3. provides a method for the sizing of water distribution systems, as per Tables 7.6.3.1 and 7.6.3.2 and A-7.6.1.1.(1). Also, pipes carrying rainwater shall have markings that are permanent and easily recognized. See CSA B.128.1 for guidance regarding markings.

Mandatory Documents   Supplementary Documents

Applicable Codes, Standards, and Guidelines	Selected Provisions & Design and Installation Implications
Ontario Electrical Safety Code O. Reg. 164/99 (current edition)	• **All electrical equipment must be approved and installed to according to the requirements of the current edition Ontario Electrical Safety Code**
CSA Standard B128.1 (2006)	• **5 Installation Requirements** • **9 Pumps** • **10 Separation** • **11 Testing** • **12 Markings** Provides guidelines for the pipes, pumps and plumbing accessories used for RWH systems, separation of rainwater pipes and potable water pipes and testing for cross-connections, as well as the markings for rainwater service pipes and outlets. *Note: Not legally binding unless adopted in future editions of the OBC.*

Mandatory Documents   Supplementary Documents

5.3 Issues for Consideration

General

The pump and pressurized distribution system is comprised of a series of interconnected components, located both inside the rainwater tank and within the building. A typical pressure system for a rainwater tank in a below-ground application is shown in Figure 5-1.

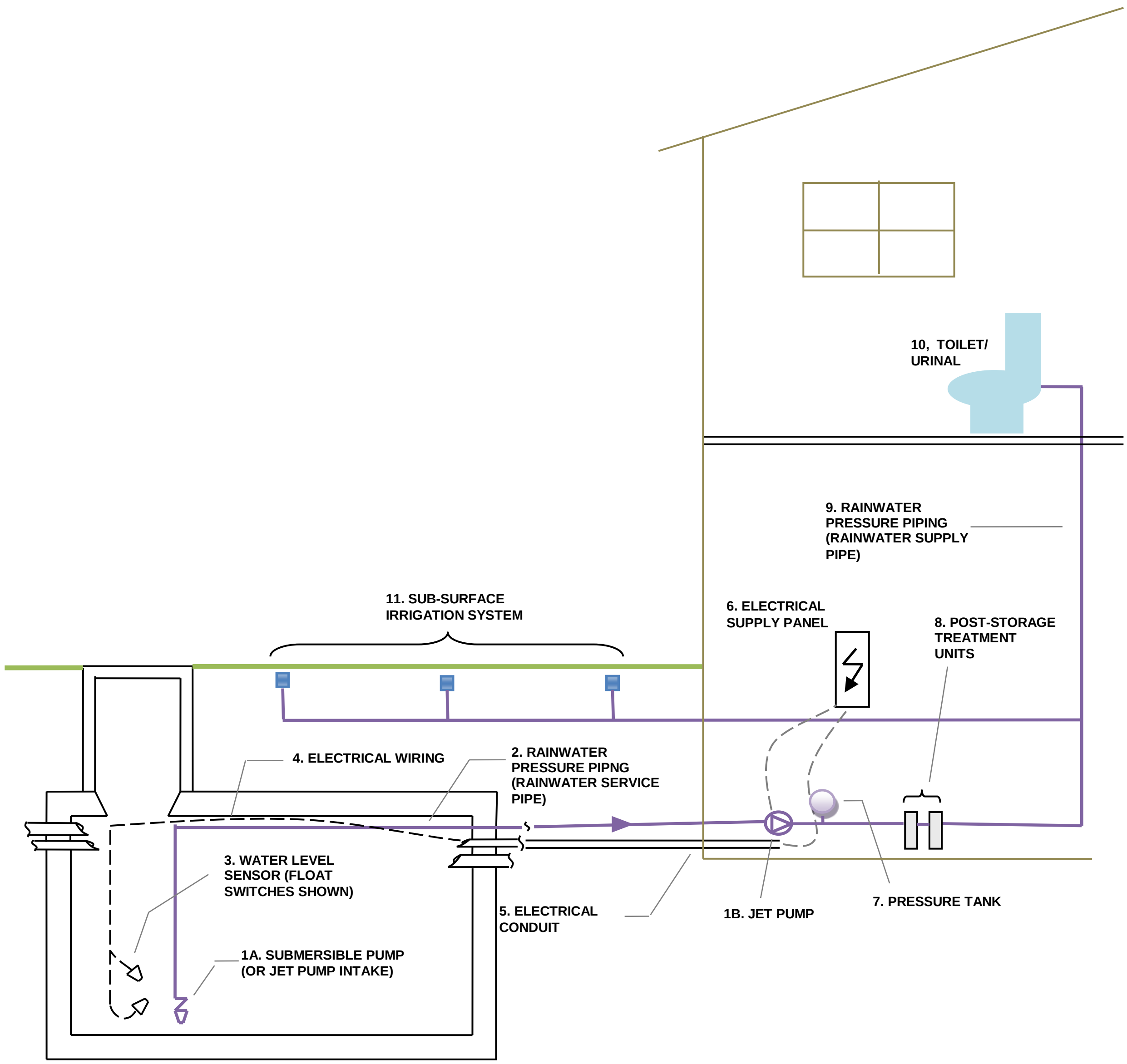


Figure 5-1. Typical schematic of pump and pressurized distribution system for below-ground rainwater tank

As shown in Figure 5-1, rainwater is drawn from the storage tank by a submersible pump located directly inside the tank [1A] or a "jet" pump located inside the building [1B]. This rainwater is pumped through a rainwater pressure piping [2], which runs from the tank to a suitable location (such as a mechanical room or basement utility room) within the building. To protect the pump from dry running, water level sensors [3], such as float switches, are often used. The electrical wiring from the water level sensor(s) and pump (if applicable) are then run through a protective electrical supply conduit [5] to an electrical supply panel [6].

Inside the building, the rainwater pressure piping is connected to a pressure tank and/or pump control unit [7] (depending upon the style of pump). If the RWH system will incorporate post-storage treatment units [8], these must be installed after the jet pump and any pressure tank and/or control unit. Following treatment (if performed), an rainwater pressure piping [9] is run to the permitted fixtures [10-11].

Pump

To select the appropriate pump for a given RWH system, four criteria must be considered:

1. Pump location, controller configuration and voltage,
2. Pump flow rate,
3. Pump system pressure, or "head," and
4. Acceptability of service interruptions.

Pump Location, Controller Configuration and Voltage

As shown in Figure 5-1, either a submersible pump located inside the tank, or a jet pump located outside the tank in an indoor/enclosed location, may be used. Other types of exterior pumps are available as an alternative to jet pumps, such as vertical multi-stage pumps, however, these are generally more suited to multi-residential and commercial applications, and as such, shall not be discussed further.

With regards to submersible and jet pumps, each has its advantages and disadvantages, which are discussed in Table 5-2.

Table 5-2. Advantages and disadvantages associated with submersible and jet pumps

Style of Pump	Advantages	Disadvantages
Submersible pump	• More efficient have a longer lifespan than jet pumps • Reduces the amount of equipment and space needed outside of the rainwater tank • Low noise	• Pump must be physically extracted from tank to perform inspection, repair and/or replacement • May be more difficult to detect pump dry running (or any malfunction) as operation of pump may not be audible • Pumps generally designed for vertical installation, but must be installed horizontally as vertical installation reduces usable capacity of cistern (increases dead space volume)
Jet pump	• Pump can be easily inspected, repaired and/or replaced • Generally less expensive than submersible pumps	• More difficult to commission than submersible pumps, as they must be 'primed' • Pump must be located in a temperature controlled space (indoors, pump house, etc.) • Pump operation may be noisy

Once a pump has been selected, the configuration of the pump controller must be determined. In general, there are two options available: constant speed pumps and variable speed drive (VSD) pumps, otherwise known as variable frequency drive (VFD) pumps.

1. **Constant speed pumps** –Following a large drop in system pressure, a constant speed pump will activate and pump water at a fixed rate to replenish the volume of water stored in the pressure tank.
2. **VSD/VFD Pumps** – Unlike constant speed pumps, VSD/VFD pumps can increase or decrease the speed of the pump impeller to provide more or less water as needed by the pressure system.

The advantages and disadvantages of each type of pump are summarized in Table 5-3.

Table 5-3. Advantages and disadvantages associated with type of pump

Pump Controller Configuration	Advantages	Disadvantages
Constant speed pump	• Generally less expensive than VSD/VFD pumps • Ideal for applications where minor variations in water pressure and flow rate are acceptable (i.e., refilling toilet tanks after flushing and operating a garden hose)	• Pressure tanks can be quite large for applications requiring high flow rates • Flow rate and system pressure may spike when pump activates, and pressure may drop if water demands are too high
Variable Speed Drive/ Variable Frequency Drive pump	• Provide constant pressure to fixtures, regardless of demand • Use very small pressure tanks, or micro-pressure tank inside the pump or control unit • Often have built in low/high voltage shutoff and dry run protection • Smaller space requirements in the building • Less electricity consumption than comparable constant speed pumps.	• Use of smaller pressure tanks requires a greater number of 'pump starts' potentially increasing pump wear • More expensive than constant speed pump systems

The final decision regarding the type of pump is its operating voltage, either 120V or 240V. Pump manufacturers generally recommend using a 240 V supply for pumps as this tends to reduce the need for heavy gauge wiring and switching components. Before selecting either voltage however, it is recommended that the homeowner contact an electrician and the pump supplier to inquire regarding the appropriate pump and wire voltage. It is also important to note that any components wired in with the pump, such as water level sensors, operate at the same voltage as the pump. Refer to *Chapter 4. Make-up Water System and Backflow Prevention* for further details.

Pump Flow Rate

The amount of flow that must be generated by the pump depends on the types and number of fixtures connected to the distribution system. One method of determining this flow rate is to sum up the required flow rates for all of the fixtures, assuming a 'worst case' scenario where all fixtures are operating at one time. This approach is not recommended, however, as it tends to over-size the pump, increasing the cost of the pump and pressure system. Instead, it is recommended that the pump flow rate be sized to handle a portion of this maximum flow, referred to as the 'maximum peak flow.'

Pump Head

Once the flow rate has been determined, the next task is to calculate the amount of pressure, or "head," the pump must provide. Two factors must be considered:

1. **Required system pressure** – This is the pressure required by the fixtures connected to the pump and pressurized distribution system, and
2. **Total dynamic head (TDH)** – This is the loss in pressure (or "head loss") that takes place as water is lifted from a low elevation to a high elevation, and the losses that take place when water is being pumped through long stretches of pipe and fittings.

Total dynamic head is comprised of three components:

1. **Static Lift** is the height that water must be lifted before arriving at the pump (applicable only for systems utilizing a jet pump),
2. **Static Height** is the height from the pump to the furthest fixture, and
3. **Friction Loss** is the pressure loss when water travels through pipes and fittings.

Figure 5-2 illustrates the components of pump head.

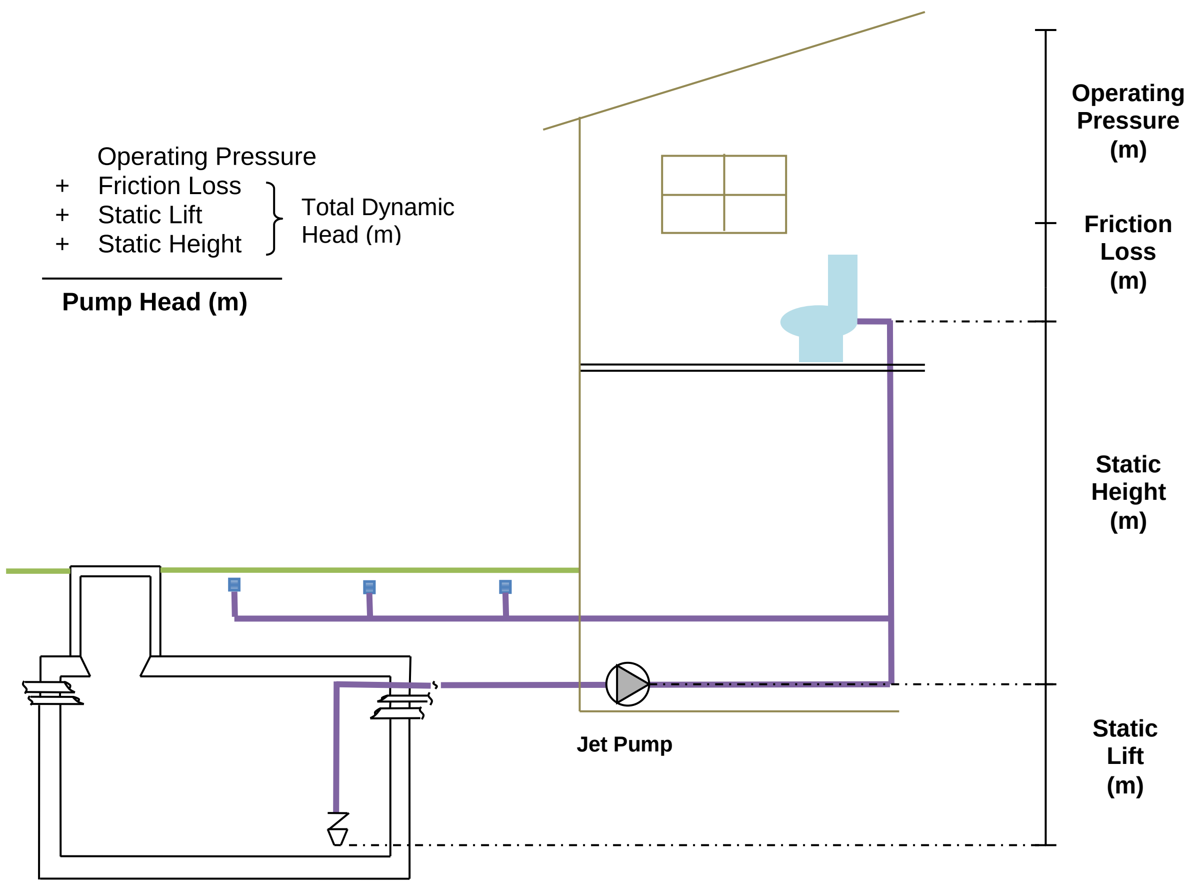


Figure 5-2. Components of Total Dynamic Head (TDH)

Once both the pump head and the flow rate are determined, a pump can be selected using pump curves provided by manufacturers.

Acceptability of Service Interruptions

A final issue to consider is whether it is acceptable for non-potable water service to be interrupted by pump downtime or other potential problems associated with the RWH system. In a typical residential setting where rainwater is used for toilet flushing and outdoor use, infrequent service interruptions are likely to be generally acceptable, and no added measures are necessary.

For residential settings where rainwater is used to supply much or all of household needs, or in multi-residential or commercial settings where water is needed for toilet and urinal flushing, service interruptions may not be acceptable. For such settings, two options are available: a dual-pump arrangement, often referred to as a duplex pump arrangement, can be installed, or an automatic bypass system can be utilized.

A drawback of duplex pump arrangements is that they tend to be much more expensive than single-pump systems; however, many offer control equipment to periodically cycle between pumps, which improves the lifespan of both pumps. Another advantage of these pumps is that they can be purchased in a pre-assembled state, and be installed in much the same way as a typical single-pump arrangement. .

Pipes

There are two distinct sections of rainwater pressure piping:

1. **Rainwater service pipe** – the section of pipe from the storage tank to a jet pump, or the section of pipe from the storage tank to the pressure tank or control unit, in the case of submersible pumps;
2. **Rainwater supply pipe** – the section of pipe from the jet pump (or pressure tank/control unit for submersible pumps) to the permitted fixtures.

Each section has unique criteria that must be considered during design and installation, resulting in different pipe material, sizing and installation requirements. For instance, below-ground rainwater tanks require rainwater service pipe that is suitable for burial and, as this pipe will always have water in it, it is critical that it is well protected from freezing. Rainwater supply piping is inside the building and must be installed in accordance with codes to ensure that a cross-connection is not made. Both sections of pipes must be sized to handle the flow generated by the pump and ensure that each fixture receives rainwater at a sufficient rate, with service piping typically requiring larger pipe diameters than supply piping.

To prevent cross-connections, rainwater piping must be marked to indicate that the pipes contain non-potable water. Markings for pipe must be distinct and easily recognizable, typically a purple colour is used to identify the piping as containing non-potable water. An example of pipe marking is shown in Figure 5-3.

WARNING: NON-POTABLE WATER — DO NOT DRINK
AVERTISSEMENT : EAU NON-POTABLE — NE PAS BOIRE

Figure 5-3. Typical marking for rainwater pressure piping

Another means of identifying rainwater pressure piping is to utilize a distinct colour of pipe – purple – to prevent future plumbing cross-connections.

Pressure Tank

Pressure tanks perform two functions in a pump and pressurized distribution system:

1. Store pressurized water to minimize the frequency of the pump cycling on and off, and
2. Maintain a constant pressure in the distribution system.

To accomplish these tasks, pressure tanks are comprised of an exterior shell with an inner bladder that is equipped with a pressure sensor connected to the pump. The pump starts when the pressure in the bladder drops to the cut-in point and shuts off when the pressure in the bladder reaches the cut-out point.

Other than the pressure sensor, the most important factor to ensure proper operation of the pressure system is sizing the pressure tank so that it is compatible with the type of pump and the pump's flow rate.

Constant speed pumps require larger pressure tanks than VSD/VFD pumps because they are designed store the volume of water discharged by the pump over a 1-2 minute period. This is the minimum time the pump is permitted to operate once activated and is referred to as "pump run time". A longer pump run time requires a larger pressure tank, but minimizes wear due to frequent pump starts. For VSD/VFD pumps, the size and style of pressure tank tends to vary by manufacturer. Some manufacturers specify the use of small (~1 Gallon) tanks that are installed in a similar manner to larger pressure tanks, whereas others incorporate micro-pressure tanks inside the pump, or in a control panel.

5.4 Design & Installation Guidelines

Design and installation guidelines:

> **Note**: refer to *Section 5.2 Applicable Codes, Standards, and Guidelines* for the specific provisions that apply when the term "in accordance with applicable provincial codes and regulations" is used.

1. Determine the fixtures connected to rainwater:
    a. In the Province of Ontario, rainwater may be used for:
        i. Toilet and urinal flushing, and
        ii. Sub-surface irrigation and below ground irrigation.
    b. Consult the applicable provincial codes and regulations to verify the fixtures for which connection to rainwater is permitted.
2. Select the pump:
    a. Determine the style and operating characteristics:
        i. Style: jet pump or submersible pump,
        ii. Controller configuration: constant speed or variable speed drive (VSD),
        iii. Operating voltage: 120V or 240V.
    b. Determine the required flow rate:
        i. Consult applicable codes and regulations, industry standards, local authorities and irrigation system manufacturer (if applicable) regarding the minimum flow rate to be supplied by the pump,
        ii. For guidance purposes only, a method for estimating minimum pump flow rate, based upon the maximum peak demand sizing method, is provided in *Appendix C*.
    c. Determine the pump head:
        i. Consult applicable codes and regulations regarding the minimum flow pressure and maximum static pressure provided by the pump,
        ii. A method for determining the pump head is provided in *Appendix C*.
    d. Consult the pump manufacturer or supplier, or use pump manufacturer's 'pump curve' charts, to select the appropriate pump model, given the pump style and operating characteristics, required flow rate, and pump head.
    e. If pump downtime is not permitted or not desired:
        i. Provide a generator or battery backup for the pump, and/or
        ii. Provide a backup pump or duplex pump arrangement.
3. Select the pressure tank:
    a. Consult the pump manufacturer or supplier regarding the minimum size of pressure tank for the pump, based upon pump controller configuration, and pump flow rate;
    b. For guidance purposes only, a method for sizing the pressure tank for constant speed pumps is provided in *Appendix C*.

4. Plan the layout of the pump and pressurized distribution system:
    a. Plan route of the rainwater service piping from the jet pump, pressure tank or control unit to the tank (refer to *Section 1.4 Design & Installation Guidelines* for guidelines and applicable provincial codes and regulations regarding installation of underground piping);
    b. Plan route of the rainwater supply piping from the jet pump, pressure tank or control unit to the permitted fixtures;
    c. Plan route of electrical conduit(s) from the location of the power supply to the tank (route with float switch wiring where possible, refer to *Chapter 4. Make-up Water System and Backflow Prevention* for further details);
    d. Ensure that there are no buried service lines (gas, electricity, water, stormwater, wastewater, phone, or cable lines) in the area where digging will take place to accommodate buried rainwater service piping and/or electrical conduit by contacting the municipality and service providers.
5. Rainwater pressure piping:
    a. Rainwater pressure piping is comprised of two distinct sections of pipe:
        i. Rainwater service pipe:
            1. Piping from the storage tank to a jet pump, or
            2. Piping from the storage tank to the pressure tank or control unit, in the case of submersible pumps.
        ii. Rainwater supply pipe:
            1. Piping from the jet pump (or pressure tank/control unit for submersible pumps) to the permitted fixtures.
    b. Rainwater service pipes:
        i. Pipe material:
            1. Polyethylene pipe (recommended), where
            2. Pipe selected must be approved by applicable provincial codes and industry standards (CSA, ASTM, etc.).
        ii. Pipe size:
            1. Pipe shall be sized to handle the maximum flow rate of the pump in accordance with the pump manufacturer’s instructions,
            2. For estimation purposes, service pipe size can be calculated using the method provided in *Appendix C*.
        iii. Tank connection:
            1. Rainwater service piping should enter the tank at a height no lower than that of the overflow drainage piping, or ideally, at a height 50 mm [2 in.] above the top of the overflow drainage pipe(s) entering the tank, or
            2. Where entering the tank at a height no lower than that of the overflow drainage piping exposes the rainwater service piping to frost, rainwater service piping may enter the tank at a lower height, provided the tank connection is water tight.
    c. Rainwater supply pipes:
        i. Pipe material:
            1. Crosslinked polyethylene (PEX) (recommended), where

        2. Pipe selected must be approved by applicable provincial codes and industry standards (CSA, ASTM, etc.).
    ii. Pipe size:
        1. Consult the applicable provincial codes and regulations pertaining to water supply pipe sizing,
        2. For estimation purposes, supply pipe size can be calculated using the method provided in *Appendix C*.

6. Installation of rainwater pressure piping:
    a. Connection:
        i. Rainwater pressure piping shall not be connected to a potable water system,
        ii. Rainwater pressure piping shall only connect to fixtures permitted by applicable provincial codes and regulations.
    b. Support and protection:
        i. Underground piping shall be located in a properly excavated space, be supported and properly backfilled in accordance with applicable provincial codes and regulations,
        ii. Piping inside a building shall be supported in accordance with applicable provincial codes and regulations,
        iii. Piping shall be protected from frost (refer to *Section 1.4 Design & Installation Guidelines* for details).
    c. Operation and maintenance considerations:
        i. Rainwater service piping connected to a jet pump must be installed on a horizontal, or on a consistent upward slope from the storage tank to the pump,
        ii. To minimize the possibility of leaks, underground rainwater service piping should be installed with no, or few, pipe fittings,
        iii. To facilitate repair and/or replacement of underground rainwater service piping, piping should be installed inside a rainwater service conduit, where the conduit material can be flexible drainage tubing (typically referred to as “Big ‘O’ ” tubing) or other suitable material.
    d. Underground non-metallic pipes should be installed with ‘tracer tape’ (also referred to as ‘tracer wire’) at a height of 300 mm [12 in.] above the pipe for the purpose of locating as-installed piping.
7. Pipe markings[20] :
    a. All rainwater pressure pipes shall be clearly identified and marked in accordance with applicable provincial codes and regulations;
    b. Pipes shall be marked as follows:
        i. Text/legend:
            1. WARNING: NON-POTABLE WATER — DO NOT DRINK AVERTISSEMENT : EAU NON-POTABLE — NE PAS BOIRE
            2. Text must be legible with letters no less than 5 mm in height, except where pressure pipe size makes 5 mm high letters impractical.

[20] Adapted from CAN/CSA-B128.1-06 Design and installation of non-potable water systems. 2006. CSA International, Mississauga, ON. Refer to CAN/CSA-B128.1-06 for further details.

    ii. Colour:
        1. Marking labels shall be purple in colour, and/or
        2. Pipes shall be purple in colour, or marked with a continuous purple stripe.
    iii. Figure 5-4 provides an example of typical pipe marking:

WARNING: NON-POTABLE WATER — DO NOT DRINK
AVERTISSEMENT : EAU NON-POTABLE — NE PAS BOIRE

Figure 5-4. Typical marking for rainwater pressure piping

  c. Spacing of markings:
    i. Markings shall be repeated at intervals of not more than 1.5 m.

8. Installation of pump :
  a. Pumps shall be installed in accordance with the manufacturer's installation instructions;
  b. Pumps shall be installed such that they are readily accessible (submersible pumps must be retrievable without entry into the tank);
  c. Pump shall be provided with dry run protection. Consult pump specifications to determine if pump has built-in dry run protection, if not, provide a water level sensor (refer to *Chapter 4. Make-up Water System and Backflow Prevention* for details);
  d. For jet pumps:
    i. Rainwater service pipe should terminate no less than 100-150 mm [4-6 in.] above the bottom of the tank,
    ii. Pump prime shall be maintained by a foot valve located at the rainwater service pipe intake, or a check valve located in the rainwater service pipe upstream of the jet pump.
  e. For submersible pumps:
    i. The pump intake should be located no less than 100-150 mm [4-6 in.] above the bottom of the tank,
    ii. Pump prime shall be maintained a check valve located in the rainwater service pipe downstream of the jet pump (consult pump manufacturer's instructions to determine if required).
  f. Electrical requirements:
    i. All wiring must be installed in accordance with the current edition Ontario Electrical Safety Code. Refer to the pump manufacturer's installation instructions for further details,
    ii. Electrical wiring installed outdoors and/or underground should be provided with protection,
    iii. The pump should be installed on a dedicated circuit, with a motor disconnect switch installed near the pressure tank or control panel (refer to the Ontario Electrical Safety Code for specifics),
    iv. For buried tanks, electrical wiring should be suitable for burial and/or wiring should be run through a protective conduit made of PVC pipe, or 'Big-O'-style drainage pipe,

v. Buried electrical wiring and/or conduits should be installed in a properly prepared and backfilled space (refer to *Chapter 1. Rainwater Catchment & Conveyance* for details).

9. Installation of pressure tank:
    a. Pressure tanks shall be installed in accordance with the manufacturer's installation instructions;
    b. Pressure tanks shall be installed such that they are readily accessible;
    c. Pressure tanks shall be installed with a means for observing the system pressure, such as a pressure gauge;
    d. The pressure sensor or pressure switch installed with the pressure tank must be wired in with the pump (and a control panel if applicable);
    e. All wiring must be installed in accordance with the current edition Ontario Electrical Safety Code.
10. Install post-storage treatment devices as required (refer to *Chapter 3. Rainwater Quality & Treatment* for details).
11. Commission the pump and pressurized distribution system in accordance with the manufacturer's instructions. Instructions for a typical constant speed pump are provided in *Section 5.5*.

5.5 Management Guidelines

1. If the pump and pressurized distribution system stop operating, or if there are problems during the commissioning process, follow the trouble shooting steps outlined below:
    a. Ensure that the proper pump and pressure equipment were selected and installed in accordance with the provided Design & Installation Guidelines;
    b. Visually examine the volume of rainwater in the storage tank:
        i. If the rainwater tank is empty, the pump and pressure system should not operate, and the fact that it is "off" may indicate that a water level sensor connected to the pump, or the pump's internal dry run protection, is acting as intended and preventing the system from operating,
        ii. If there is sufficient rainwater in the tank, and the pump and pressure are not operating, examine the electrical supply for the pump and pressure system. Verify that all necessary components are connected to the electricity supply, and that all components are supplied electricity (i.e., all on/off switches are in the 'on' position and any electrical panel breakers are also in the 'on' position),
        iii. *Note: In the event of a power failure, rainwater cannot be supplied to connected fixtures unless back-up provisions such as an automatic bypass back-up system were included in the design of the RWH system*.
2. Most often a problem with the pump and pressurized distribution system is not due to the pump itself but the associated components and equipment. The following steps are recommended for examining each of these components:
    a. A licensed plumber, electrician or other skilled technician should be consulted regarding the troubleshooting and/or repair of the pump and pressure system. The following steps are provided only as a guide.
    b. Make-up water system and water level sensors:
        i. During the visual inspection of the rainwater storage tank, if the tank appeared empty, but the RWH system includes a top-up system, this may indicate that there are problems with the back-up system. Refer to *Chapter 4. Make-up Water System and Backflow Prevention* for instructions on how to troubleshoot this system,
        ii. If the RWH system utilizes an automatic bypass make-up system, an empty tank may be normal given insufficient rainfall or heavy use. This system should automatically provide potable water to fixtures (bypassing the RWH system). If this system does not operate, or if pump operation does not resume following the addition of rainwater to the tank, this may indicate that there are problems with the back-up system,
        iii. If a manual top-up or bypass back-up system is utilized, direct intervention is required to activate these systems. These systems must be activated prior to the storage tank running empty, otherwise a water level sensor connected to the pump, or the pump's internal dry run protection, will prevent the pump and pressure system from operating,
        iv. If the top-up system appears to be functioning as intended, the problem with the pump and pressurized distribution system may lie with the water

level sensor connected to the pump. Instructions on how to inspect, test and adjust a float switch water level sensor is provided in *Chapter 4. Make-up Water System and Backflow Prevention*.

c. Pressure tank:
    i. If the pump cycles on and off repeatedly, and/or the system never comes up to the desired pressure, there may be a problem with the pressure tank,
    ii. The static pressure of the pressure tank (the pressure of the tank when there is no water inside of it) must be 14 kPa [2 psi] less than the desired cut-in pressure.

d. Pressure sensor/switch:
    i. Pump cycling and/or an inability to come up to the desired pressure may also be a problem with the pressure sensor/switch,
    ii. For VSD/VFD pumps utilizing a pressure sensor, the pressure settings will likely need to be set using a control panel (refer to the pump and pressure tank manufacturer's installation instructions for details),
    iii. For constant speed pumps utilizing a pressure switch, consult the pump, and/or pressure switch manufacturers' instructions for instructions on adjusting the pressure switch.

e. Pipes and shut-off valves:
    i. If a jet pump appears to be dry running, or if a submersible pump appears to run for a period of time, but does not discharge any water, there may be a blockage in the rainwater pressure piping,
    ii. If the tank is located outdoors and below ground, there is a chance that under extreme cold conditions rainwater may have frozen in the pipes, preventing flow in the rainwater pressure piping. It may be necessary to wait for temperatures to increase to determine if this is the source of the problem,
    iii. A blockage can also be created by a shut-off valve, located in the rainwater pressure piping, that is in the 'closed' position. Inspect all shut-off valves to ensure they are open.

f. Foot valves, check valves and leaks in the system:
    i. If the pump cycles on during times when there is no rainwater demand or if the pressure gauge shows that the system pressure slowly decreases over time, there may be a problem with the foot valve or check valve or there may be a leak in the system,
    ii. Inspect all foot valves and check valves to ensure that they are installed in the correct orientation (as indicated on the device) and that the valve is not clogged by dirt and debris,
    iii. If the foot valves and check valves appear to be operating properly, then there may be a leak in the rainwater pressure piping. Inspect all piping to ensure that there are no leaks from the pipelines or leaks from the fixtures connected to the pump and pressurized distribution system.

3. If the above steps do not resolve the issues with the pump and pressure system, the problem may lie directly with the pump. Refer to the pump manufacturer's operation instructions for troubleshooting recommendations, and if these actions are unsuccessful at

resolving the problem, consult a licensed plumber, electrician and/or pump service technician.

4. If the pump and pressurized distribution system is operating properly, it is recommended that it still be inspected once annually to:
    a. Ensure that the pump and pressure system is in good working order, and that there is no obvious sign of pump overheating or pump wear;
    b. Ensure that there are no leaks in the rainwater pressure piping;
    c. Observe the pressure system when no demands are placed on it. If the pump cycles repeatedly during a period where no demands are present, this may indicate that there are problems with the foot valve or check valve, or that there is a leak in rainwater pressure piping.
5. While inspecting and/or repairing the components of the pump and pressurized distribution system, follow all necessary safety precautions, including disconnecting the electricity supply to the pump.

Chapter 6. Overflow Provisions & Stormwater Management

6.1 Introduction

On occasion, the volume of rainwater collected from the roof catchment will exceed the storage capacity of the rainwater storage tank, causing the tank to overflow. If overflow-handling provisions are not in place, excess rainwater will back up rainwater conveyance and top-up drainage piping, until the rainwater reaches a point from which it can most easily discharge/overflow. This may be at the downspout-to-conveyance drainage pipe transition, or less ideal locations like the access opening of the tank, or at the air gap of a top-up system. Overflows at these points may cause damage to the rainwater tank itself, or cause water damage to a building's exterior or interior.

Due to the consequences of not properly handling excessive volumes of rainwater, it is important that the RWH system include sufficient overflow provisions. The design of overflow systems involves deciding where excess volumes of rain can be appropriately discharged, and how to convey these overflow volumes from the storage tank to the point of discharge. Addressing these issues generally falls under the practice of stormwater management.

The practice of stormwater management has evolved considerably in the past decades, and has shifted from simply conveying stormwater off-site to managing it through on-site practices and treatment facilities designed to mitigate the environmental impacts of runoff. RWH systems are a new addition to stormwater management practices in Canada, and as such there is little guidance on how to integrate these systems with stormwater management programs. Despite lack of specific guidelines, many aspects of stormwater management remain applicable for handling the overflows of rainwater tanks.

This chapter will discuss these stormwater management and regulatory requirements and provide guidance on how to select, install and manage the most appropriate type of overflow-handling system given these considerations and other issues such as site conditions, and tank location/ placement. Since there are very few federal or provincial regulations or guidelines on the design and installation of stormwater management systems, this chapter utilizes the Stormwater Management Planning and Design Manual from the Province of Ontario for general design criteria and method[21].

[21] Stormwater Management Planning and Design Manual. 2003. Ontario Ministry of the Environment, Toronto, ON.

6.2 Applicable Codes, Standards, and Guidelines

Table 6-1 references specific codes and standards that are applicable to overflow-handling systems.

Table 6-1. Applicable standards, codes and guidelines for rainwater overflow handling systems

Applicable Codes, Standards, and Guidelines	Selected Provisions & Design and Installation Implications
Ontario's Building Code O. Reg 350/06 (2006)	• **7.4.2.2. Connection of Overflows from Rainwater Tanks** • **7.4.3.2. Restricted Locations of Indirect Connections and Traps** Article 7.4.2.2. specifies that an overflow from a rainwater tank shall not be directly connected to a drainage system (an indirect connection is required). Indirect connections must be located in accordance with Article 7.4.3.2. *Note: Overflow drainage pipes must be sized and installed in accordance with the OBC provisions applicable to drainage piping. See Chapter 1 for details.*
CSA Standard B128.1 (2006)	• **7.7 Overflow(s) capacity** • **7.8 Overflow discharge** Specifies that the capacity of the overflow drainage pipe(s) must be equal to the capacity of the conveyance drainage pipes, and that overflows must be discharged in accordance with local regulations. *Note: Not legally binding unless adopted in future editions of the OBC.*
Stormwater Management Planning and Design Manual (2003)	• **4.5.6 Roof Leader Discharge to Soakaway Pits** Provides design and installation guidelines for lot-level infiltration systems.

Mandatory Documents   Supplementary Documents

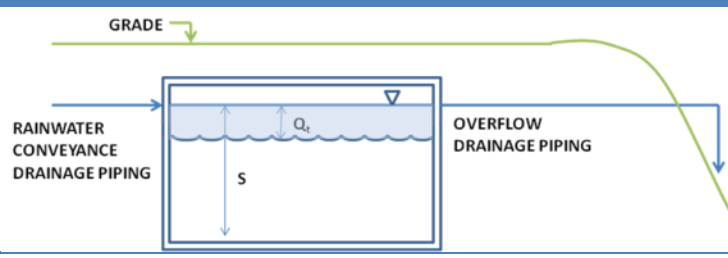
6.3 Issues for Consideration

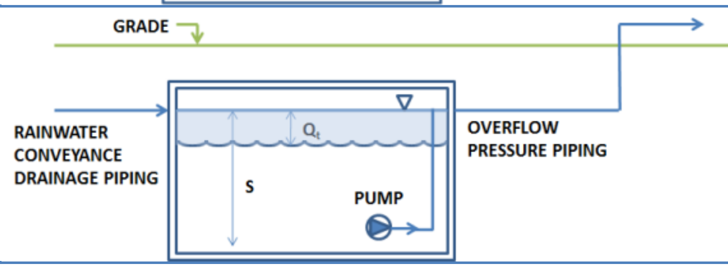
Overflow Discharge Locations

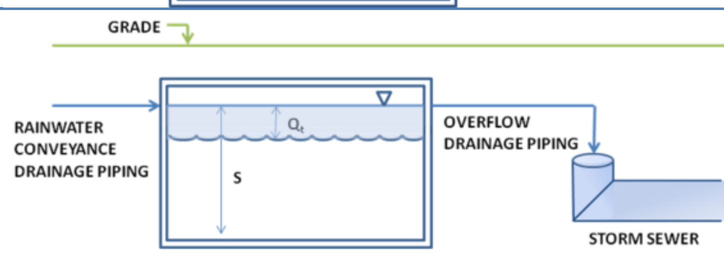
The purpose of the overflow system is to handle excessive rainwater flows, directing them away from the rainwater storage tank to a suitable location. Overflow volumes can be directed to grade, a storm sewer, or an on-site soakaway pit. In each case, rainwater can be conveyed via gravity flow or pumping. Table 6-2 describes these options and includes sketches illustrating each overflow-handling method. In these illustrations, rainwater entering the tank during a rainfall event (Q_t) has exceeded the storage capacity of the tank (S).

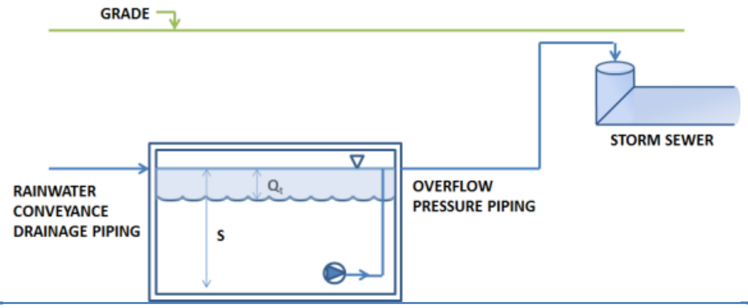
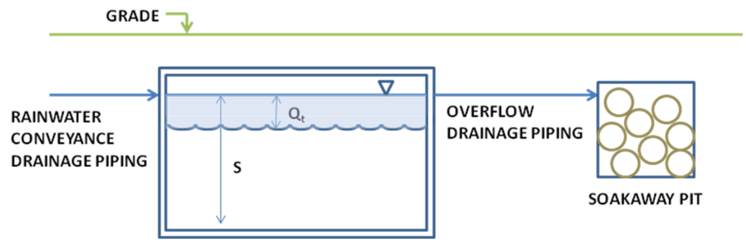
Table 6-2. Overflow discharge locations and methods of conveying rainwater overflows

<table>
<tr><th>Overflow Discharge Locations/Methods</th><th>Illustration/Example</th></tr>
<tr><td>1. Discharge to grade via gravity flow

This method is applicable for tanks located above- or below-grade where rainwater overflows can be directed to grade via gravity flow.</td><td>
</td></tr>
<tr><td>2. Discharge to grade via pump-assisted flow

This method is applicable for tanks located below-ground or integrated within buildings, where rainwater overflows must be pumped to grade</td><td>
</td></tr>
<tr><td>3. Discharge to storm sewer via gravity flow

This method is applicable for tanks located above- or below-grade where rainwater overflows can be discharged to a storm sewer via gravity flow, although the tank cannot be directly connected to the sewer[1].</td><td>
</td></tr>
</table>

4. Discharge to storm sewer via pump-assisted flow This method is applicable for below ground tanks and tanks integrated within buildings where the storm sewer is located at a higher elevation than the storage tank.	
5. Discharge to soakaway pit via gravity flow (pump-assisted flow N/A) This method is applicable for tanks located below-ground where rainwater overflows must be infiltrated on-site and pumping to grade is impractical, and/or the overflow drainage piping cannot be connected to a storm sewer.	

[1]Tanks can be indirectly connected to the storm sewer, or alternatively a backwater valve can be installed on the overflow drainage piping in the case of a direct connection.

Each overflow system has unique advantages and disadvantages, discussed in Table 6-3 (listed from most to least recommended).

Table 6-3. Comparison of the advantages and disadvantages associated with overflow discharge locations/methods

Overflow Discharge Locations/Methods	Advantages	Disadvantages
Discharge to grade via gravity flow ***(most recommended)***	• Simplest method to design, install and operate. • Low probability of rainwater backing up the overflow drainage piping	• If discharge location not prepared properly, may cause soil erosion at site. • May pose a nuisance/safety issue if discharging large volumes from big catchment surfaces. • Overflow drainage piping may freeze if large sections are above the frost penetration depth; ice may build up at the point of discharge if not designed properly.
Discharge to storm sewer via gravity flow	• Ideal for below-ground tanks as storm-sewers are also located below grade. • Storm sewers are specifically designed to collect roof runoff and direct it to an appropriate location off-site.	• Design must prevent backflow from storm sewer into rainwater tank. • Stormwater discharges can have negative environmental impacts on receiving water bodies.
Discharge to soakaway pit via gravity flow	• Permits the handling of stormwater on-site, which contributes to maintaining pre-development drainage regimes. • Environmental benefits of groundwater recharge. • In newer housing developments, an infiltration trench, serving multiple lots, may be built by the developer.	• Soakaway pits require extensive site work to design and install (high in cost). • Large rainfall events can exceed the infiltration capacity of the soil, requiring a separate overflow from the soakaway pit • Suitable only for permeable soils
Discharge to grade or storm sewer via pump-assisted flow ***(least recommended)***	• In cases where the tank is located deep underground (building sub-basements, parking garages, etc.) this may be the only method of handling overflows.	• Pump may fail in the event of a power outage. • Large pump required to handle overflow volumes generated during intense rainfall events.

Selecting the Most Appropriate Overflow Discharge Location

Selection of an overflow discharge location must not only include a comparison of the advantages and disadvantages discussed above, but also a number of other factors, which include:

1. Stormwater management requirements;
2. Applicable provincial regulations, and municipal bylaws;
3. Location/placement of rainwater storage tank; and
4. Site conditions.

Stormwater Management Requirements

In some cases, overflow from the rainwater tank may need to be handled in accordance with special stormwater management requirements. These requirements may be imposed by a municipality or applicable conservation agencies for buildings located in an environmentally-sensitive area, or in an area where the existing storm sewer infrastructure does not have sufficient capacity to accept additional stormwater flows, or for a variety of other reasons. Stipulations may include on-site retention of certain storm volumes with specified rates of release to the storm sewer, and/or on-site management through infiltration or overland flow, for example. RWH systems and overflow provisions can be designed to meet such criteria.

Local authorities, including local conservation authorities, should be consulted while designing the RWH system to verify if special stormwater management practices are required

Applicable Provincial Regulations and Municipal Bylaws

Even if there are no special stormwater management requirements, provincial regulations and municipal bylaws may still restrict the locations where rainwater overflows can be discharged. The 2006 edition of Ontario's Building Code prohibits the direct connection of an overflow from a rainwater tank to a storm sewer because of the possibility of storm sewage backing up into the rainwater tank during extreme rainfall events. Some municipalities may however accept such connections as long as they are protected by a backwater valve. Alternatively, an indirect connection may be made, where the rainwater tank overflows into either a small inceptor tank or soakaway pit, which in turn overflows into the storm sewer.

Tank Location

The location of the storage tank can also have an impact on the overflow discharge location selected. Overflow-handling is simplest with above-ground tanks, since overflows can typically be discharged to grade. Handling overflows is more challenging with below-ground tanks and/or tanks integrated within buildings (located below grade). For these tanks, proximity to a storm sewer connection or to greenspace (for infiltration or overland flow), often play a much greater role in determining where overflows can be directed.

Site Conditions

Site conditions such as topography, the availability and accessibility of space, and the existence of other buried services also affect the selection of an overflow discharge location. For instance, a flat terrain may preclude the discharge of overflow from a buried tank to grade. Similarly, space constraints and buried service lines may limit excavation for overflow drainage piping and/or a soakaway pit.

Soakaway pits are particularly sensitive to site conditions. In addition to requiring significant space, they also require a minimum soil permeability (i.e., soil cannot have a significant clay content). Sites with a large catchment area and/or low soil permeability may require a large infiltration area and/or the soakaway pit itself may require an overflow. In some cases, soakaway pits may not be feasible.

Soakaway Pits

Soakaway pits are comprised of an excavated space filled with a non-porous material, such as stone, surrounded by an outer filter fabric. If the catchment area is very large and/or the soil is not sufficiently permeable, the soakaway pit may require its own overflow drainage pipe to storm sewer or to grade. If treatment is required, for example, if the soil is very permeable and located near a well, a sand layer may be installed at the bottom of the trench. The basic version of an infiltration trench, considered to be suitable for most RWH systems, is illustrated below in Figure 6-1.

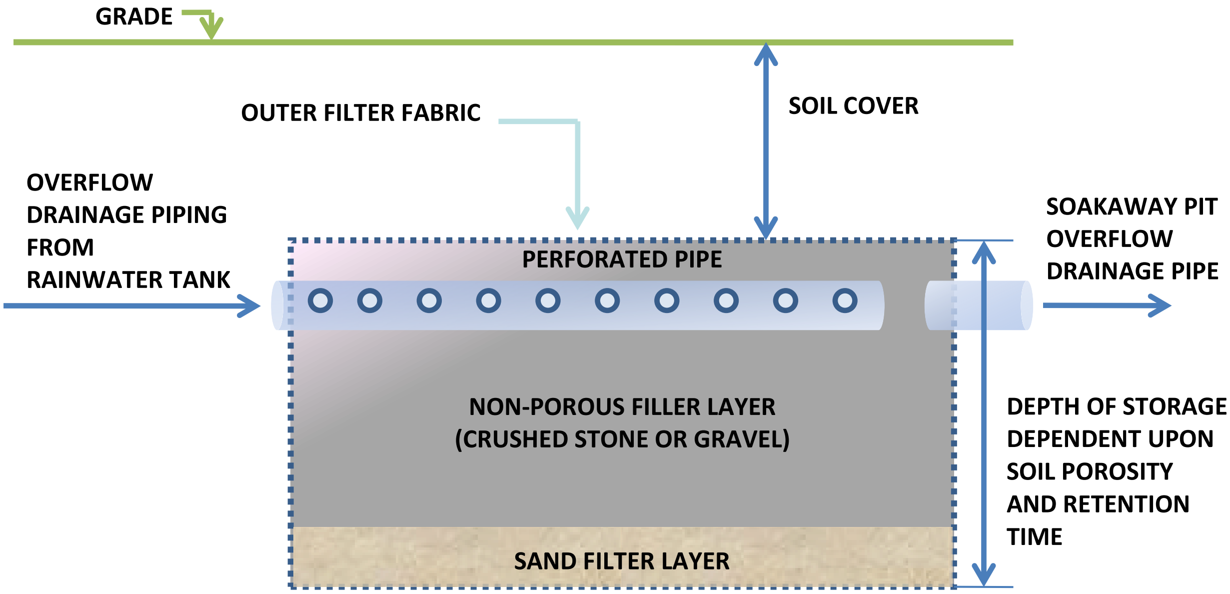


Figure 6-1. Sketch of a typical soakaway pit (cross-section view)[22]

The materials typically required for a soakaway pit include:

1. **Storage media** –crushed stone of a uniform size, used to provide a non-porous structure for the pit.
2. **Outer fabric** – non-woven filter fabric (polypropylene geotextile), used to protect the storage media from becoming clogged by the surrounding soils.
3. **Distribution pipes** – comprised of perforated overflow drainage piping, and used to distribute rainwater uniformly throughout the entire pit/trench.
4. **Filter layer** - comprised of fine sand, and placed on the outer fabric on the bottom of the trench to filter impurities prior to infiltration.

Rainwater Quality

To prevent the entry of contaminants into the tank, the overflow drainage piping should be designed similar to the conveyance network (i.e. be structurally sound with no points of entry other than those required for water flow). If discharging to grade, the overflow drainage piping should have an insect screen, located where it can be inspected and cleaned. If discharging to the storm sewer, a type of check valve, called a 'backwater valve', can be installed on the overflow drainage piping to prevent storm sewage from backing up into the tank during intense rainfall events.

[22] Adapted from Stormwater Management Planning and Design Manual. 2003. Ontario Ministry of the Environment, Toronto, ON.

Rainwater Harvesting as Part of a Stormwater Management System

Installing a RWH system for the express purpose of reducing stormwater runoff is a relatively new concept in Canada. A RWH system cannot eliminate the need for other stormwater management systems; however, if rainwater is to be managed on-site, RWH can reduce the size or complexity of other lot-level infiltration systems. Similarly, if overflow is discharged to the storm sewer, the rainwater tank can be used in place of a holding tank for detention and controlled release. As shown in Figure 6-2, the bottom portion of the tank stores rainwater for later use, and the top portion of the tank temporarily detains the rainwater and releases it at a predetermined rate through control valves. Excess volumes from extreme events are discharged through the overflow drainage piping.

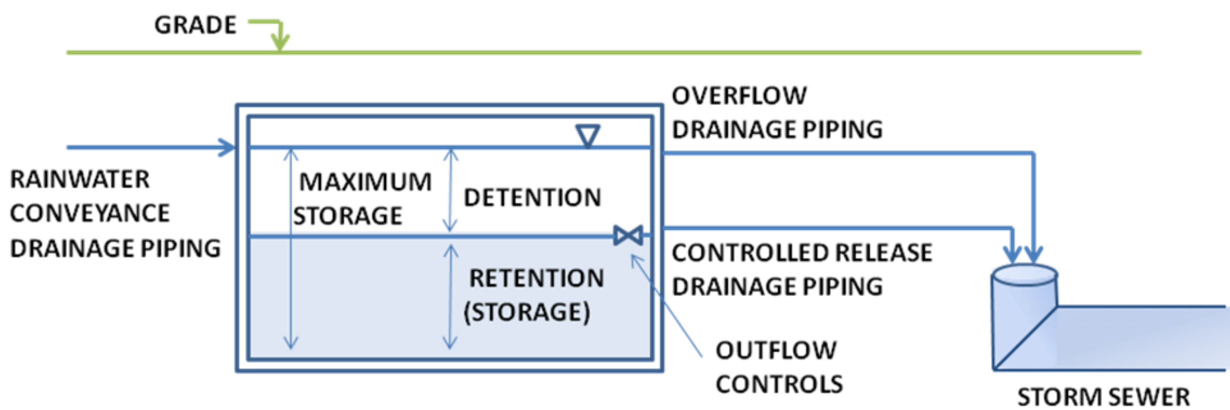


Figure 6-2. Schematic of RWH system with outflow controls and controlled release drainage piping for stormwater management. ('DETENTION' is the volume of runoff to be slowly released to storm sewer. The remaining volume 'RETENTION' is used to supply rainwater to permitted fixtures

For further guidelines on sizing a rainwater storage tank for both detention and retention, refer to *Appendix D*.

6.4 Design & Installation Guidelines

Design and installation guidelines:

Note: refer to *Section 6.2 Applicable Codes, Standards, and Guidelines* for the specific provisions that apply when the term "in accordance with applicable provincial codes and regulations" is used.

1. Determine the overflow discharge location and method:
    a. Overflow discharge locations include: grade, storm sewer, or soakaway pit;
    b. Overflow discharge methods include: gravity flow or pump-assisted flow;
    c. Overflow by pump-assisted flow is not recommended;
    d. Consult the applicable provincial codes and regulations, municipal bylaws, and local authorities regarding the permitted overflow discharge locations;
    e. Evaluate the feasibility of the overflow discharge locations:
        i. Overflow to grade:
            1. The overflow discharge location must be at a lower elevation than the flood level rim of the tank for gravity flow to be feasible.
        ii. Overflow to storm sewer:
            1. A storm sewer connection must be present at the site,
            2. The overflow discharge location must be at a lower elevation than the flood level rim of the tank for gravity flow to be feasible.
        iii. Overflow to soakaway pit:
            1. The percolation rate of site soils must be sufficient to permit infiltration of rainwater overflows discharged into the soakaway pit (refer to *Appendix D* for guidelines on sizing soakaway pits).
2. Plan the layout of the overflow system:
    a. Plan route of overflow drainage piping from the tank to the overflow discharge location (refer to *Section 1.4 Design & Installation Guidelines* for guidelines and applicable provincial codes and regulations regarding drainage piping);
    b. Ensure that there are no buried service lines (gas, electricity, water, stormwater, wastewater, phone, or cable lines) in the area where digging will take place to accommodate buried overflow drainage piping by contacting the municipality and service providers.
3. Overflow pipes:
    a. Overflow drainage pipes:
        i. Pipe material:
            1. PVC SDR35 pipe (recommended), or ABS pipe, where
            2. Pipe selected must be approved by applicable provincial codes and industry standards (CSA, ASTM, etc.).
        ii. Pipe size and slope:
            1. Overflow drainage piping shall be sized to ensure that the capacity of overflow drainage pipe(s) are no less than the capacity of the rainwater conveyance drainage pipe(s),
            2. Ensure a minimum slope of 0.5-2% (the greater the slope the better) is maintained throughout the pipe length,

        iii. Tank connection:
            1. Overflow drainage piping shall exit the tank at a height no lower than that of the rainwater conveyance drainage piping, or ideally, at a height 50 mm [2 in.] below the bottom of the conveyance drainage pipe(s) entering the tank.
        iv. Consult the applicable provincial codes and regulations pertaining to the installation of drainage piping (refer to *Section 1.2 Applicable Codes, Standards, and Guidelines* for details).
    b. Overflow pressure pipes:
        i. Pipe material:
            1. Polyethylene pipe (recommended), where
            2. Pipe selected must be approved by applicable provincial codes and industry standards (CSA, ASTM, etc.).
        ii. Pipe size and slope:
            1. Overflow pressure piping shall be sized to ensure that the capacity of overflow pressure pipe(s) are no less than the capacity of the rainwater conveyance drainage pipe(s).
        iii. Consult the applicable provincial codes and regulations pertaining to the installation of pressure piping (refer to *Section 5.2 Applicable Codes, Standards, and Guidelines* for details).
4. Discharging overflows to grade:
    a. Overflows must be discharged in a location where rainwater won't pond or collect around building foundations;
    b. Erosion prevention measures should be taken;
    c. A screen should be installed where the pipe terminates to prevent the entry of birds, rodents or insects.
5. Discharging overflows to storm sewer:
    a. Overflow drainage piping cannot be directly connected to a storm sewer, unless approved by local authorities;
    b. A direct connection may be permitted if a backwater valve is installed on the overflow drainage pipe. Consult local authorities for approval;
    c. An indirect connection can be made by overflowing:
        i. To an interceptor tank, which then overflows to storm sewer,
        ii. To a soakaway pit, which then overflows to the storm sewer,
        iii. Via overland flow to a sewer grate, or
        iv. Using an air gap, in the case of above ground tanks.
6. Discharging overflows to a soakaway pit:
    a. Consult applicable provincial and municipal guidelines regarding the design and installation of soakaway pits;
    b. For guidance purposes only, soakaway pit design and installation guidelines are provided in *Appendix D*;
    c. If there is limited space for a soakaway pit or if the soil has a low permeability, it is recommended that the soakaway pit have its own overflow, discharging overflows to grade or storm sewer.

7. Overflow discharge pump:
    a. If rainwater overflows must be pumped, the pump shall be sized to handle the capacity of the rainwater conveyance drainage pipe(s);
    b. The pump shall be selected and installed in accordance with the guidelines provided in *Chapter 5. Pump and Pressurized Distribution System*.
8. Incorporating a RWH system as part of a stormwater management system:
    a. Consult the municipality and/or conservation authority regarding how to incorporate a RWH system into other stormwater management systems;
    b. If considering utilizing a rainwater storage tank for both retention and detention purposes, refer to *Appendix D* for further details.

6.5 Management Guidelines

1. If the overflow drainage piping discharges above grade, it should be inspected annually:
    a. The point at which the overflows discharge should be examined for signs of erosion. A splash pad or several small rocks can be placed at the discharge point to protect the area from future damage;
    b. The coarse screen at the end of the overflow drainage pipe should be inspected for dirt and debris, and if necessary, be cleaned and/or replaced;
    c. If removing the coarse screen for cleaning or replacement, the inside of the overflow drainage pipe should be inspected for objects or debris that may cause clogging.
2. If the overflow drainage piping discharges below grade, inspection and/or repair is only necessary when signs of a blocked or poor performing overflow-handling system are observed, such as:
    a. Signs of water damage to the rainwater tank, tank lid or access hatch, or components located inside the tank above the maximum water level,
    b. Signs of water leaking from the tank lid or access hatch,
    c. Signs of water backing up rainwater inlet lines and top-up drainage piping, or
    d. Signs of water leaking from downspout-to-conveyance drainage pipe transitions, or leaking from top-up system air-gap.
3. If any of the above signs are observed, the components of the overflow system should be inspected and repaired:
    a. Inspect coarse screens located on the overflow drainage pipe for debris that would impede water flow, and clean, repair or replace the coarse screen as necessary;
    b. Inspect all overflow drainage pipes using a pipe scope for signs of blockages or pipe damage. All debris/blockages should be removed from the overflow drainage piping, and all damaged sections of pipe must be replaced;
    c. If problems with the overflow system take place during periods of freezing temperatures, it may be necessary to winterize the overflow drainage piping using the methods provided in *Chapter 1. Rainwater Catchment & Conveyance*;
    d. If the overflow drainage piping discharges into a soakaway pit, the pit may be clogged with dirt and debris and may not be providing sufficient infiltration capacity. It may be necessary to repair and/or expand the pit to accommodate overflow volumes;
    e. If there are no obvious problems with the overflow system, it may be necessary to simulate an overflow event (or observe one during a rainfall event). Monitor the system visually or by pipe scope to determine what is causing the problem.
4. While inspecting, cleaning, or repairing components of the overflow system, follow all necessary safety precautions, including Ontario Regulation 632/05 Confined Spaces if entry into the rainwater storage tank is required (see *Chapter 2. Rainwater Storage & Tank Sizing* for details).

Appendix

Appendix A. Rainwater Catchment & Conveyance

Collection Losses from Roof Surfaces
Sizing Gutters and Downspouts
Sizing Rainwater Conveyance Drainage Piping
Frost Penetration Depth & Pipe Freeze Protection

Appendix B. Rainwater Storage & Tank Sizing

Rainwater Harvesting Design Tool
Rainwater Storage Tank Sizing Table

Appendix C. Pump and Pressurized Distribution System

Calculation of Required Pump Capacity
Calculation of Required Pressure from Pump (Pump Head)
Calculation of Friction Loss
Calculation of Pressure Tank Size
Calculation of Pipe Size

Appendix D. Overflow Provisions & Stormwater Management

Utilizing a Rainwater Storage Tank for Retention & Detention for Stormwater Management Purposes
Design & Sizing of Soakaway Pits

Appendix A. Rainwater Catchment & Conveyance

Collection Losses from Roof Surfaces

Although 1 L of runoff can theoretically be collected from each millimetre of rainfall contacting a 1 m^2 area, some losses take place following contact with the catchment surface. These losses vary depending upon the type of catchment material and the geometry of the roof and should be considered when estimating the amount of rainwater that can be collected by the RWH system. Losses for various roof catchment materials are listed in Table A-1.

Table A-1. Collection efficiency (loss factors) associated with various roof catchments[23, 24]

Roof Catchment Material	Initial Rainfall Loss Factor (mm)	Continuous Rainfall Loss Ratio (%)
Steel Roof	0.25	20.0
Asphalt Shingle Roof	0.5	20.0
Fiberglass Roof	0.5	20.0
Asphalt Built-up Flat Roof	1.5	20.0
Hypalon (Rubber) Flat Roof	1.5	20.0

Sizing Gutters and Downspouts

Note: the guidelines for sizing gutters and downspouts provided in Section 1.4 Design & Installation Guidelines are reproduced below to assist with following the example provided. The detailed example is located following the reproduced guidelines.

1. To determine the size of gutter required for a given roof drainage area:
   a. Consult the applicable provincial codes and regulations pertaining to the design rainfall intensity for the site location (refer to *Section 1.2 Applicable Codes, Standards, and Guidelines* for details);
   b. Calculate the area of roof draining into the gutter:

$$\boldsymbol{Roof\ Drainage\ Area}\ (\mathbf{m^2}) = Length\ (\mathrm{m}) \times Width\ (\mathrm{m})$$

Equation A-1

Where: Length = length of the gutter served by a downspout (m)
Width = distance from the eave to the ridge of the roof drainage area served (m)

[23] DIN 1989-1:2001-10. DIN 1989 Rainwater Harvesting Systems - Part 1: Planning, Installation, Operation and Maintenance. 2002. Fachvereinigung Betriebs- und Regenwassernutzung e.V, fbr, Darmstadt, Germany
[24] Building Capacity for Rainwater Harvesting in Ontario: Rainwater Quality and Performance of RWH Systems. 2008. Despins, C. M.Sc. Thesis, University of Guelph.

c. Refer to Table A-2 to determine the minimum size of gutter, required based upon the roof drainage area (m^2) and design rainfall intensity values determined above:

Table A-2. Minimum gutter sizes for given roof drainage areas and rainfall intensities[25]

Minimum Required Gutter Size and Type	Maximum Roof Drainage Area Served per Downspout (m^2)[1,2] Design Rainfall Intensity (15 Min rainfall, mm):							
	18.75	25	31.25	37.5	43.75	50	56.25	62.5
100 mm [4 in.] K-style	71	53	43	35	30	27	24	21
125 mm [5 in.] K-style	130	98	78	65	56	49	43	39
150 mm [6 in.] K-style	212	159	127	106	91	79	71	64

[1] Minimum required gutter size assumes that gutters have a minimum slope (≤ 6.25%). For greater gutter slopes, the table values may be multiplied by 1.1.
[2] Maximum roof drainage area assumed roof slopes ≤ 5:12. For steeper roof pitches, multiply the table values by 0.85.

d. For other gutter types and/or larger roof drainage areas, consult the gutter manufacturer or contractor regarding the sizing of gutter.

2. To determine the size of downspout required:
   a. Refer to Table A-5 to determine the minimum size of downspout (either rectangular- or square type) based upon the size of gutter the downspout is serving:

Table A-3. Minimum downspout sizes for given size of gutter[26]

Gutter Size and Type	Minimum Downspout Size (mm [in])	
	Rectangular type	Square-type
100 mm [4 in.] K-style	50x75 [2x3]	75x75 [3x3]
125 mm [5 in.] K-style	50x75 [2x3]	75x75 [3x3]
150 mm [6 in.] K-style	75 x 100 [3x4]	100x100 [4x4]

   b. For other downspout types and/or larger gutter sizes, consult the gutter/downspout manufacturer or contractor regarding the sizing of downspout.

[25] Adapted from Moisture Resistant Homes: A Best Practice Guide and Plan Review Tool for Builders and Designers. 2006. U.S. Department of Housing and Urban Development, Washington, DC.
[26] Adapted from Moisture Resistant Homes: A Best Practice Guide and Plan Review Tool for Builders and Designers. 2006. U.S. Department of Housing and Urban Development, Washington, DC.

3. Example:

For a residential house located in Toronto, ON with a roof with the peaks and roof pitch illustrated in Figure A-1 and Figure A-2:

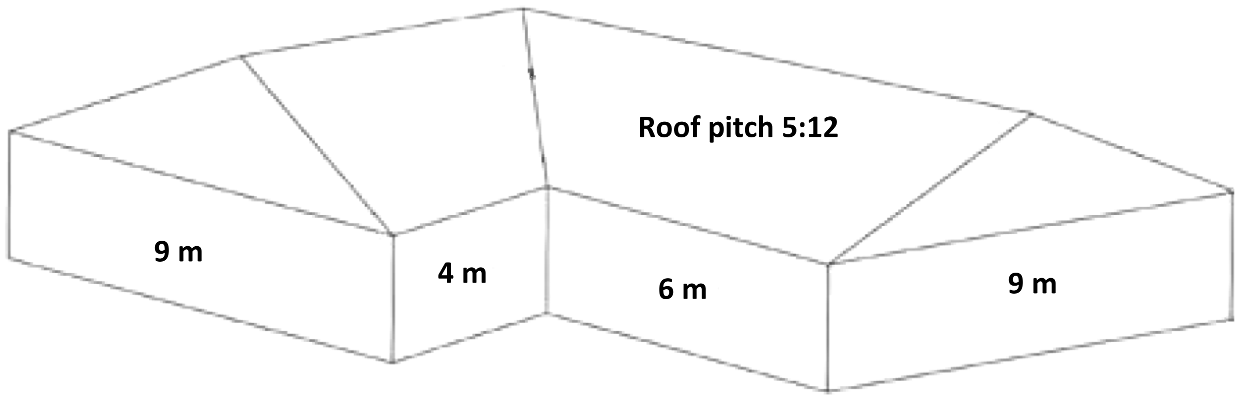


Figure A-1. Roof drainage area to be guttered (isometric 'facing' view)[27]

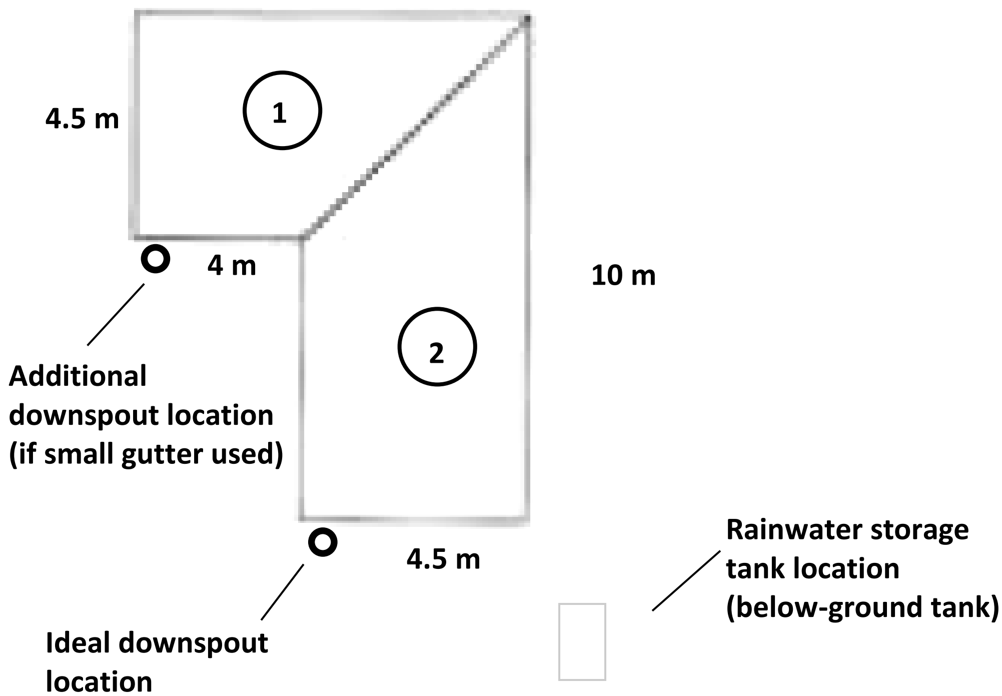


Figure A-2. Roof drainage area to be guttered (projected 'top-down' view)[28]

[27] Adapted from Moisture Resistant Homes: A Best Practice Guide and Plan Review Tool for Builders and Designers. 2006. U.S. Department of Housing and Urban Development, Washington, DC.
[28] Adapted from Moisture Resistant Homes: A Best Practice Guide and Plan Review Tool for Builders and Designers. 2006. U.S. Department of Housing and Urban Development, Washington, DC.

From the 2006 edition of Ontario's Building Code, Supplementary Standard SB-1, Table 1.2 (refer to *Section 1.2 Applicable Codes, Standards, and Guidelines* for details):

Design rainfall intensity (15 Min rainfall, mm): 25

To calculate the roof drainage area:

$$\boldsymbol{Roof\ Drainage\ Area} = Area\ 1 + Area\ 2$$

$$Area\ 1 = 4\ \mathrm{m} \times 4.5\ \mathrm{m}$$
$$Area\ 1 = 18\ \mathrm{m}^2$$

$$Area\ 2 = 4.5\ \mathrm{m} \times 10\ \mathrm{m}$$
$$Area\ 2 = 45\ \mathrm{m}^2$$

$$\boldsymbol{Roof\ Drainage\ Area} = Area\ 1 + Area\ 2$$
$$\boldsymbol{Roof\ Drainage\ Area} = 18\ \mathrm{m}^2 + 45\ \mathrm{m}^2$$
$$\boldsymbol{Roof\ Drainage\ Area} = \mathbf{63\ m^2}$$

Referring to Table A-2 (reproduced from Table 1-3), the maximum roof drainage area for this section of roof is given in the second column (25 mm rainfall intensity for the City of Toronto).

To discharge the entire roof drainage area to one downspout:

Referring to the second column of Table A-2, a 100 mm [4 in.] K-style gutter can only be used to convey rainwater from roof areas of up to 53 m^2. This area, however, is less than the drainage area calculated for this residential household – 63 m^2.

By selecting a larger gutter – a 125 mm [5 in.] K-style gutter – all of the drainage area can be discharged to one downspout as this gutter size can convey rainwater from an area of up to 78 m^2 (> 63 m^2).

Referring to Table A-3 (reproduced from Table 1-4), a 125 mm [5 in.] K-style gutter requires a 50x75 mm [2x3 in.] rectangular-type downspout, or a 75x75 mm [3x3 in.] square-type downspout.

To minimize the length of conveyance drainage piping required, the downspout should be located as close as possible to the rainwater storage tank. The ideal location of the downspout is illustrated in Figure A-2.

To discharge the roof drainage area to more than one downspout:

Referring to the second column of Table A-2, a 100 mm [4 in.] K-style gutter can be used – but additional downspouts are required because the roof drainage area considered is greater than the maximum roof drainage area served per downspout (by one downspout).

To calculate the number of downspouts required:

$$\boldsymbol{Number\ of\ Downspouts} = \frac{Roof\ Drainage\ Area}{Max.Roof\ Drainage\ Area\ Served\ Per\ Downspout}$$

$$\boldsymbol{Number\ of\ Downspouts} = \frac{63\ \mathrm{m}^2}{53\ \mathrm{m}^2}$$

$$\boldsymbol{Number\ of\ Downspouts} = \mathbf{1.2}\ (\textbf{round up to 2})$$

By selecting a smaller gutter – a 100 mm [4 in.] K-style gutter – the drainage area must be discharged to 1.2 downspouts (rounded up to 2 downspouts).

Referring to Table A-3 (reproduced from Table 1-4), a 100 mm [4 in.] K-style gutter requires a 50x75 mm [2x3 in.] rectangular-type downspout, or a 75x75 mm [3x3 in.] square-type downspout.

In addition to the one downspout located close to the rainwater storage tank (shown in Figure A-2 as the 'ideal downspout location'), a second downspout is required. Locating downspouts on interior building corners is not recommended, thus, it should be placed at the corner closest to the rainwater storage tank (see Figure A-2).

Sizing Rainwater Conveyance Drainage Piping

1. Table A-4 and Table A-5 can be used to estimate the size of conveyance drainage pipes for different catchment areas:

Table A-4. Conveyance drainage pipe size requirements for roof areas 50-950 m^2 in Ontario cities[29]

<table>
<tr><th rowspan="2">City</th><th colspan="20">Roof Area (m^2)</th></tr>
<tr><th>0</th><th>50</th><th>100</th><th>150</th><th>200</th><th>250</th><th>300</th><th>350</th><th>400</th><th>450</th><th>500</th><th>550</th><th>600</th><th>650</th><th>700</th><th>750</th><th>800</th><th>850</th><th>900</th><th>950</th></tr>
<tr><td>Windsor</td><td colspan="4">4</td><td colspan="5">6</td><td colspan="11">8</td></tr>
<tr><td>London</td><td colspan="4">4</td><td colspan="5">6</td><td colspan="11">8</td></tr>
<tr><td>Hamilton</td><td colspan="4">4</td><td colspan="7">6</td><td colspan="9">8</td></tr>
<tr><td>St. Catharines</td><td colspan="4">4</td><td colspan="7">6</td><td colspan="9">8</td></tr>
<tr><td>Kitchener</td><td colspan="4">4</td><td colspan="5">6</td><td colspan="11">8</td></tr>
<tr><td>Mississauga</td><td colspan="4">4</td><td colspan="6">6</td><td colspan="10">8</td></tr>
<tr><td>Toronto</td><td colspan="4">4</td><td colspan="6">6</td><td colspan="10">8</td></tr>
<tr><td>Barrie</td><td colspan="4">4</td><td colspan="5">6</td><td colspan="11">8</td></tr>
<tr><td>Peterborough</td><td colspan="4">4</td><td colspan="5">6</td><td colspan="11">8</td></tr>
<tr><td>Ottawa</td><td colspan="4">4</td><td colspan="7">6</td><td colspan="9">8</td></tr>
<tr><td>Sudbury</td><td colspan="4">4</td><td colspan="6">6</td><td colspan="10">8</td></tr>
<tr><td>Sault Ste. Marie</td><td colspan="4">4</td><td colspan="6">6</td><td colspan="10">8</td></tr>
<tr><td>Thunder Bay</td><td colspan="5">4</td><td colspan="8">6</td><td colspan="7">8</td></tr>
</table>

Legend

4" Pipe
6" Pipe
8" Pipe
10" Pipe
12" Pipe
15" Pipe

[29] Adapted from Ontario's Building Code. 2006. Ministry for Municipal Affairs and Housing, Toronto, ON. Assumes 1% slope.

Table A-5. Conveyance drainage pipe size requirements for roof areas 1000-3000 m^2 in Ontario cities[30]

<table>
<tr><th rowspan="2">City</th><th colspan="20">Roof Area (m^2)</th></tr>
<tr><th>1000</th><th>1100</th><th>1200</th><th>1300</th><th>1400</th><th>1500</th><th>1600</th><th>1700</th><th>1800</th><th>1900</th><th>2000</th><th>2100</th><th>2200</th><th>2300</th><th>2400</th><th>2500</th><th>2600</th><th>2700</th><th>2800</th><th>2900</th></tr>
<tr><td>Windsor</td><td colspan="8">10</td><td colspan="11">12</td><td>15</td></tr>
<tr><td>London</td><td colspan="8">10</td><td colspan="11">12</td><td>15</td></tr>
<tr><td>Hamilton</td><td colspan="2">8</td><td colspan="10">10</td><td colspan="8">12</td></tr>
<tr><td>St. Catharines</td><td colspan="2">8</td><td colspan="10">10</td><td colspan="8">12</td></tr>
<tr><td>Kitchener</td><td colspan="8">10</td><td colspan="11">12</td><td>15</td></tr>
<tr><td>Mississauga</td><td colspan="2">8</td><td colspan="8">10</td><td colspan="10">12</td></tr>
<tr><td>Toronto</td><td colspan="2">8</td><td colspan="8">10</td><td colspan="10">12</td></tr>
<tr><td>Barrie</td><td colspan="8">10</td><td colspan="11">12</td><td>15</td></tr>
<tr><td>Peterborough</td><td colspan="8">10</td><td colspan="11">12</td><td>15</td></tr>
<tr><td>Ottawa</td><td colspan="2">8</td><td colspan="10">10</td><td colspan="8">12</td></tr>
<tr><td>Sudbury</td><td colspan="2">8</td><td colspan="8">10</td><td colspan="10">12</td></tr>
<tr><td>Sault Ste. Marie</td><td colspan="2">8</td><td colspan="8">10</td><td colspan="10">12</td></tr>
<tr><td>Thunder Bay</td><td colspan="4">8</td><td colspan="11">10</td><td colspan="5">12</td></tr>
</table>

Legend

4" Pipe
6" Pipe
8" Pipe
10" Pipe
12" Pipe
15" Pipe

[30] Adapted from Ontario's Building Code. 2006. Ministry for Municipal Affairs and Housing, Toronto, ON. Assumes 1% slope.

Frost Penetration Depth & Pipe Freeze Protection

1. Local frost penetration depths for can be estimated using the following method:
    a. Locate the site on the map in Figure A-3 and identify the nearest contour line and its associated freezing index value (given in degree days);
    b. Estimate the frost penetration depth by correlating the degree-day value from Figure A-3 to the corresponding depth in Table A-6:

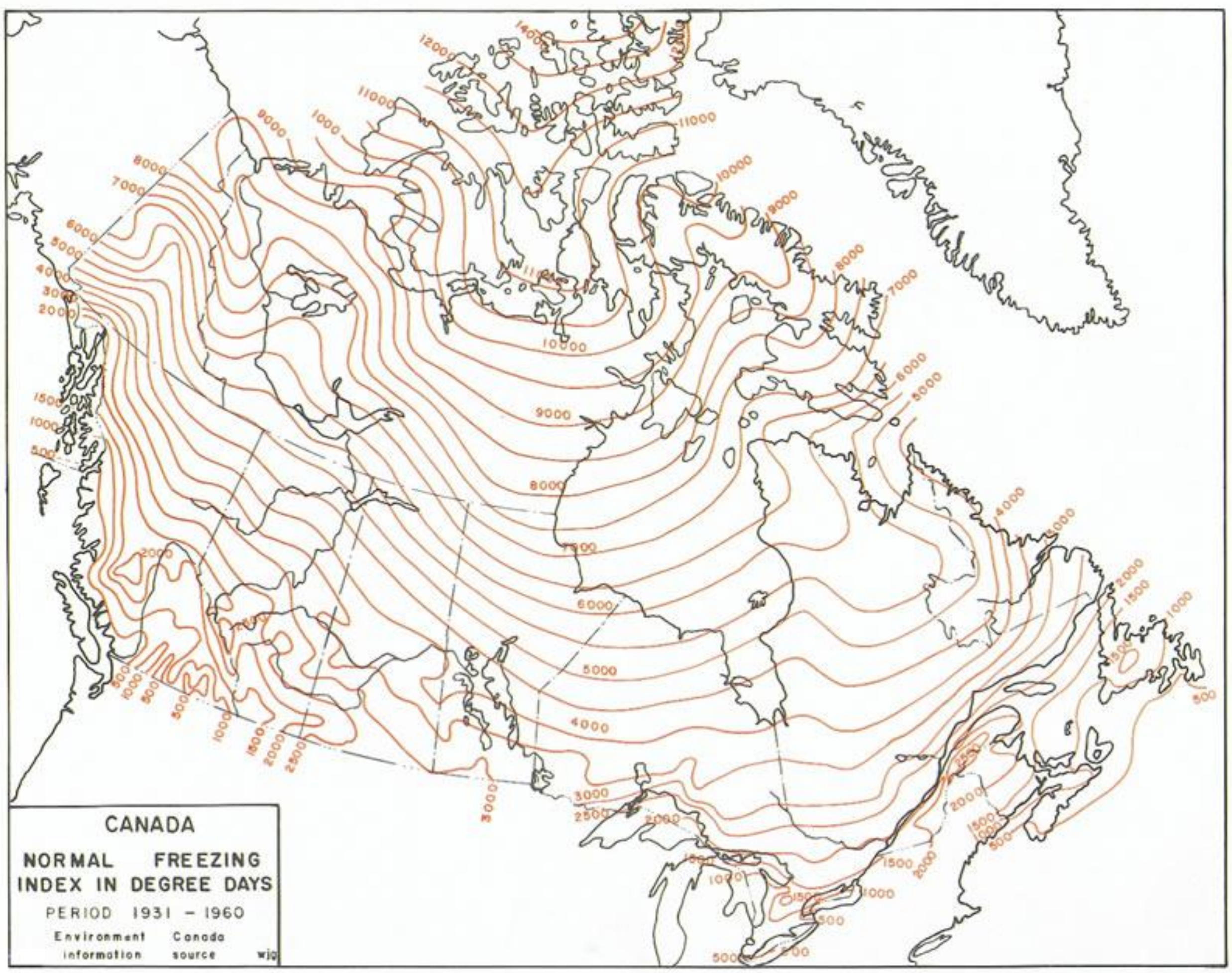


Figure A-3. Normal freezing index for Canada in degree days[31]

[31] Adapted from Canada Normal Freezing Index in Degree Days, Period 1931-1960. Environment Canada, Ottawa, ON.

Table A-6. Approximate frost depths associated with various freezing index values[32]

Freezing Index (Degree Days)	Frost Depth (m)	Freezing Index (Degree Days)	Frost Depth (m)
400	0.66	**2000**	1.98
450	0.71	**2050**	2.01
500	0.76	**2100**	2.04
550	0.81	**2150**	2.07
600	0.86	**2200**	2.1
650	0.91	**2250**	2.13
700	0.96	**2300**	2.16
750	1	**2350**	2.19
800	1.05	**2400**	2.22
850	1.09	**2450**	2.25
900	1.14	**2500**	2.28
950	1.18	**2550**	2.31
1000	1.21	**2600**	2.34
1050	1.25	**2650**	2.36
1100	1.29	**2700**	2.39
1150	1.32	**2750**	2.42
1200	1.36	**2800**	2.45
1250	1.39	**2850**	2.48
1300	1.43	**2900**	2.51
1350	1.47	**2950**	2.52
1400	1.5	**3000**	2.54
1450	1.54	**3050**	2.56
1500	1.57	**3100**	2.59
1550	1.62	**3150**	2.62
1600	1.66	**3200**	2.64
1650	1.7	**3250**	2.67
1700	1.74	**3300**	2.69
1750	1.78	**3350**	2.72
1800	1.82	**3400**	2.74
1850	1.86	**3450**	2.77
1900	1.9	**3500**	2.79
1950	1.94	**4000**	2.8

[32] Adapted from Ambient Temperatures – Below Ground (Frost Depth). 2009. Urecon Ltd., St. Lazare-de-Vaudreuil, Quebec.

2. To plan the layout of conveyance drainage piping for rainwater storage tanks located below grade:
    a. Determine the location of the tank (refer to *Chapter 2. Rainwater Storage & Tank Sizing* for guidance);
    b. Determine the frost penetration depth by consulting local building authorities regarding regulations or 'rules of thumb' for frost penetration depths. For estimation purposes, refer to the above methods in *Appendix A*;
    c. Where possible, rainwater conveyance drainage pipes and the storage tank should be buried below the frost penetration depth, otherwise additional freeze protection measures, such as insulation shall be required;
    d. To determine if the conveyance drainage pipes can be buried below the frost penetration depth:
        i. Determine the final pipe burial depth (D_f), where this depth depends upon:
            1. The local frost penetration depth, and
            2. The maximum rated burial depth of the rainwater storage tank,
            3. Where D_f shall be the lesser of the two values (i.e., if the tank cannot be buried below the frost penetration depth due to tank burial depth restrictions, then D_f shall be equal to the tank's max. rated burial depth).
        ii. Determine the initial pipe burial depth (D_i), where this depth depends upon:
            1. The total length of pipe,
            2. The slope of pipe, and
            3. The site grading,
            4. Where Di can be determined using Figure A-4 and Equation A-2:

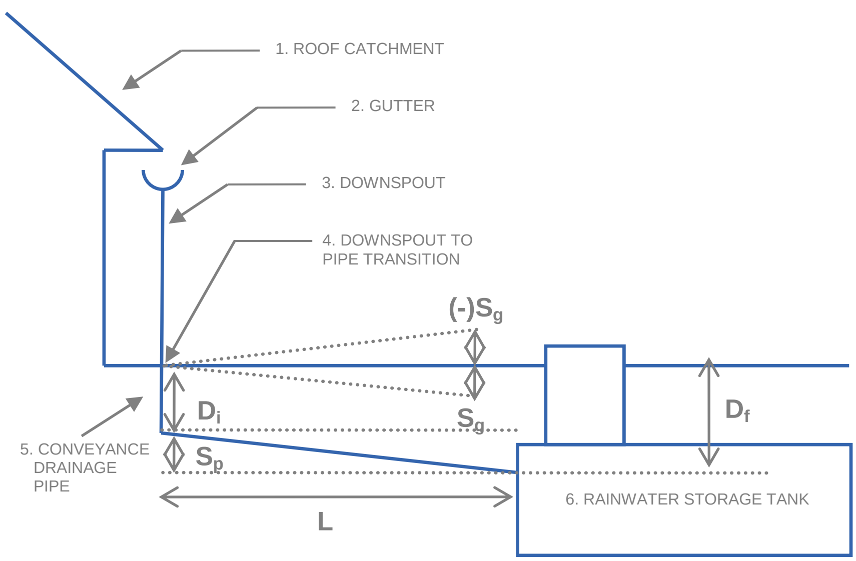


Figure A-4. Pipe conveyance (profile view)

$$\boldsymbol{D_i} = D_f - L_p S_p + L_g S_g$$

Equation A-2

Where:

D_i = Initial pipe burial depth (m)
D_f = Final pipe burial depth (m)
L_p = Length of pipe (m)
L_g = Length of pipe for which there is a grade change (m)
S_p = Pipe slope factor (0.01 recommended)
S_g = Grade slope factor, assumes downward slope

iii. If D_f and/or D_i is less than the frost penetration depth, then there is a risk of rainwater freezing in the conveyance network. In such cases, repeat the above process, while considering the following:
   1. Locate the tank in an area with the lowest elevation at the site,
   2. Minimize the distance between the furthest downspout and the tank (decrease the horizontal travel distance, H),
   3. Increase the burial depth of the tank (ensure that the tank is rated to handle increased burial depth), and/or
   4. Reduce the pipe slope to a minimum of 0.5-1%.

iv. If the conveyance drainage pipe cannot be maintained at or near frost penetration depth, consider insulating pipe (refer to the method below), or alternatively, install heat tracing for use during periods of extreme cold.

3. If burial below the frost penetration depth is not feasible, the pipe should be insulated:
   a. Figure A-5 and Equation A-3 can be used to estimate the width of insulation required:

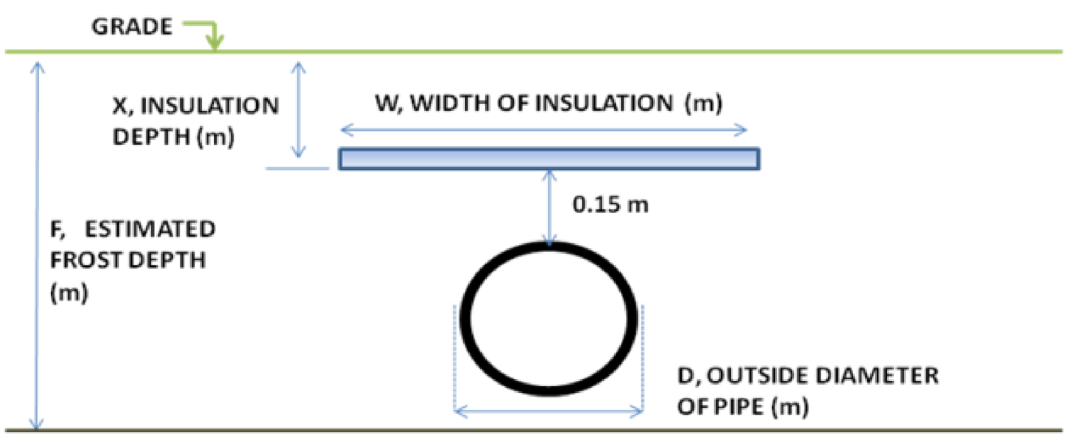


Figure A-5. Frost protection of pipe by horizontal insulation[33]

[33] Adapted from Ontario's Building Code. 2006. Ministry of Municipal Affairs and Housing, Toronto, ON.

$$\boldsymbol{W} = D + [2 \times (F - X)] - 0.3$$

Equation A-3[34]

Where:

W = width of insulation (m)
D = outside diameter of pipe (m)
X = insulation depth (m)
F = estimated frost depth (m)

b. The thickness of the insulation can be estimated using Table A-7:

Table A-7. Thickness of foam insulation given various pipe burial (backfill) depths[35]

Thickness of Foam Insulation (mm)								
		Frost Depth						
Amount of Backfill over the Insulation		1.1 m	1.3 m	1.5 m	1.7 m	1.9 m	2.1 m	2.3 m
	≤ 0.6 m	50	65	75	90	100	115	125
	≤ 0.9 m	40	50	65	75	90	100	115
	≤ 1.2 m	25	40	50	65	75	90	100
	≤ 1.5 m		25	40	50	65	75	90
	≤ 1.8 m				40	50	65	75
	≤ 2.1 m					40	50	65

[34] Adapted from Ontario's Building Code. 2006. Ministry of Municipal Affairs and Housing, Toronto, ON.
[35] Adapted from Ontario's Building Code. 2006. Ministry of Municipal Affairs and Housing, Toronto, ON, and Canada Normal Freezing Index in Degree Days, Period 1931-1960. Environment Canada, Ottawa, ON.

Appendix B. Rainwater Storage & Tank Sizing

Note: Some of the fixtures listed in this Appendix may not be permitted by the applicable provincial codes and regulations. Data and examples referencing such fixtures are provided for illustration purposes only.

Rainwater Harvesting Design Tool

1. Rainwater storage tanks can be sized using the Rainwater Harvesting System Design Tool, which can be accessed on-line;
2. Instructions on the use of the Rainwater Harvesting System Design Tool are provided with the Design Tool software package. Refer to these instructions for further details.

Rainwater Storage Tank Sizing Table

1. Rainwater storage tanks can be sized using Table B-3, which was developed using the Rainwater Harvesting System Design Tool. *Note:* Table B-3 *summarizes results from the tool for the City of Toronto, but these tank sizes should be applicable for much of southern Ontario. In regions where there is less annual rainfall than Toronto, tanks with larger storage capacities than those listed in* Table B-3 *are recommended.*
2. Household indoor rainwater demand can be estimated using Table B-1 and the following instructions:
    a. For each fixture to be supplied with rainwater, determine the fixture type and associated water usage by examining the fixture and/or referring to the manufacturer's product literature;
    b. Once the fixture type and water usage have been determined, calculate the daily rainwater usage for the fixture by multiplying the water usage (provided by the manufacturer, or using the average figures provided in Table B-1) by the number of uses per person per day (provided in Table B-1). Multiply the resulting figure by the number of occupants residing within the household;
    c. Sum these values to determine the total indoor rainwater demand (Litres per day);
    d. Sum the total indoor rainwater demand with the total outdoor rainwater demand, where applicable (refer to Table B-2 and the accompanying instructions for assistance on calculating outdoor rainwater usage);

Table B-1. Household indoor fixtures and associated water usage figures/assumptions[36]

Fixtures	Fixture Type	Water Usage	Number of Uses Per Person Per Day	Water Usage Duration
Toilet	Low flush	13.0 Litres/flush	5	-
Toilet	Ultra-low flush	6.0 Litres/flush	5	-
Toilet	Dual flush/HET	4.8 Litres/flush	5	-
Laundry	Top loading	150 Litres/load	0.37	-
Laundry	Front loading	100 Litres/load	0.37	-
Lavatory	Inefficient/old	8.0 Litres/minute	3	0.5 minutes
Lavatory	Standard	5.3 Litres/minute	3	0.5 minutes
Lavatory	High-efficiency	3.2 Litres/minute	3	0.5 minutes
Shower	Inefficient/old	9.5 Litres/minute	0.3	5 minutes
Shower	Standard	8.3 Litres/minute	0.3	5 minutes
Shower	High-efficiency	5.7 Litres/minute	0.3	5 minutes

e. Example:

For a household of five, using rainwater for toilet flushing and laundry:

- The toilets in the home are the ultra-low flush 6.0 Litre per flush type.
- The washing machine is a typical top-loading machine using 150 Litres per load.

Daily rainwater demand (Toilets) = 6.0 Litres/flush × 5 flushes per person per day × 5 persons
Daily rainwater demand (Toilets) = 150 Litres/day

Daily Indoor Rainwater Demand (Total) = 150 Litres/day

3. Household outdoor rainwater demand can be estimated using Table B-2and the following instructions:
    a. For each fixture to be supplied with rainwater, determine the fixture type and associated water usage by examining the fixture and/or referring to the manufacturer's product literature;
    b. Once the fixture type and water usage have been determined, calculate the weekly rainwater usage:
        i. For the garden hose by multiplying the water usage (provided by the manufacturer, or using the average figures provided in Table B-2) by the number of uses per week and multiplying the resulting figure by the water usage duration (provided in Table B-2),
        ii. For the irrigation system by multiplying the water usage (provided by the manufacturer, or using the average figures provided in Table B-2) by the

[36] Adapted from: Vickers, A. 2001. Handbook of Water Use and Conservation. Water Plow Press. Amherst, MA.

irrigated area (in m^2), and multiplying the resulting figure by the number of times the irrigation system is used per week (provided in Table B-2).

c. Convert this weekly rainwater usage to a daily usage by dividing the above figure by 7;
d. Repeat this process for each of the fixtures to be supplied with rainwater, and sum these values to determine the total outdoor rainwater demand (Litres per day);
e. Sum the total outdoor rainwater demand with the total indoor rainwater demand, where applicable (refer to Table B-1 and the accompanying instructions for assistance on calculating indoor rainwater usage);

Table B-2. Household Outdoor Fixtures and Associated Water Usage Figures/Assumptions[37]

Fixtures	Fixture Type	Water Usage	Number of Uses per Week	Water Usage Duration
Garden Hose	Hose with 13 mm [1/2 in.] supply	11 Litres/minute	3	30 minutes
Garden Hose	Hose with 18 mm [3/4 in.] supply	19 Litres/minute	3	30 minutes
Irrigation System	Providing equivalent of25 mm [1 in.] rainfall per use	25 Litres/m^2	3	-
Irrigation System	Providing equivalent of 13 mm [1/2 in.] rainfall per use	12.5 Litres/m^2	3	-
Irrigation System	Providing equivalent of 6 mm [1/4 in.]" rainfall per use	6 Litres/m^2	3	-

f. Example:

For a household using rainwater for both a garden hose and an irrigation system:

- The garden hose has a ½" supply, and is used three times each week, for approx. 30 minutes each time
- The irrigation system provides the equivalent of ¼" rainfall per use, and has an irrigated area of 50 m^2.

Weekly rainwater demand (Garden hose) = 11 Litres/minute × 30 minutes × 3 uses per week
Weekly rainwater demand (Garden hose) = 990 Litres/week

Daily rainwater demand (Garden hose) = 1017 Litres/week ÷ 7 days/week
Daily rainwater demand (Garden hose) = 141 Litres/day

[37] Residential Water Systems: Goulds Pumps Technical Data, Water Products. 2007. ITT Corporation, White Plains, NY.

Weekly rainwater demand (Irrigation System) = 6 Litres/m^2 × 50 m^2 irrigated area × 3 uses per week
Weekly rainwater demand (Irrigation System) = 900 Litres/week

Daily rainwater demand (Irrigation System) = 900 Litres/week ÷ 7 days/week
Daily rainwater demand (Irrigation System) = 129 Litres/day

Daily Outdoor Rainwater Demand (Total) = 141 Litres/day + 129 Litres/day
Daily Outdoor Rainwater Demand (Total) = 270 Litres/day

4. Calculate the daily rainwater demand (Litres per day) by summing the household indoor rainwater demand and the outdoor rainwater demand;
    a. Example:

       Summing indoor & outdoor demand:

       Daily Rainwater Demand (Total) = 150 Litres/day + 270 Litres/day
       Daily Rainwater Demand (Total) = 420 Litres/day

5. Refer to Table B-3 to find the recommended tank size using the daily rainwater demand (Litres per day) and the roof catchment area (m^2);
6. Note: How were Table B-3 recommended storage volumes determined?
    a. For each unique combination of daily rainwater demand and roof catchment area (i.e., for a RWH system with a daily rainwater demand of 50 Litres/day and a roof catchment area of 100 m^2) rainwater storage tanks of increasing storage capacities were modelled using the Rainwater Harvesting Design Tool;
    b. While comparing the multiple tanks, if a tank with a larger storage capacity provided a significant increase in the water savings provided by the RWH system, when compared against a smaller tank, the Design Tool recommended the larger tank.
    c. This process was repeated with increasing storage tank volumes until the water savings increase provided by the larger tank was considered to be insignificant;
    d. The criteria that was used to distinguish between a significant and insignificant was as follows:
        i. If larger tank provides ≥ 2.5% increase in water savings per 1,000 Litres, select larger tank and continue process to examine the water savings of subsequent larger tanks;
        ii. If larger tank provides < 2.5% increase in water savings per 1,000 Litres, do not consider the tank, and recommend the largest storage tank that met the ≥ 2.5% criteria.

Table B-3. Recommended storage tank capacities for catchment areas and rainwater demands for RWH systems located in Toronto, Ontario

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 assuming:

1. Historical rainfall for the City of Toronto, from 1961-2005 (median annual rainfall: 678 mm);
2. Optimum rainwater storage tank capacity values include an assumption of a 20% unused volume (typically referred to as 'dead space') .

Appendix C. Pump and Pressurized Distribution System

Note: Some of the fixtures listed in this Appendix may not be permitted by the applicable provincial codes and regulations. Data and examples referencing such fixtures are provided for illustration purposes only.

Calculation of Required Pump Capacity

1. For estimation purposes only, the maximum peak demand (minimum recommended pump flow rate) can be calculated using Table C-1, Table C-2, and methods below. *Note that this method is an industry standard method – be sure to consult local building authorities to ensure that the below flow rates are permitted for the fixtures served by the rainwater harvesting system.*

Table C-1. Minimum recommended water flow rate for various indoor fixtures[38]

Indoor Fixtures	Minimum Flow Rate (Per Fixture)
Shower or Bathtub	19 LPM [5 GPM]
Lavatory	1 LPM [0.3 GPM]
Toilet	2.7 LPM [0.7 GPM]
Kitchen Sink	1.6 LPM [0.4 GPM]
Washing Machine	19 LPM [5 GPM]
Dishwasher	7.6 LPM [2 GPM]

[38] Adapted from Residential Water Systems: Goulds Pumps Technical Data, Water Products. 2007. ITT Corporation, White Plains, NY. (flow rates from Jet and Submersible Pump Selection for Private Residences table, total usage column values ÷ 7)

Table C-2. Minimum recommended water flow rate for various outdoor fixtures[39]

Outdoor Fixtures	Minimum Flow Rate (Per Fixture)
Garden hose with 13 mm [1/2 in.] supply	11 LPM [3 GPM]
Garden hose with 18 mm [3/4 in.] supply	19 LPM [6 GPM]
Irrigation system	Varies (Consult supplier/ contractor)

2. Example:

Using Table C-1, if a given pump and pressure system must provide rainwater to three toilets, a washing machine and hose bib the maximum peak demand can be determined as follows:

Table C-3. Example calculation – sizing maximum peak demand

Indoor Fixtures	Number of Fixtures	Minimum Flow Rate (Per Fixture)	Total Flow Rate
Toilet	3	2.7 LPM	8.1 LPM
Washing machine	1	19 LPM	19 LPM
Hose watering (1/2 in. supply)	1	11 LPM	11 LPM
Maximum peak demand			**38 LPM**

As shown in Table C-3, the total water usage is determined by multiplying the number of fixtures by the minimum flow rate for each fixture, and is summed for all types of fixtures to estimate the maximum peak demand.

For the above application, a pump providing a minimum flow rate of 38 LPM [10 GPM] pump is recommended.

[39] Adapted from Residential Water Systems: Goulds Pumps Technical Data, Water Products. 2007. ITT Corporation, White Plains, NY. (flow rates from Yard Fixtures table)

Calculation of Required Pressure from Pump (Pump Head)

1. The pump head can be calculated using the following equations:
    a. Pump Head (m, or ft) = Required System Pressure + Total Dynamic Head

       Where:

       Required System Pressure is the operating pressure required for the rainwater fixtures (275-415 kPa [~40-60 psi] for typical residential applications). Pressure can be converted from kPa or psi to m or ft using Table C-4:

Table C-4. Conversion factors for 'kPa' and 'psi'

	Pressure (kPa)	Pressure (psi)
Conversion to Metres (m)	Height (m) = ____ kPa x 0.10	Height (m) = ____ psi x 0.70
Conversion to Feet (ft)	Height (ft) = ____ kPa x 0.33	Height (ft) = ____ psi x 2.31

    b. Total Dynamic Head (m, or ft) = Static Lift + Static Height + Friction Loss

       Where:

       Static Lift is the height from the water level to the pump (applicable only for jet pumps),
       Static Height is the height from the pump to the furthest fixture, and
       Friction Loss can be calculated using the method provided below.

Calculation of Friction Loss

1. To calculate the Friction Loss component of the Total Dynamic Head:
   a. Calculate the friction head losses that occur due to the flow rate and pipe sizes using Table C-5 (table values assume a SCH40 PVC pipe or similar material such as PE-polyethylene or PP-polypropylene is utilized):

Table C-5. Friction head losses for SCH40 PCV pipe at various flow rates[40]

Flow Rate, Q (LPM)	F_{100}, Friction Head (m / 100 m pipe) Pipe Diameter					
	13 mm [½ in.]	18 mm [¾ in.]	25 mm [1 in.]	32 mm [1 ¼ in.]	38 mm [1 ½ in.]	50 mm [2 in.]
8	4.8	1.2	0.38	0.1		
19	25.8	6.3	1.9	0.5	0.2	
30	63.7	15.2	4.6	1.2	0.6	0.2
38	97.5	26	6.9	1.8	0.8	0.3
57		49.7	14.6	3.8	1.7	0.5
76		86.9	25.1	6.4	2.9	0.9
113				13.6	6.3	1.8

   b. Example:

Using Table C-5, for a pump generating a flow rate of 38 LPM [10 GPM], with a rainwater service pipe diameter of 32 mm [1 ¼ in.] and a rainwater supply pipe diameter of 18 mm [¾ in.]:

$F_{100\text{-SE}}$, Friction head (m /100 m pipe) = 1.8 m/ 100 m pipe-service pipe

$F_{100\text{-SU}}$, Friction head (m /100 m pipe) = 26 m / 100 m of pipe-supply pipe

[40] Adapted from Residential Water Systems: Goulds Pumps Technical Data, Water Products. 2007. ITT Corporation, White Plains, NY.

c. Calculate the friction head losses that occur due to the type of pipe fitting and pipe size using Table C-6 (table values assume a SCH40 PVC pipe or similar material such as PE-polyethylene or PP-polypropylene is utilized).

Table C-6. Equivalent length of pipe for different fittings[41]

Fitting	Equivalent Length of Pipe (m) Pipe Diameter 13 mm [½ in.]	18 mm [¾ in.]	25 mm [1 in.]	32 mm [1 ¼ in.]	38 mm [1 ½ in.]	50 mm [2 in.]	75 mm [3 in.]
90° Elbow	0.5	0.6	0.8	1.1	1.3	1.7	2.4
45° Elbow	0.2	0.3	0.4	0.5	0.6	0.8	1.2
Gate Valve (shut-off valve) (Open)	0.1	0.2	0.2	0.2	0.3	0.4	0.5
Tee Flow – Run	0.3	0.6	0.6	0.9	0.9	1.2	1.8
Tee Flow - Branch	1.0	1.4	1.7	2.3	2.7	3.7	5.2
In Line Check Valve (Spring) or Foot Valve	1.2	1.8	2.4	3.7	4.3	5.8	9.8
90° Elbow	0.5	0.6	0.8	1.1	1.3	1.7	2.4

d. Example:

Using Table C-6, for a pressure system with three 32 mm [1 ¼ in.] 90° elbows on the rainwater service piping, and five 18 mm [¾ in.] 90° elbows on the rainwater supply piping:

$L_{F\text{-}SE}$, Equivalent Length of Pipe (m) = 3 x 1.1
$L_{F\text{-}SE}$, Equivalent Length of Pipe (m) = 3.3 m-service pipe

$L_{F\text{-}SU}$, Equivalent Length of Pipe (m) = 5 x 0.6
$L_{F\text{-}SU}$, Equivalent Length of Pipe (m) = 3.0 m-supply pipe

e. To calculate the total friction head losses, Equation C-1 should be used:

$$\boldsymbol{Friction\ Loss} = \left[(L_{P-SE} + L_{F-SE}) \times \frac{F_{100-SE}}{100m\ pipe}\right] + \left[(L_{P-SU} + L_{F-SU}) \times \frac{F_{100-SU}}{100m\ pipe}\right]$$

Equation C-1

[41] Adapted from Residential Water Systems: Goulds Pumps Technical Data, Water Products. 2007. ITT Corporation, White Plains, NY.

Where:

Friction Loss = Combined friction losses (m) for the service piping (SE) and supply piping (SU)
L_P = Linear length of pipe (m)
L_F = Equivalent length of the pipe fittings (m)
F_{100} = Friction loss per 100 m of pipe

f. Example:

Using the above equation, the losses for a pump and pressure system using the above pipe diameters and number of fittings, where the length of the rainwater service piping was 15 m and the rainwater supply piping was 10 m:

$$\boldsymbol{Friction\ Loss} = \left[(15\ m + 3.3\ m)\ \times \frac{1.8\ m}{100m\ pipe}\right] + \left[(10\ m + 3\ m)\ \times \frac{26\ m}{100m\ pipe}\right]$$

$$\boldsymbol{Friction\ Loss} = [0.33\ \text{m}]\ +\ [3.38\ \text{m}]$$
$$\boldsymbol{Friction\ Loss} = 3.7\ \text{m}\ [12.2\ \text{ft.}]$$

For the pump and pressure system described above, the friction loss is equivalent to 3.7 m of pipe, which can be used to calculate the Total Dynamic Head.

Calculation of Pressure Tank Size

1. To size a pressure tank that is compatible with a constant speed pump:
   a. Use the following equation to calculate the required capacity for the pressure tank:

$$\boldsymbol{Tank\ Size\ (L)} = 3.78\ \times \left(\frac{Pump\ flow\ rate\ (GPM) \times Pump\ run\ time\ (min)}{Drawdown\ factor}\right)$$

Equation C-2

Where:

Pump flow rate (capacity) was determined above,
Pump run time is provided by the pump manufacturer/supplier (typically, 1-2 minutes), and
The drawdown factor can be determined using Table C-7:

Table C-7. Drawdown factors for various cut-in/cut-out pressures[42]

System Pressure (Cut-in/Cut-out Pressure)	Drawdown Factor
138/276 kPa [20/40 psi]	0.37
276/414 kPa [40/60 psi]	0.27
414/552 kPa [60/80 psi]	0.21
552/689 kPa [80/100 psi]	0.17

Calculation of Pipe Size

1. To determine the required pipe size diameter for the rainwater service piping and supply piping, the following steps can be used for estimation purposes:
   a. For the service piping:
      i. The diameter of the rainwater service pipe can be sized using the equation below (the equation assumes PVC or similar material such as PE-polyethylene or PP-polypropylene is utilized):

$$\boldsymbol{Pipe\ Diameter}\ (\mathbf{mm}) = 25.4 \times \left(\frac{0.098 \times \frac{Q}{3.78}^{1.85}}{F_{100-SE}} \right)^{\frac{1}{4.87}}$$

Equation C-3[43]

Where:

Q = the pump flow rate (LPM)
F_{100} = the friction loss per 100 m of pipe (see following steps for details)

      ii. Before this equation can be solved, however, the maximum permitted head loss (F100-SE) must be set. A general rule of thumb is that this loss not exceed 5 m / 100 m pipe [5 ft / 100 ft pipe][44] , however the pump manufacturer/supplier should be contacted to confirm that these head losses will not impair pump performance or cause a loss of prime,

[42] Adapted from Residential Water Systems: Goulds Pumps Technical Data, Water Products. 2007. ITT Corporation, White Plains, NY.
[43] Adapted from Hazen-Williams Equation - Calculating Friction Head Loss in Water Pipes. 2005. The Engineering ToolBox.
[44] Planning for an Individual Water System. Fourth Edition Revised. 1982. Turner, H.J., Athens, GA.

iii. Example:

Assuming that $F_{100\text{-}SE}$ = 5 m / 100 m of pipe, the pipe diameter can be calculated as follows for a 38 LPM [10 GPM] pump:

$$\textit{Pipe Diameter}\ (\mathbf{mm}) = 25.4 \times \left(\frac{0.098 \times \left(\frac{38}{3.78}\right)^{1.85}}{5}\right)^{\frac{1}{4.87}}$$

$$\textit{Pipe Diameter}\ (\mathbf{mm}) = 27.2$$

$$\textit{Pipe Diameter}\ (\mathbf{mm}) \cong 32\ \text{mm}\ \left[1\ {}^{1}/_{4}\ in.\right]$$

b. For the supply piping:

i. Rainwater supply pipe must be sized in accordance with applicable provincial codes and regulations. The following information is provided for estimation purposes only,

ii. To size the rainwater supply pipe, refer to Table C-8 and instructions below:

Table C-8. Supply pipe sizing for various fixtures[45]

Fixture	Minimum Size of Supply Pipe	Hydraulic Load (fixture units)
Toilet	10 mm [⅜ in.]	3
Urinal	13 mm [½ in.]	3
Hose bib	13 mm [½ in.]	2
Washing machine	13 mm [½ in.]	2
Lavatory	10 mm [⅜ in.]	1
Bathtub (with or without shower)	13 mm [½ in.]	2

iii. In Table C-8, the minimum diameter of pipe that can be used to supply an individual residential plumbing fixture is listed in the second column (i.e., for toilets, the minimum size of supply pipe permitted is 10 mm [⅜ in.]),

iv. The values in the third column, hydraulic load (fixture units), are used to determine the pipe diameter of the piping immediately following the pressure tank/control unit. This represents the diameter of the main branch from which smaller supply pipes will be run to individual fixtures,

v. The hydraulic load of the pump and pressure system is calculated by summing up the number of fixture units based upon the types and number of fixtures connected to the system,

[45] Adapted from Ontario's Building Code. 2006. Ministry of Municipal Affairs and Housing, Toronto, ON.

vi. Example:

If three toilets and one washing machine are connected to the system, the hydraulic load can be calculated as follows:

Hydraulic load (fixture units) = (3 x 3) + (1 x 2)

Hydraulic load (fixture units) = 11 fixture units

vii. Once the number of fixture units have been determined, the required size of rainwater supply pipe can be determined using Table C-9:

Table C-9. Maximum allowable pipe lengths[46]

Pipe Diameter	Maximum Allowable Length (m) 12	18	24	30
	Number of Fixture Units Served			
13 mm [½ in.]	11	9	7	6
18 mm [¾ in.]	31	28	24	22
25 mm [1 in.]	63	53	47	42
32 mm [1 ¼ in.]	140	126	108	96
38 mm [1 ½ in.]	286	286	286	275

viii. Example:

Referring to Table C-9, if the total length of the supply pipe is 17 m, and the hydraulic load is equal to 11 fixture units:

Pipe diameter = 18 mm [¾ in.]

Note: With the example above, ¾ in. pipe must be used since 17 m > 12 m, so the 18 m column must be referenced, following which 11 fixture units > 9 fixture units (making ½ in pipe insufficient), therefore ¾ in. pipe must be used, as 11 fixture units < 28 fixture units.

[46] Adapted from Ontario's Building Code. 2006. Ministry of Municipal Affairs and Housing, Toronto, ON.

Appendix D. Overflow Provisions & Stormwater Management

Utilizing a Rainwater Storage Tank for Retention & Detention for Stormwater Management Purposes

1. To design a rainwater harvesting system for the purpose of extended detention and controlled release of stormwater, the following schematic (Figure D-1) and guidelines are provided for estimation purposes only:

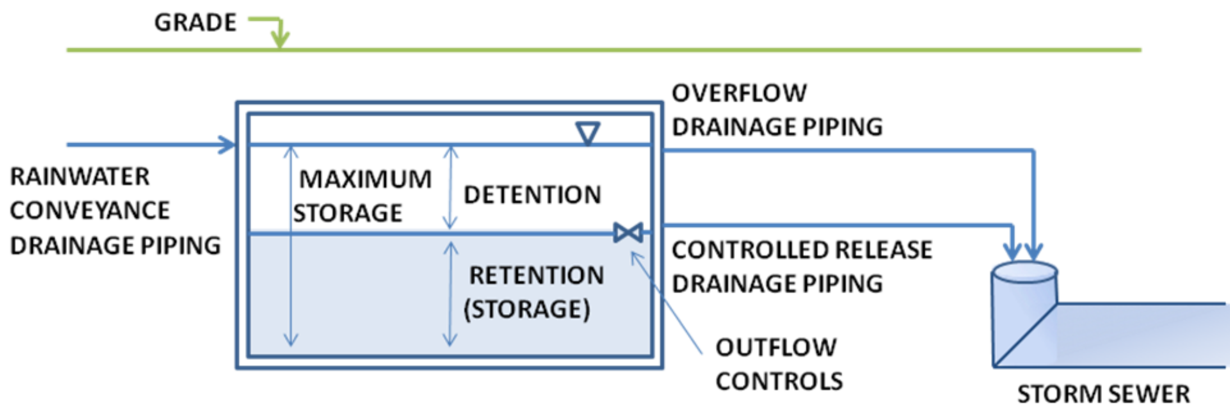


Figure D-1. Schematic of RWH system with outflow controls and controlled release drainage piping for stormwater management. ('DETENTION' is the volume of runoff to be slowly released to storm sewer. The remaining volume 'RETENTION' is used to supply rainwater to permitted fixtures)

   a. To size the retention (storage) volume:
      i. Refer to *Appendix B* for guidelines regarding the sizing of rainwater storage tanks. The storage tank volume determined using the methods provided in *Appendix B* shall be the retention volume of the rainwater tank.
   b. To size the detention volume:
      i. Note: while a rainwater tank can be used to provide extended detention for stormwater management purposes, the required storage volumes may be very large for large roof areas,
      ii. Contact the local conservation authority and/or municipality regarding the size of rainfall event or volume of stormwater to be detained in the tank for the particular site;

iii. Example:

If a municipality requires that 5 mm of rainfall must be detained, then for a roof with a 200 m^2 catchment area:

$$\textbf{\textit{Detention Volume}}\ (\boldsymbol{L}) = Rainfall\ event\ (mm) \times Area\ (m^2\ )$$

Equation D-1

$$\textbf{\textit{Detention Volume}}\ (\boldsymbol{L}) = 5\ mm\ \times 200\ m^2$$
$$\textbf{\textit{Detention Volume}}\ (\boldsymbol{L}) = \mathbf{1000}\ \boldsymbol{L}$$

c. Given the detention volume, the maximum storage depth can be calculated by:

$$H = \frac{V}{w\ \times l}$$

Equation D-2[47]

Where:

H = Maximum storage depth, measured from the bottom of the overflow drainage pipe to the centreline of the drawdown pipe (m)
V = Stormwater detention volume (m^3)
w = Width of the rainwater storage tank (m)
l = Length of the rainwater storage tank (m)

d. Next, the rate of discharge from the controlled release pipe can be determined as follows:

$$Q = Q_{AVG}\ \times F$$

Equation D-3[48]

Where:

Q = Peak discharge rate (m^3/s)
Q_{AVG} = Average discharge rate, (discharge volume/drawdown time) (m^3/s)
F = Peaking factor (typically 1.5)

e. Finally, to size the diameter of the controlled release pipe:

$$D^2 = \frac{4\ Q}{C_d\ \pi\ \sqrt{2gH}}$$

Equation D-4[49]

[47] Adapted from Low Impact Development Stormwater Management Manual (Draft).2008. Toronto and Region Conservation Authority, Toronto, ON.
[48] Low Impact Development Stormwater Management Manual (Draft).2008. Toronto and Region Conservation Authority, Toronto, ON.

Where:

D= Required controlled release pipe diameter (m)
Q= Peak discharge rate (m^3/s)
C_d = Coefficient depending on the type of orifice (available in engineering texts or manuals)
g = Acceleration due to gravity (9.8 m/s^2)
H = Maximum storage depth, measured from the bottom of the overflow drainage pipe to the centreline of the drawdown pipe (m)

f. Example:

For a rainwater harvesting system with the characteristics listed in Table D-1, a rainwater harvesting system for detention and controlled release can be sized as follows:

Table D-1. RWH system characteristics (example)

Detail	Value
Storage tank volume	18 m^3
Maximum stormwater detention volume	9 m^3
Storage tank dimensions (l x w x h)	6.2m x 2.6m x 1.3m

$$H = \frac{V}{w \times l}$$

$$H = \frac{9\ \mathrm{m}^3}{6.2\ \mathrm{m} \times 2.6\ \mathrm{m}}$$
$$H = 0.56\ \mathrm{m}$$

$$\boldsymbol{H \approx 0.6\ \mathrm{m}}$$

Given this height, the centerline (middle) of the controlled release pipe would need to be installed at a height 0. 6 m below the bottom of the overflow drainage pipe.

[49] Adapted from Stormwater Management Planning and Design Manual. 2003. Ontario Ministry of the Environment, Toronto, ON.

The peak discharge from the rainwater storage tank, over a 24 hour period would be:

$$Q_{AVG} = \frac{9\ \mathrm{m}^3}{24\ hr\ \times 60\ \frac{min}{hr}\ \times 60\ \frac{s}{min}}$$

$$Q_{AVG} = 0.000104\ \mathrm{m}^3/_\mathrm{s}$$

$$Q = Q_{AVG}\ \times F$$

$$Q = 0.000104\ \frac{m^3}{s}\ \times 1$$

$$\boldsymbol{Q = 0.000156\ \mathrm{m}^3/_\mathrm{s}}$$

Assuming the depth in the cistern is 0.56 m when the full 9 m^3 is being stored, the required pipe size would be:

$$D^2 = \frac{4\ Q}{C_d\ \pi\ \sqrt{2gH}}$$

$$\mathrm{D} = \sqrt{\frac{4\ \times 0.000156}{0.62\ \pi\ \sqrt{2\ \times 9.8\ \times 0.56}}}$$

$$\mathrm{D} = 0.0098\ \mathrm{m}$$

$$\mathbf{D\ \approx 10\ mm}$$

Thus, from these calculations, a 10 mm diameter pipe is required, however, in practice, such a small orifice would not be used as it would be prone to clogging, or to freezing during the winter. A minimum orifice size recommended for controlled release pipes is 75 mm[50]. Consult the local conservation authority and/or municipality regarding the minimum controlled release pipe diameter sizing.

[50] Low Impact Development Stormwater Management Manual (Draft).2008. Toronto and Region Conservation Authority, Toronto, ON. 75 mm is the minimum orifice size required for controlled release pipes in stormwater retention ponds located in the City of Toronto.

Design & Sizing of Soakaway Pits

Soakaway pits are comprised of an excavated space filled with a non-porous material, surrounded by an outer filter fabric. A basic infiltration trench, be suitable for most RWH systems, is illustrated below in Figure D-2.

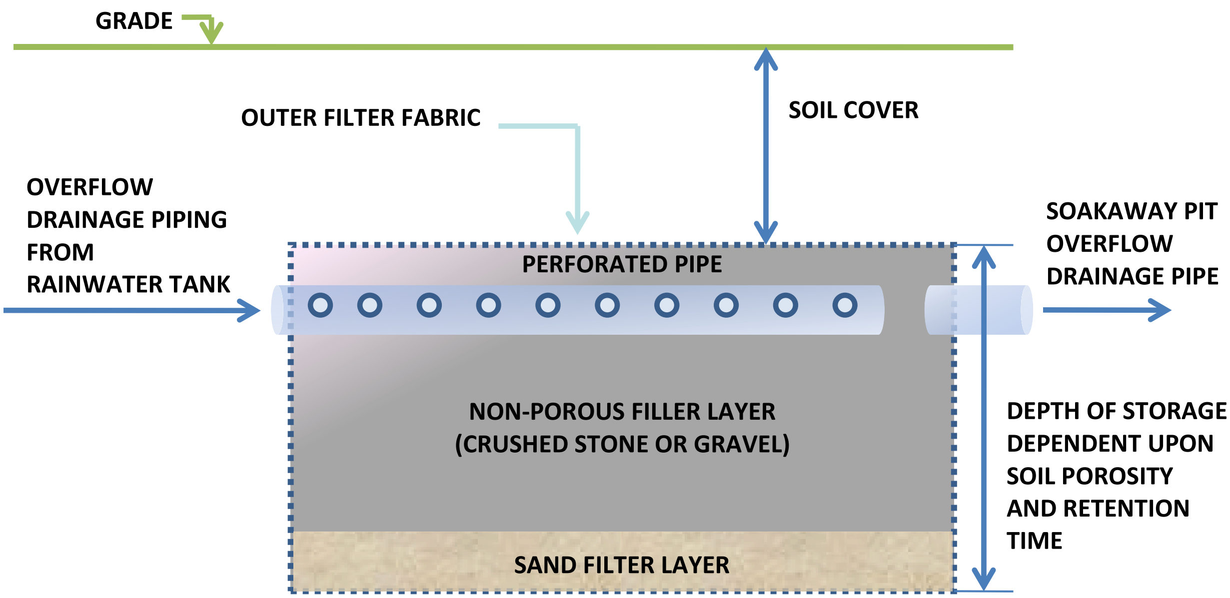


Figure D-2. Sketch of a typical soakaway pit (cross-section view)[51]

The materials required for a soakaway pit include:

1. **Storage media** – crushed stone of a uniform size, used to provide a non-porous structure for the pit.
2. **Outer fabric** – non-woven filter fabric (polypropylene geotextile), used to protect the storage media from becoming clogged by the surrounding soils.
3. **Distribution pipes** – perforated drainage pipe used to distribute rainwater uniformly throughout the entire pit/trench.
4. **Filter layer** - fine sand placed on the outer fabric on the bottom of the trench to filter impurities prior to infiltration.

[51] Adapted from Stormwater Management Planning and Design Manual. 2003. Ontario Ministry of the Environment, Toronto, ON.

1. General design considerations[52]:
    a. The soakaway pit should be located at least 4 m [13 ft.] away from a building foundation or other buried structure, and 1.5 m [5 ft.] from buried water or utility lines;
    b. The length of the pit (parallel to the overflow drainage pipe) should be maximized compared to the width;
    c. The maximum height of the pit/trench should be 1.5 m [5 ft.];
    d. The soakaway pit should be buried sufficiently to protect it from freezing.
2. To size a soakaway pit or infiltration trench, the following guidelines are provided for estimation purposes only[53] :
    a. The depth of the soakaway pit can be calculated using Equation D-5 (further details below):

$$d = \frac{P \times T}{1{,}000}$$

Equation D-5

Where:

d = Maximum allowable depth of the soakaway pit (m)
P = Percolation rate (mm/hour)
T = Drawdown time (hour)

    b. Given the storage depth, the size (area) of the soakaway pit can then be calculated using Equation D-6:

$$A = \frac{V}{d \times n}$$

Equation D-6

Where:

A = Surface area of soakaway pit (m^2)
V = Runoff volume to be infiltrated (m^3)
d = Maximum allowable depth of the soakaway pit (m)
n = Porosity of storage media (0.4 for clear stone)

    c. When performing Equation D-5 and Equation D-6, the following sizing guidelines are recommended:

[52] Adapted from Stormwater Management Planning and Design Manual. 2003. Ontario Ministry of the Environment, Toronto, ON, and Low Impact Development Stormwater Management Manual (Draft).2008. Toronto and Region Conservation Authority, Toronto, ON.
[53] Adapted from Stormwater Management Planning and Design Manual. 2003. Ontario Ministry of the Environment, Toronto, ON.

i. Soakaway pits can only be used in areas where soils have a percolation rate ≥ 15 mm/hr. Refer to Table D-2 for approximate percolation rates for soils. *Note: to ensure that soils have the necessary infiltration capacity, soils may need to be tested*,

Table D-2. Minimum soil percolation rates[54]

Soil Type	Percolation Rate "P" (mm/hr)
Sand	210
Loamy sand	60
Sandy loam	25
Loam	15

ii. A conservative drawdown time of 24 hr (T = 24 hr) should be chosen when calculating the depth of the soakaway pit/infiltration trench,

iii. The maximum depth (d) of the soakaway pit should be no more than 1.5 m to maximize the infiltration capacity of the pit/trench. If the calculated depth is > 1.5, use 1.5,

iv. The surface area of the trench should be configured in a 4:1 ratio for length to width to ensure the full bottom area of the trench is being used for infiltration,

v. A maximum storage volume equal to the runoff from a 4 hour - 15 mm/h storm is recommended. i.e.,

$$V = \frac{Catchment\ Area\ (m^2) \times 15\ \frac{mm}{hr} \times 4\ hr}{1{,}000\ \frac{mm}{m}}$$

Equation D-7

[54] Adapted from Stormwater Management Planning and Design Manual. 2003. Ontario Ministry of the Environment, Toronto, ON.

d. Example:

For a rainwater harvesting system with the characteristics listed in Table D-3, a soakaway pit can be sized as follows:

Table D-3. RWH system characteristics (example)

Detail	Value
Catchment area (A)	150 m^2
Soil percolation rate (P)	60 mm/hr
Storage media porosity (d)	0.4 clear stone

$$d = \frac{P \times T}{1{,}000}$$

$$d = \frac{60 \frac{mm}{h} \times 24h}{1{,}000}$$

$$d = 1.44 m$$

Given the depth of the soakaway pit, the size (area) of the pit/trench can be calculated by:

$$V = \frac{Catchment\ Area\ (m^2) \times 15\ \frac{mm}{hr} \times 4\ hr}{1{,}000\ \frac{mm}{m}}$$

$$V = \frac{150\ \mathrm{m}^2 \times 15\ \frac{mm}{hr} \times 4\ hr}{1{,}000\ \frac{mm}{m}}$$

$$\boldsymbol{V = 9\ \mathrm{m}^3}$$

$$A = \frac{V}{d \times n}$$

$$A = \frac{9\ m^3}{1.44\ \mathrm{m} \times 0.4}$$

$$\boldsymbol{A = 15.6\ m^2}$$

Given this example, to infiltrate the rainwater on-site given the design criteria of the rainwater harvesting system and the surrounding soils, the soakaway pit would need to be 1.4 m deep, with an area of 16 m^2.

3. The soakaway pit must be buried at a sufficient depth to protect it from frost. Figure D-3 indicates the required soil cover, based on soil type and depth of soakaway pit.

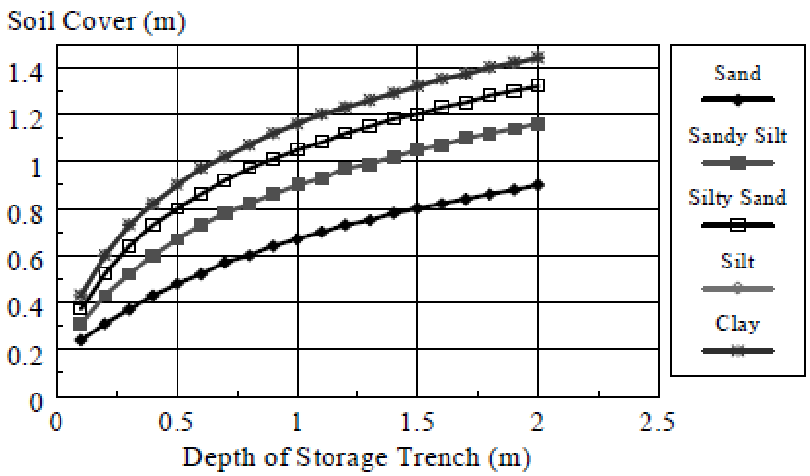


Figure D-3. Soil cover for soakaway pits, based on frost heave[55]

[55] Stormwater Management Planning and Design Manual. 2003. Ontario Ministry of the Environment, Toronto, ON.