Rainwater Harvesting in Toronto
Potential Energy Conservation & Greenhouse Gas Emission Reductions

An Analysis of Benefits & Implementation Barriers

Prepared for
the Toronto Atmospheric Fund

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By
RiverSides

RiverSides
Where Water Quality Begins

Riversides, 511 Richmond St. W., Toronto ON, M5V 1Y3--Tel: 416 868 1983

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Executive Summary

This paper helps quantify on a macro scale in Toronto how rainwater harvesting can contribute to electricity savings and associated greenhouse gas (GhG) emission savings. The municipal water supply and wastewater system in Toronto, as in other cities, is energy-intensive, responsible for 33% of the City corporation's electricity use, 6% of its natural gas use[1], and 10% of its GhG emissions.

Rainwater harvesting entails the capturing of rainwater from hard surfaces such as roofs for use on-site. It has been used by humans in various parts of the world through the ages, and many people today rely on it where other sources of water are limited or of poor quality. In Toronto, rainwater harvesting has not been common but is emerging as a green building practice.

Rainwater harvesting saves energy use by the centralized water system in two ways: First, by replacing potable water, it saves the energy required for the centralized water system to treat and pump water long distances. Second, by capturing rainwater in the combined sewer area, it reduces the amount of water ending up at the treatment plant to undergo energy-consuming treatment.

In this paper we focus solely on the electricity use by Toronto Water[2]. In 2006, Toronto Water treated and pumped 512,560 ML of water, using 345 GWh of electricity (at a cost of $30M), which resulted in 83,000 t eCO_2[3,4]. On the wastewater side, it treated 444,232 ML of wastewater, using 192 GWh (at a cost of $14M), which resulted in 46,000 t eCO_2. From these numbers we can conclude that Toronto Water uses approximately 1 kWh/m^3 for water supply and wastewater treatment.

The scenario this paper explores is one in which rainwater is harvested from the roofs of all large buildings (buildings with a roof area of at least 350 m^2) in Toronto. The resulting electricity savings and greenhouse gas reductions are calculated. These large buildings, whose roof area totals 134,780,000 m^2, are likely Industrial, Commercial and Institutional (ICI) sector buildings and Multi-Unit Residential Buildings (MURBs). We have assumed that all this roof area is available, although in reality harvesting rain from some roof areas may not be practical. We have also assumed that there are sufficient water end-uses in each of the buildings to take advantage of all the rainwater collected.

Using an annual precipitation of 792.7mm, and assuming that 80% of this can be captured by rainwater harvesting (due to losses to evaporation, first flushes, splashing, snow blow-off, and cistern overflows), we calculate that widespread rainwater harvesting in Toronto could reduce centralized water supply demand by 85,000 ML, or 17%.

Assuming that electricity use by the centralized water supply system is directly proportional to water volume, we calculate that approximately 58 GWh of electricity (costing ~$5.1M) and 14,000 t eCO_2 in greenhouse gas emissions would be saved annually by this scenario.

On the wastewater treatment side, there are also savings. Assuming that 40% of the buildings are in the combined sewer area, and very conservatively assuming that only 1/3 of the rainwater landing on roofs goes to treatment (with 2/3 overflowing as combined sewer overflows), we calculate that 11,000 ML (or 3%) of wastewater is eliminated from the treatment process.

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[1] excluding vehicles

[2] A more comprehensive analysis would have also included natural gas use, which is not used for water supply, but provides half the energy for wastewater treatment.

[3] "eCO2" = Equivalent to carbon dioxide

[4] GhG emission factor of 242 g eCO_2/kWh was used, which is the value specified by the Toronto Atmospheric Fund (TAF) for calculating GhG emission reduction impacts.

If we assume (simplistically) that electricity use at the wastewater treatment plant is directly proportional to the wastewater volume[5], we calculate that approximately 4.9 GWh of electricity (costing ~ $370 K) and 1,200 t eCO_2 in greenhouse gases would be saved annually by this scenario.

In addition to reducing energy requirements and GhG emissions, rainwater harvesting has many other environmental, social and economic benefits. These include water conservation, reduced stormwater run-off, reduced combined sewer overflows, decreased pressure on water and wastewater infrastructure, and climate change adaptation.

While interest in this green building technique is growing rapidly, there are some barriers to the widespread implementation of rainwater harvesting. One significant barrier is the high capital investment and ongoing cost in comparison to municipal water. There are also barriers in terms of regulations and policies. It was not until 2006 that the Ontario Building Code allowed for rainwater to be used indoors, and it is limited to toilet flushing. A lack of local technical expertise and knowledge also raises costs and inhibits the development approvals process.

Considering the multiple benefits there is a strong argument for investment in the support of rainwater harvesting by the City of Toronto. A combination of financial incentives, policy incentives and capacity building is recommended; the City's Green Roofs Program is cited as a model.

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We'd like to thank the many people who took the time to review the report or provide information, including Ted Bowering, Grazyna Gajewski, Abhay Tadwalkar and other helpful staff at Toronto Water, Tim Van Seters of Toronto and Region Conservation Authority, Andrew Hellebust of Rivercourt Engineering, and Carol Maas of the POLIS Project on Ecological Governance, and many others.

The opinions expressed in this document are those of RiverSides and do not reflect the opinions of our funders, supporters or reviewers. Any errors or omissions are the responsibility of RiverSides.

[5] In fact, energy requirements at a wastewater treatment plant may be more dependent on organic matter volume than water volumes. However, given the fact that the Toronto Water's wastewater system uses natural gas for half its energy, and given a lack of data as to what percentage of the electricity and natural gas are used for processing water volume vs. organics, we have chosen to use this simplistic assumption to provide at least some preliminary numbers.

Background

RiverSides has been a strong proponent of rainwater harvesting as a key tool that protects watersheds by treating rainwater as a resource. RiverSides is a non-profit organization in Toronto working to protect urban waterways through stormwater pollution prevention. RiverSides works in partnership with governments, non-governmental and community organizations, and businesses, to investigate and promote best practices in stormwater management. A key part of our mission is to help individuals and communities make the connection between everyday activities and the health of our watersheds, and to reframe urban development in terms of watershed sustainability.

As Toronto began investigating ways to reduce GhG emissions, awareness of the energy inputs required for urban infrastructure increased. At the same time, around the world, research into energy supply in water supply systems raised the issue of the intersection between water and energy. As Toronto's water and wastewater system is one of the largest contributors to electricity demand by the Corporation of the City of Toronto, and rainwater is a major untapped source of water that currently flows unused into the wastewater side of the system, RiverSides saw the natural fit with rainwater harvesting for Toronto's long term sustainability.

Revision History

This report originally published in August 2009 has been revised due to subsequent comments by reviewers and further research. The following table lists all changes.

Section	Description of Revision	Important Change?
Title	Changed title to more clearly describe the report.	
throughout	Applied significant digits. (There were previously too many digits wrongly conveying more precision than there existed.)	
throughout	Inconsequential typos fixed. Minor rewording.	
Table of Contents	2.2.1 GhG Emission Factor ~~in~~ for Ontario ~~in 2006~~	
Executive Summary	Totally revised.	Yes
Acknowledgements	Revised & added names of recent reviewers.	
Introduction	Improved to better reflect the report.	
1.1.2 Toronto's Water Supply System – Description of System	18 pumping stations ~~throughout the City~~ (deleted because a couple may be in the Region of York)	
1.2.2 Toronto's Wastewater System – Description of System	Revised to say that 70% of the Combined Sewer Area is actually partially separated. Added description of what a partially separated system is.	
1.2.2.4 End-of-Pipe Capture of CSOs and Polluted Stormwater	Added new subsection to describe end-of-pipe solutions.	
2 Energy Use and GhG Emissions of Toronto's Water & Wastewater System	Added note to say that we are using 2006 data. Added note saying we chose only to focus on electricity use, not natural gas. Provided 2006 data for natural gas in a footnote.	
2.2.4 Total GhG Emissions from Electricity Use for both Water Supply and Wastewater Treatment	129.953 t eCO_2 should be 129,953 $teCO_2$ (i.e. comma)	

Section	Description of Revision	Important Change?
2.3 Summary Table	Added note that Toronto Water uses 1kWh/m^3 of water supply.	
4 Proposed Large-Scale Implementation of Rainwater Harvesting in Toronto	Added explanation of overall calculations, noting that we have assumed that all the roof area (of buildings >350m^2) can be used, when in reality, the use of some roof areas may not be practical or desirable.	Yes
4.3 Calculation of Rainwater Available for Harvest	Explained in full the assumptions we are making in using an 80% capture factor. In particular, we are optimistically assuming that there are sufficient rainwater end-uses in all large buildings such that all available roof area will be used and that overflows will thus be minimal.	Yes
4.4 Calculation of Volume to Wastewater Treatment that can be Reduced	Revised numbers to take into account estimate that of the stormwater landing in the combined sewer area, only 1/3 reaches the treatment plant; the other 2/3 goes to CSOs.	Yes
4.5.1 Electricity Saved due to Reduction in Water Demand	Explained our assumption that electricity use for water supply is directly proportional to water supply volume. Inserted a discussion of electricity use by rainwater harvesting systems.	Yes Yes
4.5.2 Electricity Saved due to Reduction in Wastewater Treated	Explained our assumption that electricity use for wastewater treatment is directly proportional to wastewater volume, but that the relationship is not so simple. Revised numbers as per Section 4.4.	Yes Yes
4.5.3 Total Electricity Saved due to Rainwater Harvesting Implementation	Revised numbers as per Section 4.5.2.	Yes
4.6 Calculation of GhG Emissions Reduced	Revised numbers as per Section 4.5.	Yes
4.7 Summary Table	Shows all revised Section 4 numbers.	Yes
5.1 Stormwater Management	Restructured to better emphasize stormwater runoff reduction benefit.	Yes
5.2 Rainwater Harvesting as a Means to Reduce Infrastructure Expansion Costs	Corrected to say that wastewater infrastructure is designed based on average day flow (not peak day flow).	Yes
6.2.2 Green Development Standard	Revised to say Green Development Standard Tier 1 performance measures are now mandatory.	
7.5 A Home-Grown Model – The Green Roofs Program	Updated to mention the new Toronto Green Roof By-Law.	
8 Conclusions	Revised numbers as per Section 4.	Yes
9 References	A few new references were added.	
Appendix D	Map added showing partially separated sewers within the combined sewer area.	
Appendix E	Masaryk Park-Cowan Community Centre: Deleted reference to hand pump. Hand pump was not used because the pressure was so high.	

Introduction

This paper examines the potential for electricity savings and associated greenhouse gas (GhG) emission reductions from large-scale rainwater harvesting across Toronto.

This paper starts with a discussion of the link between water supply in Toronto and energy use, describing the size and state of Toronto's water supply and wastewater system to understand where and how that energy is used. This is followed by a discussion of rainwater harvesting, its benefits, history, and costs; and then calculations of the potential reductions in electricity use and associated GhG emissions for both water supply and wastewater treatment from rainwater harvesting.

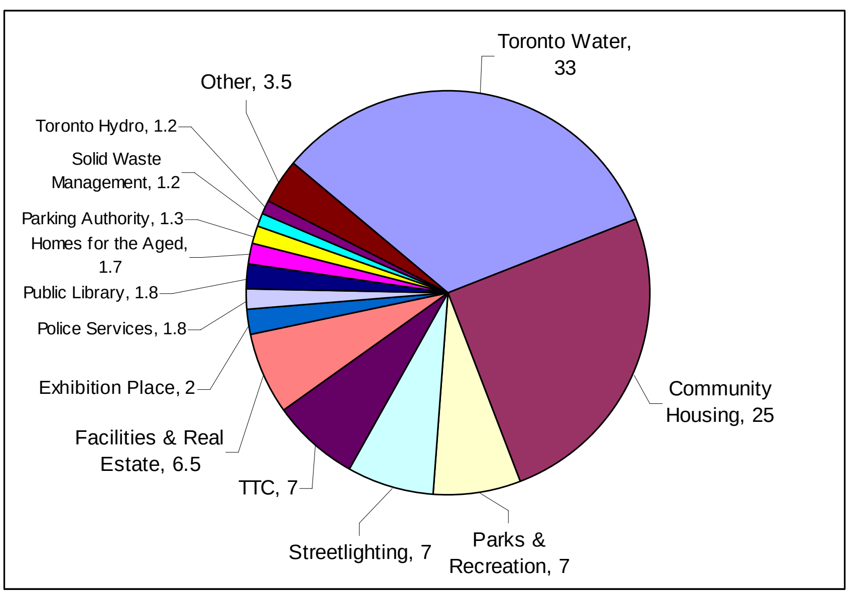
The next part of the paper is a discussion of other key benefits of rainwater harvesting and the current regulatory environment. The paper closes with a discussion of key barriers to widespread implementation of rainwater harvesting in Toronto, and recommendations to push it forward as a viable green building strategy.

1 Toronto's Water and Wastewater System

Toronto's water and wastewater system uses a large amount of energy, primarily to pump and treat water and wastewater, and consequently generates a considerable amount of GhG emissions.

Based on 2004 data, Toronto Water - the division of the City of Toronto responsible for the management of all of Toronto's water and wastewater - accounts for 33% of the total electricity and 6% of the total natural gas used (excluding vehicles) by the City of Toronto corporation (ICF 2007). At 33%, Toronto Water[1] is the largest electricity user within the corporation, followed by Toronto Community Housing at 25%, and Parks & Recreation, streetlighting, and TTC each at 7% (ICF 2007).

Figure 1 – City of Toronto Corporate Electricity Use – Percentage by use – 2004 (ICF 2007)



Toronto Water in 2004 was responsible for 10% of the City corporation's total GhG emissions of 1.60 MT eCO_2,[2] a total that includes emissions from the City's vehicle fleet (not including public transit vehicles) and methane released from its landfills (ICF 2007). If we exclude methane from landfills, which accounts for a staggering 45% of the total, Toronto Water accounts for 18% of the City corporation's GhG emissions (ICF 2007). The GhG contribution of Toronto Water and the City corporation (including landfills)

[1] Toronto's electricity expenditure on water supply and wastewater treatment is in line with other municipalities in Ontario. Generally, based on survey results of 145 local governments, water systems account for one third of a municipality's electricity expenditure (Power Application Group Inc. 2005).
[2] "eCO2" = Equivalent to carbon dioxide

to the City of Toronto community at large is not insignificant. The City corporation's 1.60 MT eCO_2 is 6.8% of the 23.4 MT eCO_2 emitted by the community at large, which includes all residences, the Industrial, Commercial and Institutional (ICI) sector and all vehicles on the road (including public transit) (ICF 2007).

1.1 Toronto's Water Supply System

1.1.1 Service

Toronto's water supply system is the largest in Canada (Toronto Water 2005 Multi-Year Business Plan). It supplies water to the City's 2.6 million residents and the ICI sector, as well as in bulk to the southern portion of the Region of York, which includes approximately 400,000 residents (Toronto Water 2009 Operating Budget Presentation to Budget Committee & Toronto Water Recommended 2009 Budget). Based on 2003 data, 16% of the total water produced goes to the Region of York (Toronto Water 2005 Multi-Year Business Plan).

According to the City's Water Efficiency Plan (2002), in Toronto, there are 448,000 water accounts, of which most (418,000) are for single family residences and a smaller amount (30,000) are for Multi-Unit Residential Buildings (MURBs) and ICI. In terms of volume of water use, however, MURBs and ICI use a larger portion (52%) of the total water, with MURBs using 19% and ICI using 33%. Single family residential uses 34% and the remaining 14% of water is accounted for as non-revenue water (street cleaning, parks irrigation, fire fighting, sewer rehabilitation, illegal connections, accounting errors, meter inaccuracies, system leaks and breaks) (Toronto Water Water Efficiency Plan 2002).

1.1.2 Description of System

See Diagram in Appendix A.

Toronto's water supply system consists of 4 water treatment plants (R.C. Harris, F.J. Horgen, R.L. Clark, Island), 18 pumping stations, 10 underground storage reservoirs, 4 elevated storage tanks, 510 km of trunk watermains and 5,015 km of distribution watermains (Toronto Water Recommended 2009 Budget). Water is taken from deep in Lake Ontario through intake pipes, treated at the plants through physical and chemical means, and then pumped through watermains to storage or directly to the end user.

Since Toronto is built on a long, sloping hill, considerable effort is required to pump water to all users. For instance, to get water from the waterfront at 76.5 m above sea level to the highest point in Toronto (at Steeles Ave. W. and Keele St.) at 209 m above sea level (City of Toronto website (geography) 2008), water must be pumped upwards 133m. The area served by Toronto Water is divided into 6 pressure zones based on elevation, with Zone 6 being the northernmost. In order to reach Zone 6, the water must be pumped through 3-5 pumping stations (Toronto Water website 2008).

Toronto's water distribution system includes 10 underground storage reservoirs and 4 elevated storage tanks. This storage capacity is crucial so that pumping rates do not need to fluctuate moment-to-moment based on fluctuating demand. When the amount of pumped water exceeds the demand, the excess water goes to storage; when demand exceeds the amount of pumped water, stored water takes up the slack. Further, this storage capacity allows pumping to be done in a cost-effective manner: pumping can be minimized during the day, when electricity costs are higher, and maximized during off-hours, when electricity costs are lower. (Toronto Water website 2008)

1.2 Toronto's Wastewater System

1.2.1 Service

Toronto Water manages the wastewater (sewage and stormwater) of the entire City of Toronto. As well, it treats a small portion of sewage from the Region of Peel (Toronto Water Recommended 2009 Budget).

1.2.2 Description of System

See Diagram in Appendix B.

Newer parts of the City have separated sewer systems, in which sewage and stormwater are collected and conveyed separately in sanitary sewers and storm sewers. In the older parts of the City, however, sewage and stormwater are collected together in combined sewers. The following paragraphs first describe the sewage system and stormwater system each on their own, and then return to an explanation of combined sewers and combined sewer overflows (CSOs). Lastly, end-of-pipe capture efforts for both stormwater and CSOs are described.

1.2.2.1 Sewage System

Toronto's sewage system consists of 4 sewage treatment plants (Ashbridges Bay, Highland Creek, Humber, North Toronto) and an extensive system of sewers. Sewage from residential and ICI customers travels by gravity – and by pumping where there is an upslope – to one of the treatment plants. At the treatment plants, the sewage undergoes physical and biological treatment, resulting in water, which is treated with chlorine and released into the lake, and raw sludge. The raw sludge is digested to generate methane to heat the plants or to generate electricity. The resulting biosolids are incinerated, processed into fertilizer or disposed of in landfill (Toronto Water, Fleming 2008).

1.2.2.2 Stormwater System

Toronto's stormwater system consists of pipes that collect water from roofs and foundation drains, 122,500 catchbasins at the edges of roads that collect surface run-off, and an extensive system of sewers that lead to 2,600 outfalls or outfall pipes which empty at rivers or the lake (Toronto Water website 2008). At most outfalls, the stormwater discharges directly into the watercourses without any interruption or treatment. This can result in erosion, entry of pollutants into the watercourses, and temperature impacts. During large storm events, the system can be overwhelmed resulting in flooding of properties and roads.

1.2.2.3 Sewers

Toronto's extensive system of sewers consists of 358 km of trunk (i.e., large) sewers, 4,397 km sanitary sewers, 1,301 km of combined sewers, and 4,305 km of storm sewers and 82 wastewater pumping stations that keep wastewater moving when gravity is not sufficient (Toronto Water Recommended 2009 Budget).

In the *separated sewer system*, the sanitary sewers convey only sewage and the storm sewers only convey stormwater. However, as mentioned previously, *combined sewer systems*, which are located in the older parts of Toronto, collect and convey sewage and stormwater together. In Toronto, there are also *partially separated sewer systems*, where a "combined sewer" collects sewage along with roof stormwater and foundation drain water, but stormwater from roads and surfaces are collected separately in a storm sewer. Appendix C shows how combined and partially separated sewer systems differ from separated sewer systems. See Appendix D for maps showing Toronto's Combined Sewer Area, which consists of 30% combined sewer systems and 70% partially separated systems (Toronto Water, Bowering 2009).

During dry weather, the combined sewers function well, with only sewage contents going to the treatment plant. However, during wet weather, stormwater enters the combined sewers and is also sent to the treatment plant. During large rain events, the additional stormwater overloads the system resulting in stormwater-infused sewage overflows called *"combined sewer overflows"* or *CSOs* to occur at outfalls. There are 72 combined sewer outfalls in Toronto (Toronto Water D'Andrea 2008).

1.2.2.4 End-of-Pipe Capture of CSOs and Polluted Stormwater

CSOs and polluted stormwater are a major contributor to poor water quality in Toronto and are being addressed by the City's Wet Weather Flow Management Master Plan. Under this Plan, Toronto Water has been implementing a number of initiatives, which include end-of-pipe solutions such as the Eastern Beaches detention tanks[3] and the Western Beaches Tunnel[4]. These large structures capture and treat some of the CSOs and polluted stormwater that would otherwise go straight to the lake.

1.3 Physical Condition of Toronto's Water and Wastewater System

Toronto's water and wastewater system is aging and there is a significant backlog in needed infrastructure renewal. The total backlog is estimated to be $1.8 billion ($1.3 billion in watermain and sewer infrastructure and $0.55 billion in treatment plants and facilities) (Toronto Water Recommended 2009 Budget). Significant long-term investment is required to clear the backlog and keep it from growing.

Many of Toronto's watermains and sewer pipes are beyond their expected service life. The expected service life of a Toronto watermain is 50-100 years. Seventeen per cent (17%) of the pipes are now 80 to 100 years old, and 6.5% of the pipes are over 100 years old (Toronto Water Recommended 2009 Budget). The expected service life of a sewer pipe in Toronto is 80-100 years (Toronto Water 2005 Multi-Year Business Plan). Seven per cent (7 %) of the pipes are now between 80 and 100 years old, and 4% are over 100 years old. (Toronto Water Recommended 2009 Budget)

As a result of the condition of its watermains, Toronto has approximately 1,500 watermain breaks per year (Toronto Water website 2008). This is significantly more than what other municipalities experience. Compared to 9 other municipalities in Ontario in 2003, Toronto had the most breaks, 30.5 breaks/100km, twice the average of 14.9. (Toronto Water 2005 Multi-Year Business Plan).

As a result of the age of its sewer pipes and the fact that many are combined sewers, Toronto has a large number of sewer backups each year, more than most other municipalities (Toronto Water 2005 Multi-Year Business Plan).

[3] The Eastern Beaches detention tanks consist of two tanks. The Kenilworth tank (2250 m^3) collects CSOs, which are eventually treated at Ashbridges Bay Treatment Plant (Genivar 2009, Bowering 2009). The Maclean Ave. tank has two compartments (each 4000m^3), one of which collects CSOs (which also goes to Ashbridges Bay Treatment Plant) while the other collects stormwater (Genivar 2009).

[4] The Western Beaches Tunnel captures CSOs from the area south of St. Clair Ave. W., between High Park and Christie St., roughly. The design intention of this system is to treat the CSOs with settling and UV. Currently, however, the system is not working and the CSOs are sent to the treatment plant. (Bowering 2009)

1.4 Capacity of Toronto's Water and Wastewater System

It has been estimated that the population in Toronto will grow from 2.59 million in 2001 to 2.86 million in 2011, and that employment numbers will grow from 1.45 million to 1.62 million in the same time period. The peak day demand for water is projected to increase to 2,245 ML/day, the annual average day demand to 1,411 ML/day, and the wastewater flow to 988 ML/day by 2011 without intervention. (Note that the wastewater flow is estimated at 70% of the annual average day demand. Losses of 30% are assumed due to irrigation, evaporation (e.g. cooling towers) and consumer product manufacturing (e.g. beverages)). (Toronto Water Water Efficiency Plan 2002)

To meet these increased demands, the City had a choice to expand the infrastructure at a cost of $220 million ($130 million for water and $90 million for wastewater) or to reduce the projected 2011 "business as usual" demands by 15% at a cost of $74.3 million. The City has chosen the latter more economical route and is implementing it through its Water Efficiency Plan. Changes to the Ontario Building Code in 1996 mandating water-efficient toilets and showerheads in new construction will contribute to the targetted reductions by 62 ML/day. The Water Efficiency Plan will achieve the rest of the reductions by reducing the peak day demand by a further 275 ML/day and the wastewater flow by a further 86 ML/day. (Toronto Water Water Efficiency Plan 2002)

Initiatives underway under the Water Efficiency Plan include toilet rebates, clotheswasher rebates, and residential outdoor water audits. As well, there is the ICI Watersaver program. Under this program, commercial and institutional customers receive an incentive of $0.30 per litre of permanent daily reduction in water use and wastewater flow that they achieve by changing their equipment or processes. (Georgopoulos 2007). Note that industrial customers are no longer eligible under this program. A new program has been introduced for industrial customers. Industrial users get a reduced fee (20% less than 2008 general water rate of $1.7352/ m^3) for consumption above 6000 m^3 per year as long as they submit a water conservation plan and commit to implementing water efficiency improvements (Toronto Water website 2008).

1.5 Finances of Toronto's Water and Wastewater System

Toronto Water has water assets totalling $8.7 billion and wastewater assets totaling $17.9 billion. All of its operating and capital costs are covered by user fees, which are in the lower range when compared to other major cities in Canada (Toronto Water Recommended 2009 Budget).

In terms of cost of water treatment, when compared to other Ontario municipalities, in 2003, Toronto had the lowest cost ($61.35/ML as compared to the average of $160). This is due to Toronto's economy of scale and its direct access to lake water. With respect to cost of water distribution, however, Toronto's costs were higher ($8,176/km as compared to the average of $6,530/km). This is due to Toronto's aging watermains, the requirement to pump uphill 6 pressure zones, and Toronto's urban setting where traffic, TTC tracks, the abundance of utilities, on-street parking and narrow streets make it difficult to undertake maintenance and repair activities. Costs for sewage collection, treatment and disposal and stormwater management are also higher than average. (Toronto Water 2005 Multi-Year Business Plan)

2 Energy Use and GhG Emissions of Toronto's Water & Wastewater System

Toronto Water, as mentioned in Section 1, accounts for 33% of the City corporation's electricity use and 6% of its natural gas use. Specifically, in 2004, Toronto Water used 563,442,743 kWh (or 2,026,772 GJ) of electricity and 10,879,360 m^3 (415,700 GJ) of gas (ICF 2007). From this, it can be seen that most of the energy used by Toronto Water is electricity (83%).

In this paper we have chosen to focus on the operational electricity use by Toronto Water.[10] (A more comprehensive energy analysis would have also included natural gas use, which is not used for water treatment/supply, but supplies 50% of the energy required for wastewater treatment.[11]) We use 2006 data.

2.1 Electricity Use and Cost for Water Supply and Wastewater Treatment

2.1.1 Electricity Use and Cost for Water Supply

In 2006, 345,016,470 kWh of electricity was used to treat and pump 512,560,000 m^3 of drinking water. This cost the City $30,318,430 (Tadwalkar 2008, Toronto Water)

Approximately half of the electricity used is for treating and the other half for pumping (Toronto Water Gajewski 2008).

2.1.2 Electricity Use and Cost for Wastewater Treatment

In 2006, 191,978,615 kWh of electricity was used to treat 444,232,000 m^3 of wastewater. This cost the City $14,410,613. Note that the electricity required to pump the wastewater is not included here. The data was not available. It is assumed that the electricity required to pump wastewater is small in comparison to the electricity required to treat it as most sewage and stormwater travels by gravity (Gajewski 2008, Toronto Water).

2.1.3 Total Electricity Use and Cost for Water Supply and Wastewater Treatment

In 2006, a total of 536,995,085 kWh of electricity at a cost of $44,729,043 was used to treat and pump water and treat wastewater.

2.2 GhG Emissions due to Electricity Use for Water Supply and Wastewater Treatment

As mentioned in Section 1, Toronto Water is responsible for 10% of the City corporation's greenhouse gases. In this Section, we quantify the GhG emissions associated with the electricity used by Toronto Water in 2006. In order to do this we use a GhG emission factor.

2.2.1 GhG Emission Factor for Ontario

The GhG emission factor allows us to calculate the quantity of greenhouse gases emitted based on the amount of electricity used. The factor varies from year to year based on the electricity generation mix, which for Ontario is mainly a mix of nuclear and hydroelectric, which do not have operational GhG emissions, and coal and natural gas, which do.

[10] Note that our analysis focuses strictly on *operational* electricity consumption; it does not include 'embodied energy' – that energy required for the materials used in this system, e.g. energy used in the manufacturing of the equipment, concrete or pipes for infrastructure, chemicals used for treatment of water, etc. Embodied energy and the associated GhG loadings are beyond the scope of our analysis but do play a role in determining the overall carbon loading of the water and wastewater system.

[11] In 2006, 17,345,316 m^3 (661,533 GJ) of natural gas costing $7,001,697 was used for wastewater treatment (data from Ashbridges Bay, Humber and Highland Creek Treatment Plants combined). (Toronto Water Gajewski 2008)

We use a GhG emission factor of 242 g eCO_2/kWh, which is the value specified by the Toronto Atmospheric Fund (TAF) for calculating GhG emission reduction impacts (TAF 2009). This emission factor is based on the emissions resulting from the electricity generation mix in Ontario and assumes transmission losses of 10%. It is within the normal range for Ontario, which can go as low as 110 and as high as 308 (Environment Canada, National Inventory Report: 1990 to 2006, Greenhouse Gas Sources and Sinks in Canada).

2.2.2 GhG Emissions from Electricity Use for Water Supply

Using the TAF GhG emission factor for Ontario, we calculate the GhG emissions in 2006 that resulted from electricity use for Toronto's water supply as follows:

345,016,470 kWh x 242 g eCO_2/kWh = 83,494 t eCO_2

2.2.3 GhG Emissions from Electricity Use for Wastewater Treatment

Using the TAF GhG emission factor for Ontario, we calculate the GhG emissions in 2006 that resulted from electricity use for Toronto's wastewater treatment as follows:

191,978,615 kWh x 242 g eCO_2/kWh = 46,459 t eCO_2

2.2.4 Total GhG Emissions from Electricity Use for both Water Supply and Wastewater Treatment

The total GhG emissions from electricity use for both water supply and wastewater treatment in 2006 was 129,953 t eCO_2.

2.3 Summary Table

The following table summarizes the electricity, cost and GhG emissions data of this Section:

Table 1 – Toronto Water & Wastewater Systems – Volumes, Electricity Use & Cost, and GhG Emissions – 2006

	Volume (m^3)	Electricity Use (kWh)	Electricity Cost	GHG Emissions from electricity use (t eCO_2)
Water Supply	512,560,000	345,016,470	$30,318,430	83,494
Wastewater Treatment	444,232,000	191,978,615	$14,410,613	46,459
Total		536,995,085	$44,729,043	129,953

From the data in the above table, we estimate that Toronto Water uses about 1 kWh/m^3 (536,995,085 kWh ÷ 512,560,000 m^3) for water supply and wastewater treatment.

From the table, it can also be seen that the water supply component uses more electricity (64%) than the wastewater treatment component (36%). Since, half the water supply electricity component is for treatment and the other half for distribution, we can say that 1) water treatment, 2) water distribution and 3) wastewater treatment each are responsible for approximately one third of the electricity usage by Toronto Water.

3 Rainwater Harvesting

In Section 1, we described Toronto's energy-intensive water supply and wastewater system and in Section 2 quantified the amount of electricity used and greenhouse gases emitted by the system. In this Section, we introduce rainwater harvesting, which could provide a way to reduce the amount of centralized water supply and wastewater treatment required, and consequently reduce the amount of electricity required and greenhouse gases emitted.

In this Section, we describe rainwater harvesting – what it is, its benefits, its history and use around the world, its key components, its costs, and examples of it in Toronto.

3.1 Brief Description

Rainwater harvesting, simply, is the collection, conveyance and storage of rainwater from roofs or hard surfaces for use at or near the same location. Uses may include non-potable uses (such as irrigation, toilet flushing, laundry, vehicle washing, cleaning, cooling, industrial processes, and fire suppression) and potable uses (such as drinking, cooking, washing dishes and bathing). Rainwater harvesting systems can vary in scale from a small residential rain barrel used just for watering a garden to a large-scale system in a commercial building.

3.2 Benefits of Rainwater Harvesting

In a modern city, rainwater harvesting has the potential to provide a number of benefits to the municipal water utility, to the local environment and to the user. These benefits include:

Benefits:

- savings in energy and chemicals required to pump and treat water
- potable water conservation
- in combined sewer areas, savings in energy and chemicals to treat wastewater due to less stormwater being sent to the wastewater treatment plant
- in combined sewer areas, fewer combined sewer overflows
- less stormwater entering rivers causing erosion, pollution and temperature effects
- reduced peak day demand and wastewater flows, mitigating costly expansion of water system infrastructure
- some savings on utility bills to users
- soft, warm, chlorine-free plant-friendly water

Further discussion of benefits is also included in Section 5.

3.3 History and Use

3.3.1 Around the World

Rainwater harvesting is an ancient practice and has been used throughout the world. There is archeological evidence of rainwater harvesting being used as early as 4,000 years ago (TWDB 2005).

In some parts of the world, rainwater harvesting has been a common practice. In Australia, rainwater harvesting has been the only source of water for 3.2 million people or 20% of the population for 150 years (Hill 2005).   On the US Virgin Islands, where there is little surface water or groundwater, most residents rely on rainwater (Solomon 2008). In Hawaii, an estimated 60,000 residents in rural areas where municipal water is not available and well drilling is too expensive rely on rainwater (State of Hawaii 2008).

In recent years, rainwater harvesting has greatly increased in some rural areas around the world suffering from water shortages, such as in Africa, China, and Brazil (Margraf 2005). In addition, there has been a recent resurgence of rainwater harvesting in India, a country with one of the longest rainwater harvesting traditions (Payne & Neuman 2007)

Rainwater harvesting is also emerging in modern industrialized cities, as cities are becoming aware of the limits of the modern water infrastructure and its environmental impacts. In Europe, Germany is leading the way in the installation of rainwater harvesting systems, which are used mainly for irrigation, toilets and laundry. In 2001, there were approximately 500,000 rainwater harvesting systems in Germany (Margraf 2005), and the numbers are increasing at about 80,000 systems per year (fbr 2005/2006). This rapid rate of adoption is supported by national standards (DIN standard) and the large number of rainwater harvesting equipment suppliers in the country.

In Japan, rainwater harvesting is promoted as a way to not only mitigate water shortages, but also control floods and secure water for emergencies such as earthquakes (UNEP 2002, fbr 2005/2006). In Tokyo, there were about 1000 buildings with rainwater harvesting in 2003 (fbr 2005/2006).

In the US, which has its dry southwestern states, rainwater harvesting is becoming more and more visible. The American Rainwater Collection Systems Association (ARCSA) estimated a number of years ago that there were over 250,000 rainwater harvesting systems supplying household needs (Beers 2001). There are likely very many more households as well as Industrial, Commercial and Institutional (ICI) buildings in both wet and dry regions now harvesting rainwater due to the various financial incentives provided by state and city governments.

3.3.2 In Canada and Ontario

In Canada, rainwater harvesting is not common practice. There are pockets in Canada, however, where rainwater harvesting is practiced out of necessity. In Nova Scotia, it is estimated that there are up to 500 households that rely on rainwater for drinking water, due to insufficient groundwater or groundwater of poor quality. The groundwater may have mineral concentrations due to gypsum deposits, or have excessive iron, manganese, uranium or arsenic concentrations. Also, there may be saltwater intrusion in coastal areas. (Dalhousie University 2008). Out west, in the Gulf Islands near Victoria, where reliable surface water or ground water may not be available, several homes and businesses rely on rainwater as their only water source (CRD 2007).

In Ontario, the Region of Waterloo and City of Guelph are researching rainwater harvesting applications in collaboration with the University of Guelph, developers and provincial and federal governments. This is partly due to the rapidly growing population and groundwater sources that will not be able to meet future demand.

3.3.3 In Toronto

In Toronto, rainwater harvesting is rare, but growing in popularity. Small-scale domestic rainwater harvesting with rain barrels is supported by the City via the sale of rain barrels at the City's Environment Days. In terms of larger scale rainwater harvesting applications in the ICI and MURB (Multi-unit Residential Buildings) sector there are a handful of emerging examples, which are listed in Appendix E.

An example of a commercial facility is the Canadian headquarters of SAS (a software firm) on King St. It captures almost 1 million litres of rainwater and snowmelt per year from its unique inverted roof design and terraces for use in toilets. It is estimated that the system can reduce the building's potable water demand by up to 80% in a "wet" year. (McDermott 2008)

An example of an industrial facility is the Canpar Distribution Facility. It collects rainwater from its large warehouse roof into a large 44 m^3 cistern for use in toilets and for irrigation. It is estimated that this system reduces the annual potable water demand for irrigation by 65%, and the annual potable water demand for sewage conveyance by 78%. (Canada Green Building Council 2008).

The Sustainable Technologies Evaluation Program (STEP) at the Toronto and Region Conservation Authority is monitoring and evaluating rainwater harvesting systems in 3 other new buildings in Toronto (TRCA 2008).

3.4 Components of a Rainwater Harvesting System

The basic components of a rainwater harvesting system are:

- a catchment area
- a conveyance system (gutters and downspouts)
- filter(s) (depending on use, catchment surface etc., filtration systems vary)
- a storage tank (also called cistern)
- overflow management
- a distribution system

More sophisticated systems may include:

- first-flush divertors and roof washers
- pump(s)
- pressure tanks
- a treatment system
- connection to a back-up water supply (e.g. municipal water) when rainwater is low, with appropriate backflow prevention

Further elaboration on the components of a rainwater harvesting system is available in Appendix F.

3.5 Operation and Maintenance Requirements of Rainwater Harvesting Systems

Operation and maintenance requirements for a typical rainwater harvesting system includes the following:

- clean gutters, filters, first-flush divertors, and roof washers regularly
- clean cistern annually
- monitor tank levels in order to detect leaks
- replace cartridges regularly and maintain treatment equipment
- clean UV unit regularly and replace unit as required
- test water quality regularly
- maintain pumps

3.6 Cost of a Rainwater Harvesting System

Estimating costs for a full rainwater harvesting system is very complex and varies significantly for new build versus retrofit situations. Some key considerations for costs include building water demand, type of water use, whether the cistern is above- or underground, whether snow melt is collected, and whether ground-level storm water is collected. Additionally, the cost of design and installation of rainwater harvesting systems varies based on expertise available and complexity of the system.

Because of this variability, it is beyond the scope of this report to identify specific rainwater harvesting system costs and estimates.

In terms of system components, the cistern is often the most expensive part. Its cost varies from $0.50 to $4.00 per US gallon depending on size and material (TWDB 2005). Examples of the approximate costs of some of the other basic components for low rise residential and small buildings are (TWDB 2005):

- gutters - $3.50 to $12 /ft, including materials and installation
- roof washer - $50-$800
- pump and pressure tank - $1000 (or on-demand pump – approximately $300-$400)
- cartridge filter - $20-$60
- UV light disinfection - $350-$1000; $80 for standard small UV bulb
- ozone disinfection - $700-2600 plus $1,200 or more if an in-line monitor is added
- chlorine disinfection - $1/month manual dose or $600- $3000 automatic self-dosing system

3.6.1 New build

In terms of the overall cost of a rainwater harvesting system in new construction, a rough estimate of $1/US gallon of storage capacity is often quoted (Goedken 2006). However, according to two companies in the industry, this estimate is low (Hall 2008, Sujer 2008). Costs of up to $4/US gallon or $1/litre may be more realistic (Water Resources Engineering, Inc. 2002).

Examples of costs from the few rainwater harvesting systems in Toronto fit with this rule of thumb of $1/L: the Metro Label Printing Facility system cost approximately $1/L and Brookside Public School's system cost approximately $0.77/L (TRCA 2008). The small tank at the Masaryk-Cowan Community Centre cost half this price at $0.50/L, largely because it is a simple system (above-ground cistern, summer use only, for irrigation), and because of the volunteers that helped with design and installation (Greenest City 2008). See Appendix E.

With new construction, design and project management for the rainwater harvesting system and its construction are part of the overall project budget, which brings down costs relative to a retrofit situation (Roebuck 2007).

3.6.2 Retrofits

The cost of retrofitting a rainwater harvesting system, i.e. installing a system in an existing building, is even harder to generalize for a number of reasons. Firstly, space inside the building or in the ground would have to be allocated, and inconvenient excavation or complicated manoevering may be required (freerain 2008). Second, if the rainwater is to be used for toilets or other indoor use, replumbing would be required, which may require extensive disruptive work (freerain 2008). Thirdly, the downspouts or internal drains must all be redirected to the cistern (freerain 2008). This may be difficult to do, especially with internal drains (Vasquez 2007).

3.6.3 Cost effectiveness

In general, it appears that in the current state, rainwater harvesting is not economical in many cases without the help of government incentives. Rainwater harvesting can not compete with municipal water, which is relatively cheap, but can perhaps compete with the cost of a well in rural areas (TWDB 2005). The costs are high, especially in a retrofit situation, while water rates are low in many jurisdictions, including Toronto. (In Toronto, the 2008 general water rate was $1.7352/ m^3 while the industrial rate was 20% less at $1.3881/ m^3 (Toronto Water website 2008)).

It ought be mentioned however, that water rates will not always be low. Projected annual increases of roughly 9% are anticipated up to 2014 to address Toronto Water's aging infrastructure (Toronto Water Recommended 2009 Budget). This would mean that by 2014, the water rates would be approximately 65% higher.

The most cost-effective applications are rainwater harvesting systems for buildings with large catchment areas and high non-potable water use, due to economies of scale. Thus, some advantageous rainwater harvesting applications may include: industrial buildings with large roof area and cooling, processing or other non-potable demands; commercial or institutional buildings with toilets and landscaping (Goedken 2006)(ecozi 2008).

Another cost-effective way to implement rainwater harvesting may be to integrate it with other water reuse systems. For example, rainwater harvesting could be combined with a grey water reuse to maximize the use of equipment (Water Resources Engineering 2002); also grey water is a steady supply whereas rainwater may be intermittent (Hoffman 2008). Rainwater harvesting could also be combined with air conditioning condensate reuse, which would be particularly useful where there are dry summers (Hoffman 2008).

4 Proposed Large-Scale Implementation of Rainwater Harvesting in Toronto

In this Section, we consider the impact of large-scale implementation of rainwater harvesting in Toronto, and how this would reduce municipal water supply and wastewater volumes and consequently municipal electricity requirements and GhG emissions.

We first calculate the amount of water that can be harvested by rainwater harvesting and the amount of wastewater flow that is eliminated from the wastewater treatment plants by harvesting the rainwater. We then calculate the amount of electricity saved and GhG emissions prevented.

Specifically, the scenario explored is one in which all large buildings in Toronto with roof area over 350 m^2 collect rainwater from their roofs. These buildings are assumed to be either Industrial, Commercial and Institutional (ICI) or Multi-unit Residential Buildings (MURB). Note that we have assumed that all the roof areas (of buildings > 350m^2) can be used for rainwater harvesting. In reality, for some buildings it may not be practical to harvest rain due to conveyance problems (e.g. internal roof drains that are too difficult to access) or lack of space for a cistern. In addition, some buildings may have insufficient non-potable water uses to make use of all of the rainwater landing on their roofs.

Other simplifications/assumptions we have made are noted throughout the discussion.

4.1 Available Roof Area

To demonstrate the potential volume of rainwater available for harvesting, we first identify the total roof area, the most common catchment surface, available in Toronto.

According to a 2005 study "Report on the Environmental Benefits and Costs of Green Roof Technology for the City of Toronto," (prepared for City of Toronto and Ontario Centres of Excellence – Earth and Environmental Technologies (OCE-ETech), prepared by Ryerson University, Project Contact: Hitesh Doshi, Department of Architectural Science, Oct. 31, 2005), the total building roof area in Toronto of buildings with greater than 350 m^2 roof area is 13,478 hectares or 134,780,000 m^2, which is 21% of the total land area of Toronto (63,175 hectares).

Our analysis considers only buildings with a roof area over 350 m^2 in size. This was selected based on the data available, however is also relevant as the larger roof area increases the economy of scale for a rainwater harvesting system by providing a large catchment area. It is assumed that these buildings are ICI or MURB in use.

It is also worth noting that there is significantly more rainwater available for harvest. Our analysis only considers the roof area of buildings, but there is significantly more stormwater available if ground-level storm water collection is included. The full lot area of a development can include significant parking areas, walkways and other hard surfaces capable of collecting water.

4.2 ICI and MURB focus

Our focus is primarily on the Industrial, Commercial, Institutional (ICI) sector and Multi-Unit Residential Buildings (MURBs), for a number of reasons, though this is not meant to exclude or imply that low rise residential is not a key player in rainwater harvesting. This is for simplification and to focus strategically on the areas with highest impact first.

The majority of new buildings in Toronto, especially in the core, combined sewer area, are MURBs, and new buildings need to meet stormwater management guidelines, so already have requirements to capture rainwater and possibly to retain it.[12]

As mentioned in section 1.1, the ICI and MURB sectors are high water users: They represent only 6% of all Toronto Water customers, but use a large portion (52%) of the water produced by the City (Toronto Water Water Efficiency Plan 2002).

MURBs and ICI buildings are likely to have high non-potable water demands.[13] In the industrial sector, major uses of water that can potentially use non-potable water include cooling, processing, or washing. In the commercial and institutional sector, major uses of water that can potentially use non-potable water include cooling, irrigation, cleaning, toilets and laundry. MURBS and commercial and institutional sector buildings will tend to have high occupancy, which means their toilet demand will be high.

4.3 Calculation of Rainwater Available for Harvest

According to Environment Canada, the average annual precipitation (rain and snow) in Toronto is 792.7 mm (Environment Canada, Canadian Climate Normals 1971-2000, Toronto Lester B. Pearson International Airport).

To calculate the amount of rainwater that can be harvested annually, we multiply the available roof area by the annual precipitation, and apply a factor that takes into account losses due to evaporation, first flushes, splashing, snow blow-off, and cistern overflows.

We will assume roof losses due to evaporation, first flushes, snow blow-off, etc. to be in the range of 10%. According to the Toronto Region Conservation Authority (TRCA) Sustainable Technologies Evaluation Program (STEP)'s evaluation of the rainwater harvesting system at the Metro Label printing facility in Toronto, which has a flat roof typical of ICI and MURB buildings, roof losses amounted to about 13% (TRCA 2008).

Estimating the amount of cistern overflows is more difficult as it can vary significantly from system to system. Currently there is limited research on how much water is actually captured by rainwater harvesting systems

[12] Due to stormwater management regulations under the Wet Weather Flow Master Plan Policy, all new developments are required to manage the quantity and quality of stormwater flow for 24 hours from an average 5mm rainfall. This includes ground level stormwater from parking lots, walkways, and water flowing down the sides of the building.

[13] The Handbook of Water Use and Conservation (Vickers 2001) provides a good description of ICI water uses.

and how much overflows. Of the research we reviewed, we found examples of both a low and a high overflow rate.

An example of high overflows is the rainwater harvesting system at the Metro Label printing facility, which has an 18,000 L cistern, collects from a 950 m^2 section of the roof, and serves toilets and external hose bibs (TRCA 2008). According to the TRCA STEP's research, cistern overflows were about 40% of the total precipitation landing on the roof. According to TRCA, overflows of this magnitude are expected (TRCA, Van Seters 2009). Overflows occur due to the fact that cistern sizes are finite and rainfall patterns do not conveniently match with water end-use patterns.

In contrast, a University of Guelph study that monitored a domestic rainwater harvesting system for 1 year reported much less overflow. The system has an 8000 L cistern and a 100 m^2 roof and serves toilets and laundry. Just 10% of the total precipitation landing on the roof overflowed (Farahbakhsh et al 2009).[14]

The key to reducing overflows is to expand water end-uses. The more the rainwater cistern is drawn down by various end-uses, the more it is available to capture rainwater.

For the purposes of our calculations, we have chosen to use a capture factor of 80%. We are assuming a roof loss of 10% and an overflow loss of 10%. We are optimistically assuming that there will be sufficient end-uses in all the large ICI and MURB buildings to take advantage of all the rainwater captured on all the available roof area, and that overflows will be minimal.

Vol. of water that can be harvested per year

= 134,780,000 m^2 roof area x 792.7 mm x 80% capture

= 85,470 ML ~ 85,000 ML

Considering that the total water treated by Toronto Water annually is 512,560 ML, the implementation of rainwater harvesting across the City on all buildings with roof area greater than 350 m^2 would reduce water demand by 16.7 % ~ 17%

4.4 Calculation of Volume to Wastewater Treatment that can be Reduced

If rainwater harvesting is implemented across the combined sewer area of the City, some rainwater would be diverted from the combined sewers and this would lead to less rainwater undergoing treatment at the sewage treatment plant. It is this benefit that we quantify in this subsection.

We first calculate the relevant roof area. We approximate that 40% of the buildings in Toronto are in the core (i.e. combined sewer) area of Toronto (Planning 2006).

Roof area in combined sewer area

= 134,780,000 m^2 roof area x 40%

= 53,912,000 m^2

[14] According to the study, 790 mm fell on a 100m^2 roof and 65,000 L was captured and 8000 L overflowed. Thus, we calculate that the total precipitation falling on the roof was 790 mm x 100 m^2 = 79,000 L, and that the % overflow was
8,000 L ÷ 79,000 L x 100% = 10%.

To calculate the volume of rainwater that would be eliminated from the combined sewers, we multiply the available roof area by the annual precipitation, and apply a factor of 80%, based on our discussion in the previous section (Section 4.3).

Vol. of water that can be eliminated from the combined sewers

= 53,912,000 m^2 roof area in combined sewer area x 792.7 mm x 80% capture

= 34,190 ML ~34,000 ML

According to Toronto Water (Bowering 2009), a significant amount of stormwater falling in the combined sewer area and entering combined sewers ends up as combined sewer overflow (CSO). It has been approximated that 1/3 of stormwater entering combined sewers in the combined sewer area goes to the treatment plant, and 2/3 overflows. It is unknown how this translates to the amount of rainwater landing on roofs in the combined sewer area that goes to treatment or overflow. We anticipate that more than 1/3 of rainwater landing on roofs would get to the treatment plant because 70% of the combined sewer area is actually partially separated, which means that rainwater from roofs would have a higher chance of going to treatment than other stormwater. However, in the absence of data, we will conservatively assume 1/3 of rainwater landing on roofs in the combined sewer area goes to treatment. Thus, we calculate the volume of wastewater that can be eliminated from the treatment plant as follows:

Vol. of water that can be eliminated from wastewater treatment

= Vol. of water that can be eliminated from the combined sewers x 1/3

= 34,190 ML x 1/3 = 11,396 ML ~11,000 ML

Note that this amount is conservative for another reason. As described in Section 1.2.2.4, some of the CSO volume is captured in the Eastern Beaches detention tanks, and eventually goes to the treatment plant. As well, currently, CSO volume from the Western Beaches Tunnel also goes to the treatment plant (temporarily, until the UV system is functioning).

Considering that the total wastewater treated by Toronto Water annually is 444,232 ML, the implementation of rainwater harvesting across the City on all buildings with roof area over 350 m^2 would reduce wastewater to be treated by 2.6% ~ 3%.

4.5 Calculation of Electricity Saved

4.5.1 Electricity Saved due to Reduction in Water Demand

As noted in Section 2.1.1, in 2006, 345,016,470 kWh of electricity was used to treat and pump 512,560 ML of drinking water. This cost $30,318,430.

In order to calculate the amount of electricity saved due to the reduction in water demand due to rainwater harvesting, we have assumed for simplicity that the amount of electricity use is directly proportional to the volume of water supply.[15]

[15] This is not an entirely correct assumption as there is some base electricity use required regardless of water volume (Maas 2009), but it is a good approximation. In general, the more water treated and pumped, the more electricity is used (Cheng 2009, Toronto Water).

Assuming direct proportionality then, 58 GWh of electricity and $5.1 M would be saved annually by a reduction in annual water demand of 85,000 ML as a result of rainwater harvesting implementation.

Note that to be more complete in our analysis, we should have considered the electricity required to pump the rainwater in the rainwater harvesting systems and subtract that from the electricity savings calculated above. This is because municipal water arrives at the end user pressurized to 40-60psi (TWDB 2005) while rainwater does not and may thus require pumping up or pressurization. We have ignored this energy requirement in our calculations.[16]

4.5.2 Electricity Saved due to Reduction in Wastewater Treated

As noted in Section 2.1.2, in 2006, 191,978,615 kWh (=691,123 GJ) of electricity was used to treat 444,232 ML of wastewater. This cost $14,410,613.

Similar to our calculation in 4.5.1 for water supply, in order to calculate the amount of electricity saved due to the reduction in wastewater due to rainwater harvesting, we have assumed for simplicity that the amount of electricity use is directly proportional to the volume of wastewater processed by the wastewater treatment plant.

In actual fact, the relationship is not so simple, as the energy requirements at a wastewater treatment plant are more dependent on organic matter volume than water volumes (Gajewski 2009, Maas 2009). However, given the fact that the wastewater treatment plants also use a considerable amount of natural gas (half of the energy used is provided by natural gas)[17], and lack of data as to what percentage of the electricity and natural gas are used for processing water volume vs. organics, we have chosen to use this simplistic assumption to provide at least some preliminary numbers.

Assuming then that the electricity requirement is directly proportional to the volume of wastewater treated, ~4.9 GWh of electricity and ~$370 K would be saved annually by a reduction in annual wastewater treated of 11,000 ML as a result of rainwater harvesting implementation.

4.5.3 Total Electricity Saved due to Rainwater Harvesting Implementation

In total, ~63 GWh of electricity costing ~$5.5 M would be saved annually due to the implementation of rainwater harvesting across the City on all buildings with roof area over 350 m^2.

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[16] The amount of electricity used by rainwater harvesting systems can be significant. In an Australian study (Retarnal et. al. 2009), domestic rainwater harvesting systems were observed to use approximately 1.5 kWh/m^3, which is more than the 1 kWh/m^3 (see Section 2.3) that Toronto Water's centralized system uses. This high electricity use was attributed to small pumps, which are less efficient than larger pumps; the use of these pumps at low flow rates at which they are not efficient; frequent "on" and "off" of the pumps; and "trickle top-up" mains, where mains water is depressurized. However, this same report states that the energy efficiency of rainwater harvesting systems can be significantly improved through better pump and system selection and design, and that ICI and MURB applications (which are the focus of our report) will be more efficient because they will have bigger pumps and larger, more continuous flows. That better energy efficiency can indeed be achieved is supported by a Toronto rainwater harvesting system installer who estimates the electricity use of his domestic systems with pressure tanks to be 0.25 kWh/m^3 (Thompson 2009).

Other factors to consider that may reduce the electricity requirements of rainwater harvesting systems are: (i) some end uses of rainwater harvesting will not require high pressure, and (ii) an elevated tank could in some cases be used to provide pressure by gravity. Overall, we are optimistic that rainwater harvesting systems can be designed to be much more energy efficient than centralized systems. An on-site rainwater harvesting system after all does not have to treat to potable standards in most cases or pump water through kilometers of aging pipes. To achieve this, however, it is critical that energy efficiency be made a clear design goal.

[17] In 2006, 17,345,316 m^3 (661,533 GJ) of natural gas costing $7,001,697 was used for wastewater treatment (data from Ashbridges Bay, Humber and Highland Creek Treatment Plants combined). (Toronto Water Gajewski 2008). Therefore, for wastewater treatment, half the energy is from electricity, and half is from natural gas.

4.6 Calculation of GhG Emissions Reduced

4.6.1 GhG Emissions Reduced due to Reduction in Water Demand

As noted in Section 4.5.1, 58 GWh of electricity would be saved by a reduction in annual water demand as a result of rainwater harvesting implementation.

Using the TAF GhG emission factor for Ontario, we calculate the GhG emissions reduction due to reduction in annual water demand as a result of rainwater harvesting implementation.

58 GWh x 242 g eCO_2/kWh = 14,000 t eCO_2

4.6.2 GhG Emissions Reduced due to Reduction in Wastewater Treated

As noted in Section 4.5.2, 5 GWh of electricity would be saved by a reduction in annual wastewater treated as a result of rainwater harvesting implementation.

Using the Toronto Atmospheric Fund (TAF) GhG emission factor for Ontario, we calculate the GhG emissions reduction due to reduction in annual wastewater treated as a result of rainwater harvesting implementation.

5 GWh x 242 g eCO_2/kWh = 1,200 t eCO_2

4.6.3 Total GhG Reduction due to Rainwater Harvesting Implementation

In total, 15 kt eCO_2 would be eliminated annually due to the implementation of rainwater harvesting across the City on all buildings with roof area over 350 m^2.

4.7 Summary Table

Table 2 – Potential Reduction in Water and Wastewater Volumes, Electricity, and GhG Emissions due to Rainwater Harvesting Implementation on all Toronto Buildings with Roof Area over 350m^2 – 2006

	2006 – actual	Reductions due to Rainwater Harvesting on all buildings with roof area over 350 m^2
Annual water volume treated & pumped	512,560 ML	85,000 ML (17% reduction)
Electricity required & cost	345 GWh $30.3 M	58 GWh $5.1 M
Greenhouse gases emitted	83,494 t eCO_2	14,000 t eCO_2
Annual wastewater volume treated	444,232 ML	11,000 ML (3% reduction)
Electricity required & cost	192.0 GWh $14,411 K	4.9 GWh $370K
Greenhouse gases emitted	46,459 t eCO_2	1,200 t eCO_2
Total electricity required	537 GWh $44.7M	63 GWh (12% reduction) $5.5M
Total Greenhouse gases emitted	129,953 t eCO_2	15 kt eCO_2

5 Ecosystem, Social and Economic Benefits of Rainwater Harvesting for City of Toronto

The capture and use of roof- and ground-level run-off can generate numerous ecosystem, social and economic benefits for the City of Toronto. It is an effective building-by-building water conservation system that frees up Toronto's energy-intensive potable water system capacity, simultaneously freeing up energy-intensive sewage treatment capacity, and reducing the volume of untreated sewer system overflows being introduced into Lake Ontario.

Incorporated within a green building system, rainwater harvesting addresses and fulfills numerous City goals of conservation, wet weather flow management and climate change adaptation. In this section, we discuss the benefits of rainwater harvesting beyond energy conservation and GhG emission reductions. Evaluating the full range of benefits is important for identifying allies, partners and strategies to utilize this green building method.

Properly supported and applied, rainwater harvesting will bring considerable benefit to bear in achieving the following City of Toronto Departmental and Programmatic Goals. Rainwater harvesting:

- provides a contribution toward the City's energy conservation and GhG reduction plan goals (6% GHG emission reduction city-wide by 2012, 30% by 2020) (City of Toronto 2007)
- conserves municipally-treated potable water and can help avoid costly expansion of municipal water and waste water infrastructure assets (15% reduction of water use by 2011) (Toronto Water, Water Efficiency Plan 2002)
- achieves significant stormwater run-off elimination and reduced combined sewer overflows, supporting the Wet Weather Flow Management Master Plan
- contributes to Toronto's climate change adaptation strategy by increasing water supply security and preparing for changing precipitation patterns
- helps reach the objectives of the Mayor's Clean and Beautiful City program, by supporting the clean up of our rivers and re-opening waterfront beaches

5.1 Stormwater Management

One of the strongest arguments in support of rainwater harvesting is the management of stormwater at the lot-level. This reduces stormwater run-off and combined sewer overflows.

5.1.1 Stormwater Run-off

Stormwater run-off in all parts of the city is a major source of water pollution. Stormwater run-off carries heat and ground-level pollutants (oil and gas, fertilizers, pesticides, road salts, pet waste) at high velocity directly to water bodies causing temperature increases and erosion of stream banks, which negatively impact aquatic life, as well as pollution that affects us all. In addition, large volumes of stormwater cause flooding. By reducing run-off, rainwater harvesting would significantly reduce these negative impacts.

5.1.2 Combined Sewer Overflows

The reduction of combined sewer overflows (discussed in Section 1.2.2.3) has significant benefits to the City of Toronto by reducing pollution at waterfront, enabling waterfront beach recreation opportunities, reducing pollution in Toronto's rivers and lake, and reducing the stress on the combined sewer system.

Stormwater management benefits for the environment are difficult to quantify, however one area that we can look at is the value of reducing combined sewer overflows (CSOs). According to the Ryerson University Green Roofs report (Ryerson University 2005):

1) Toronto Water states that the total annual CSO volume[18] is 10,187 ML,

2) the Toronto Wet Weather Study recommends underground CSO storage of 259 ML, and

3) the Toronto Wet Weather Study estimates underground CSO storage costs to be $1.340/L.

According to our calculations in Section 4.4, rainwater harvesting in the combined sewer area could eliminate 34,000 ML of water annually from the combined sewers. From this it can be inferred that rainwater harvesting could make a significant contribution to reducing CSOs (as 34,000 ML is greater than the annual CSO volume of 10,187 ML). As well, it can be seen that if rainwater harvesting costs approximately $1/L of storage, it may be a more economical solution than underground CSO storage. Aside from preventing CSOs and reducing stormwater flows, by investing in rainwater harvesting, the City would also provide additional water supply capacity and eliminate the treatment of stormwater in sewage treatment plants.

5.2 Rainwater Harvesting as a Means to Reduce Infrastructure Expansion Costs

Rainwater harvesting can play a significant role in achieving load reductions for both water and wastewater and, as a result, reduction in the need for infrastructure expansion.

In Section 1.4, we mentioned Toronto's Water Efficiency Plan (WEP) and how it aims to reduce demand in order to avoid costly infrastructure expansion. The Water Efficiency Plan appears to be on track in achieving its goals without the large-scale rainwater harvesting as described in this paper; however, as an illustration, we have used the WEP infrastructure dollar costs to quantify the potential infrastructure expansion cost savings that rainwater harvesting as described in this paper could provide if needed.

The sizing of the water supply system is based on the peak loads. Thus, water supply infrastructure must be able to handle the peak day water demand. In Toronto, the peak day water demand would occur in the summer, on a hot day where water is used for irrigation and cooling.

The sizing of the wastewater system, on the other hand, is based on the average day wastewater flow. It can not be based on the peak, which occurs during the largest storm, where loads are well beyond the average daily flow and overflows occur.

According to the 2002 Water Efficiency Plan, the cost to expand water supply infrastructure would be $0.47/L/day and the cost to expand wastewater infrastructure would be $0.65/L/day. Based on various Statistics Canada construction indices, we estimate that construction costs have increased roughly 30% from 2002 to 2007[19]. Therefore, we estimate the costs to be higher: $0.61/L/day for water supply infrastructure and $0.85/L/day for wastewater infrastructure.

Rainwater harvesting would be very effective in reducing the peak day water demand because harvested rainwater could be used for irrigation, the largest use of water on peak days (Toronto Water 2008). In Section 4, we calculated that rainwater harvesting across the City would reduce the annual water demand by 85,000 ML. On an average day then, water demand would be reduced by (85,000 ML ÷ 365 days =) 230 ML by rainwater harvesting. Let us assume that the peak day water demand could be reduced by this amount. (This is a conservative assumption. In reality, the reduction due to rainwater harvesting will be higher than 230 ML/day, since on a hot, dry day, irrigation demands would be highest and rainwater most used.) This would

[18] to Black Creek, Humber River, West Don River, Massey Creek, Lower Don River, Western Beaches, Inner Harbour, Eastern Beaches, and Scarborough Lake

[19] Based on the following 3 construction indices' increases from 2002 to 2007: Toronto residential construction 33%, Toronto industrial construction 37%, Ottawa infrastructure construction 22% (Statistics Canada 2008)

result in a water supply infrastructure expansion cost savings of at least (230 ML/day x $0.61 /L/day =) $140 million.

With respect to wastewater flow, in Section 4, we calculated that rainwater harvesting across the City would reduce the annual wastewater flow by 34,000 ML. On an average day then, wastewater flow would be reduced by (34,000 ML ÷ 365 days =) 93 ML by rainwater harvesting. Let us assume that the average day wastewater flow could be reduced by this amount. This would result in a wastewater infrastructure expansion cost savings of (93 ML/day x $0.85/ L/day =) $80 million.

Therefore, based on our illustration, implementation of rainwater harvesting on all roofs in Toronto over 350 m^2 has a potential to save at least ($140 M + $80 M =) $220 million in potential infrastructure expansion costs, if needed.

5.3 Global Warming – Mitigation and Adaptation

In terms of global warming and the City of Toronto's responsibility to pursue climate change mitigation and adaptation policies, rainwater harvesting can contribute to both of these goals. In particular, it can assist in adapting to future climate conditions and provide increased security in water supply.

5.3.1 Adapting to Future Climate Conditions

In the future, it is expected that there will be more extreme weather conditions such as high temperatures and droughts. Global warming experts also predict increased intensity of storm events in the future, combined with more significant fluctuations in rain patterns (Toronto Environment Office, 2008).

During heat waves and droughts, two weather conditions that frequently occur together and contribute to peak use of energy and water, rainwater harvesting can assist by providing an additional much needed water source and in reducing municipal water demand, reduce energy demand. During especially high energy demand periods, energy needs are met by 'dirtier' sources such as coal, so any reduction in energy use at this time is particularly effective in lessening smog conditions.

Also, larger storm events will increase the peak loads for wastewater management, as more stormwater enters the system. Here too rainwater harvesting will be effective in reducing the peak, consequently reducing the deleterious effects of excessive stormwater runoff, combined sewer overflows, and flooding.

5.3.2 Water supply security

Rainwater harvesting also provides a more stable water source than surface waters. Research in Australia compared centralized supply (local dams, replenished by natural rainfall run-off) and decentralized rainwater harvesting systems (which are filled with urban stormwater run-off) and concluded that rainwater harvesting systems provide a water supply with even small amounts of rainfall, as rainfall in urban areas will always create significant stormwater run-off, no matter how infrequent (Coombes & Barry, 2007). The predicted future weather patterns may reduce flows which will have a myriad of other environmental impacts (including increased contaminant load and decreased dilution of wastes, temperature changes etc), thus any solutions that can reduce pollution and help provide a stable water supply should be pursued.

6 Regulatory Environment

Regulations and legislation controlling building structure is a fundamental issue that inhibits or supports the installation of rainwater harvesting systems on existing and new buildings. Of greatest significance to buildings in Toronto are the Ontario Building Code, which regulates plumbing in buildings, and the regulations of the Toronto Planning Department which regulates land uses, stormwater management, lot size and orientation among other things.

There are a number of policies and programs at the federal, provincial and municipal level that affect rainwater harvesting implementation in Toronto. Below, we will discuss a few of the key policies, including the Ontario Building Code, the Wet Weather Flow Management Master Plan, and the Green Development Standard.

6.1 Ontario Building Code Act

Prior to amendments passed in June 2006, the Ontario Building Code Act expressly restricted the use of non-potable water for interior applications utilizing plumbed fixtures. Though there were a small number of advanced rainwater harvesting systems installed despite the earlier restrictions in the OBC, this was based on special circumstances, a long approvals process and the expert knowledge of the designers and building inspectors enforcing the code.

In June 2006, the Act was changed, and now, Section 7.1.6.3. Water Distribution Systems specifies that storm sewage or greywater can be used for toilet flushing. These revisions allow for the use of rainwater for purposes of toilet flushing and irrigation provided that non-potable water plumbing is clearly identified in order to prevent cross connections and misuse. Increasing the number of indoor uses permitted would increase the cost-effectiveness of system installation.

Unfortunately, the OBC incorrectly characterizes rainwater as synonymous with *greywater,* a term used to describe sanitary water (from sinks, shower, laundry) that is treated minimally on site, which requires different treatment and carries much higher public health risks. This misnomer has been noted by other rainwater harvesting experts and is hopefully to be corrected in the future (CMHC 2008).

6.2 Toronto Policy

6.2.1 Wet Weather Flow Master Plan

The Wet Weather Flow Management Master Plan (WWFMMP) was created to address the issues of combined sewer overflows and "…provides direction on how to manage wet weather flow on a watershed basis and in a manner that recognizes rainwater and snowmelt as a resource." (Wet Weather Flow Management Policy, 2003). The Master Plan pursues a combination of solutions and takes a 'Hierarchical Approach' favouring 'Source Controls' (where the rain falls) over 'Conveyance' and 'End-of-Pipe' (where stormwater pipes discharge) solutions. Source controls include the residential Downspout Disconnection program and by-law and other programs to promote on-site infiltration of rainwater. One end-of-pipe initiative under the WWFMMP is to construct large tanks and tunnels, such as the tanks in the Eastern Beaches and the Western Beaches Tunnel, to capture CSOs and polluted stormwater in major storm events.

Rainwater Harvesting fits squarely at the top of the hierarchy, as a tool to capture and retain stormwater and snowmelt at the lot level, treating it as a resource. In the General Policy Statement, the WWFMMP calls for "the reuse of stormwater at source whenever possible" (Policy 4.1.7).

In terms of specific policy and programs, a key tool is the Wet Weather Flow Management Guidelines, which specify that a Stormwater Management Plan must be submitted with all development applications in the City. This stormwater management plan must outline specific actions that will be taken to manage the quantity and quality of stormwater run-off from a site, including installing basic oil and grit separators that provide preliminary treatment, preventing run-off from flowing onto neighbouring property and ensuring that there is no net increase in run-off from a site after development (Wet Weather Flow Management Guideline 2006).

The result is that most new development has a complex catchment system to collect stormwater, and in some parts of the city, due to limited stormwater infrastructure capacity, developments are also required to retain stormwater in tanks to be released slowly to the storm sewer.

The combination of these policies strongly supports rainwater harvesting, and the WWFMMP can be used to more directly and explicitly promote rainwater harvesting across Toronto.

6.2.2 Green Development Standard

The Toronto Green Development Standard (GDS) is a set of performance measures created by the City to encourage sustainable development and buildings that address the City's environmental concerns. The GDS offers a ‘menu’ of sustainable building approaches to achieve a required rating in various categories using indicators from other rating systems, as well as new measures related to Toronto-specific policy and environmental concerns. The GDS consists of ‘Tier 1’ and ‘Tier 2’ performance measures.

Since its launch in 2007, the GDS has been a voluntary standard, but as of January 31, 2010, the Tier 1 performance measures have become mandatory for all new buildings in Toronto (Tier 2 performance measures remain voluntary) (City of Toronto, website for GDS, accessed April 2010). The GDS supports rainwater harvesting and stormwater reuse, and promotes it as a water conservation and water pollution prevention tool. Rainwater harvesting is currently included as a Tier 2 option for landscape irrigation for medium and high-rise residential and ICI buildings.

7 Recommendations

A number of barriers prevent the more widespread use of rainwater harvesting in Toronto. These include policy, financial, capacity and perception. At a national meeting in 2008 of rainwater harvesting experts, convened by the Canadian Mortgage and Housing Corporation, the top three barriers identified were economics, policy, and technical capacity. At this same meeting, the recommended next steps featured standardization in the form of manuals, guidelines and certification of design and maintenance of systems; financial incentives for building owners through subsidies, and an expansion of permitted uses to help reduce the costs.

7.1 Financial Incentives

A key barrier to the adoption of rainwater harvesting as common practice is the high capital costs to design and install the system. Incentives, loans and grants to assist with the initial costs would greatly assist building owners to implement effective, large size rainwater harvesting systems.

Current Toronto grants and incentive programs, such as the Eco Roof Incentive program, described below in Subsection 7.5, would help new and existing building owners. Toronto Water’s WaterSaver program provides rebates of up to $0.30 per litre to existing commercial and institutional building owners that reduce their daily water use. The program allows the City to ‘buy back’ water supply capacity from existing customers to meet future need, and requires a process including a water use audit, reduction measures, and monitoring of reductions (City of Toronto website 2008).

Eventually, as technical capacity in rainwater harvesting increases and costs of installation drop, more building owners will look into rainwater harvesting as a serious option, as municipal rates inevitably increase to raise necessary funds to pay for renewal of aging infrastructure.

7.2 Regulatory Process

Closely related to financial barriers are approval process and policy barriers. For new builds, or renovations requiring permits, any increase in the time for the development approvals process that delays building by even a few weeks adds significantly to the carrying cost of a building and can be a major disincentive. A 2006 study by the marketing consulting firm Freeman Associates showed that building and property owners consider the development approvals process long and cumbersome, and believe they could be slowed further by using innovative building techniques. The additional costs, most importantly in terms of time needed for design and the approvals process, are considered more significant than the system costs itself (Freeman and Associates, 2006).

Reducing this approvals time period by providing 'fast track' options if certain criteria are met or if certain pre-approved systems are used, or simply by training planning staff and inspectors to be familiar with the key issues around rainwater harvesting, can remove this disincentive.

Concerns about public health have been one core reason that regulatory bodies are reluctant to promote rainwater harvesting without further study. A CMHC meeting of rainwater harvesting experts in 2008 identified a number of needs to ensure consistency and safety with rainwater harvesting as a water supply including clear national standards, no risk of cross connections and contamination of the municipal water supply, long term safety and maintenance, and water quality monitoring (CMHC, 1998)(CMHC, 2008). The Canadian Standards Association created a set of national standards for water reuse equipment in 2006.

7.3 Technical Expertise and Capacity Building

A lack of capacity is one of the most significant barriers to greater use of rainwater harvesting in Toronto. This includes a lack of local experts and practitioners, technical experts to maintain and repair systems, and the technical knowledge of approvals staff and inspectors to quickly evaluate proposals (CMHC 2008). Part of the lack of expertise is related to the lack of a national rainwater harvesting association in Canada that can build capacity and support training activities and certification (as there is in other countries where rainwater harvesting is widespread such as Germany, Australia and the United States). Another related capacity issue in Canada is the lack of readily available rainwater harvesting products and equipment – purpose-built filters, pumps and cisterns are imported or custom-built. Until there is more technical knowledge and capacity, the cost to design, install and maintain a system will remain high, and out of reach for many building owners.

Local demonstration sites provide valuable local information regarding Toronto climate conditions and costs. The Toronto and Region Conservation Authority Sustainable Technologies Evaluation Program (STEP) evaluates and monitors green building technology in a Toronto context. STEP is monitoring three rainwater harvesting sites in new buildings – the Metro Label Printing facility in Scarborough, Brookside Public School, and the Minto Roehampton high-rise condominium in North Toronto. This monitoring provides valuable information for rainwater harvesting system performance in cold weather, Toronto's precipitation patterns, costs, and build local expertise in implementation (TRCA 2008).

Another key capacity building project that will have a significant impact on rainwater harvesting in Toronto and across Canada is the Rainwater Project in Guelph. The University of Guelph, City of Guelph, CMHC, Reid Heritage Homes and others have partnered to install and monitor rainwater harvesting systems in residential developments. The research will increase knowledge about the performance, maintenance and cost of individual systems, as well as small regional ones (shared by a few buildings). The provincial and federal governments are working with this project to assist in the modeling and writing of new policies and regulations.

7.4 Perception and Attitudes

A lack of knowledge about water issues, and the link between water and energy, affects the willingness of the public, building owners and policy makers to pursue rainwater harvesting as a tool for energy and water conservation, and stormwater management. The key fact noted in this paper, that Toronto's water system accounts for one third of the City's electricity use is a fact that would surprise many, and raising awareness about the many implications of water use and the benefits of rainwater harvesting would help to change attitudes. In terms of water conservation, the 'water abundance myth' that there is more than enough water in Canada for all of our needs, believed by most Ontarians, leads to a lack of urgency around water conservation (Brandes, 2007). Additionally, most Toronto residents are unaware that stormwater run-off is the main cause of water pollution; and finally, the perception of stormwater as a nuisance to be managed rather than as a resource that can be used means that many people simply overlook rainwater harvesting (Allen, 2007).

7.5 A Home Grown Model – the Green Roofs Program

Toronto's award-winning Green Roofs program is a prime example of how the City of Toronto can identify an effective solution that addresses multiple environmental issues in the city and encourage sustainable building technology in a creative way[20]. In 2001, the City of Toronto implemented a pilot study of different types of green roofs in small plots at City Hall, and in 2005 launched a two-year pilot program to offer subsidies to any building in the city (City of Toronto website 2008).

The Green Roof strategy has included public and expert consultation, the production of research reports, the creation of new policies, an information website and a fact sheet for builders, developers and engineers outlining building code and regulatory implications for green-roof development in Toronto.

The Green Roof subsidy program has resulted in the launching of a larger Eco-Roofs Incentive Program in 2009 that provides incentives for green roofs or 'cool' roofs (roofs that reflect thermal energy from the sun). The incentive program is for existing ICI buildings and provides $50 per square meter of green roof and between $2 - $5 per square meter of cool roof (City of Toronto 2008).

As further evidence of the City's commitment to green roofs, Toronto hosted the 2009 World Green Roof Congress, and recently passed the Toronto Green Roof Bylaw (effective January 31, 2010), which requires a green roof on all new buildings or additions with a gross floor area of more than 2000 m^2.

Using a similar model for rainwater harvesting would help to build public acceptance, create Toronto demonstration sites, build capacity among designers, engineers and municipal staff, and reduce the capital cost burden for building owners.

[20] Federation of Canadian Municipalities' FCM-CH2MHill Sustainable Community Award

8 Conclusion

In this report we have quantified the available electricity and GhG emission savings from the implementation of rainwater harvesting on all large buildings in Toronto. These preliminary calculations indicate that rainwater harvesting has the potential to significantly reduce Toronto Water's electricity use and GhG emissions (12%). Specifically, Toronto Water would save 63 GWh/year of electricity (saving $5.5 million/year) and 15 kt eCO_2/yr in associated GhG emissions. In addition, it has other benefits including reduced storm water run-off and combined sewer overflows, potential infrastructure savings, and preparedness for climate change.

There are financial, regulatory, technical capacity and public perception challenges to the implementation of rainwater harvesting in Toronto. The high cost of rainwater harvesting may be the greatest barrier to its widespread use. However, the multiple benefits of harvesting rain as the valuable resource that it is – and the environmental cost of not doing so – provide a strong argument for a concerted effort and bold investment in rainwater harvesting to overcome these challenges.

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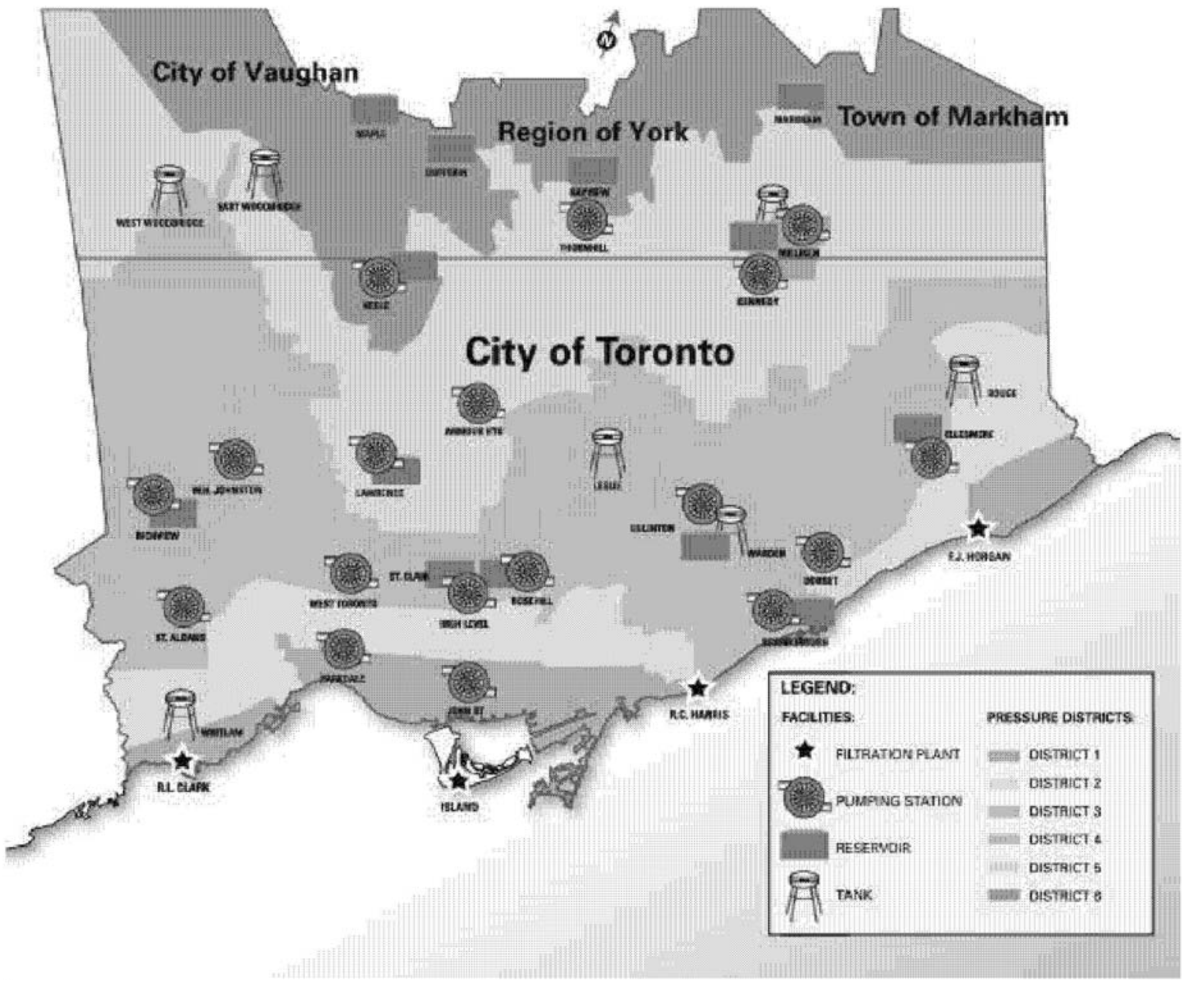
Appendices

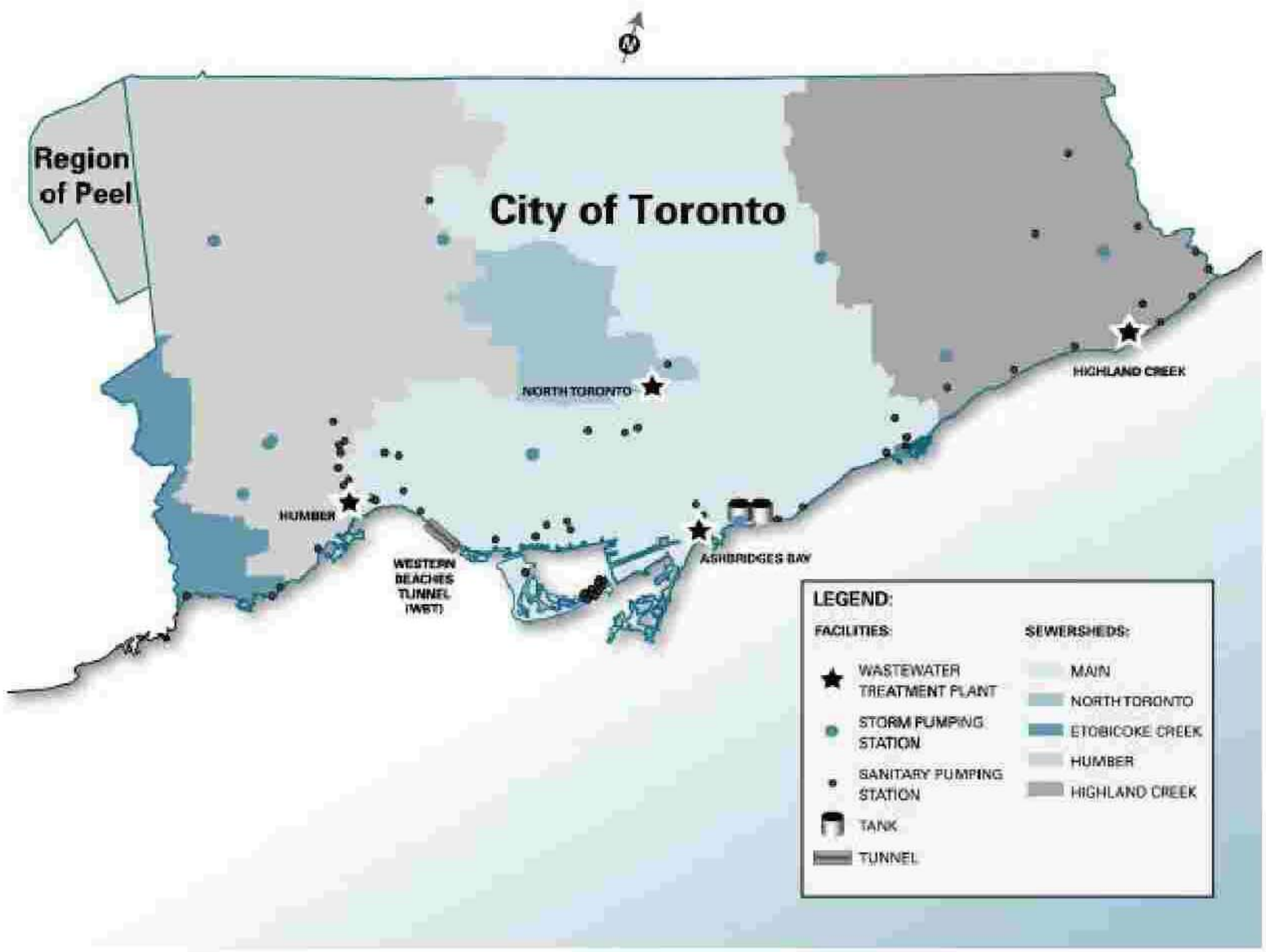
Appendix A: Toronto's Water Supply System

(courtesy of Toronto Water, from 2005 Multi-Year Business Plan)



Appendix B: Toronto's Wastewater Treatment System

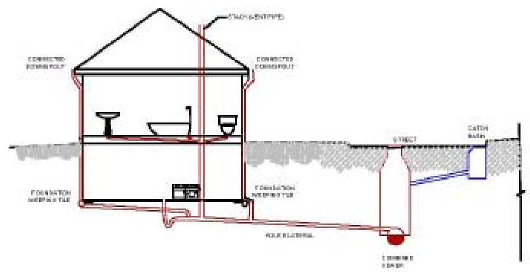
(courtesy of Toronto Water, from 2005 Multi-Year Business Plan)



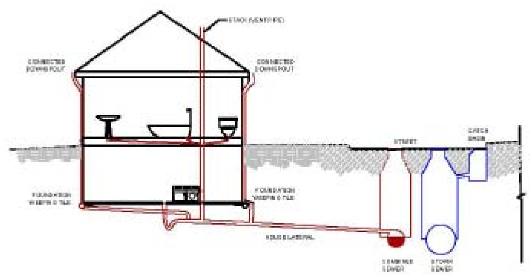
APPENDIX C – Diagrams of Combined Sewer, Partially Separated Sewer, Separated Sewer Systems

(courtesy of Toronto Water)

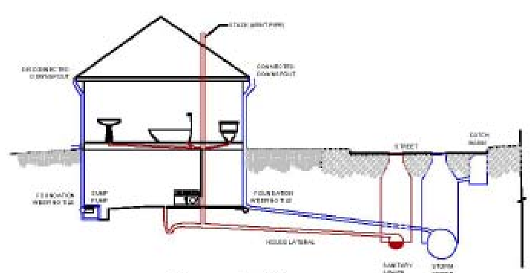
Toronto's Sewer Systems



Combined Sewer



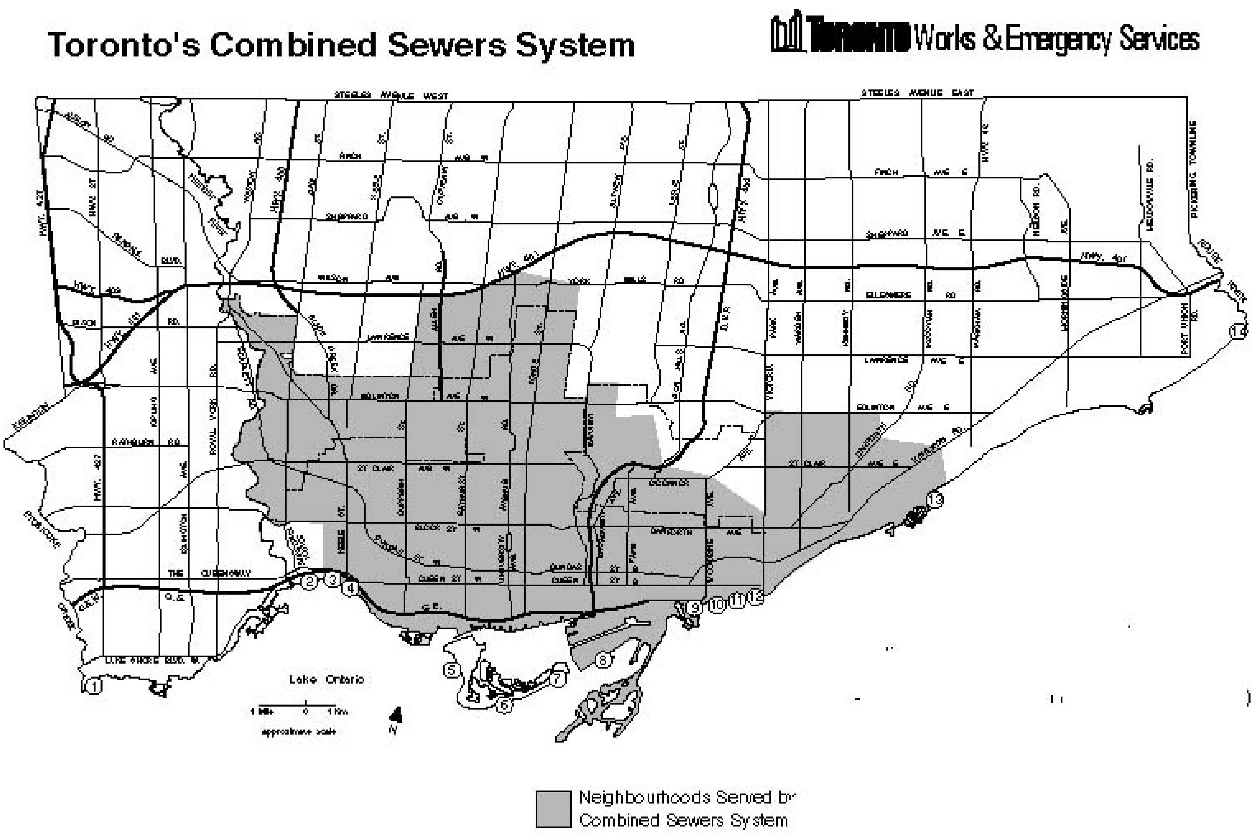
Partially Separated Sewer

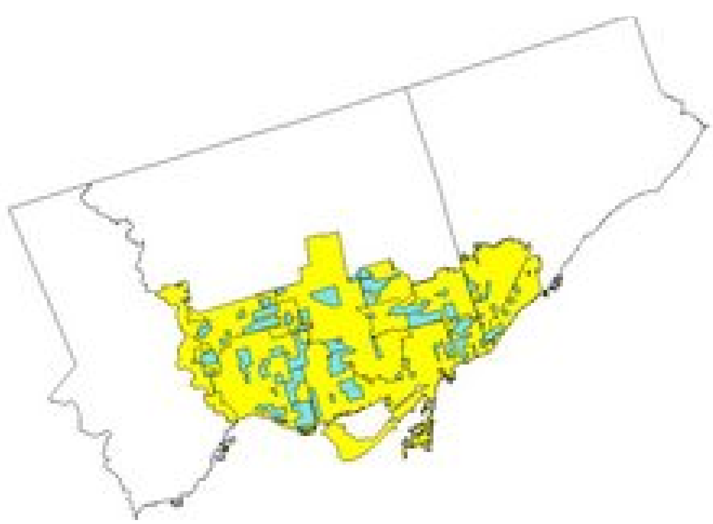


Separated Sewer

APPENDIX D – Maps showing Toronto's Combined Sewer Area

(courtesy of Toronto Water)





yellow = partially separated (70%)

blue = combined (30%)

APPENDIX E – Data on Rainwater Harvesting Applications in Toronto

Building	**Canpar Distribution Facility** (opened in 2006**)**	**SAS Canada Building** (completed in 2005, first commercial LEED building in Toronto)	**Metro Label printing facility** (completed in 2006)	**Minto Development's High-rise apartment** (completed Spring 2007)	**Brookside Public School** (built in 2007)	**Automotive Building**, **Exhibition Place** (to be completed May 2009)	**Masaryk Park-Cowan Community Centre** (installed in fall 2008)	**Artscape Wychwood Barns** (opened Nov. 2008)
Location	Western Toronto	280 King St. E. (near Parliament St.)	999 Progress Ave., Scarborough	150 Roehampton Ave. (near Yonge & Eglington)	75 Oasis Boulevard, Scarborough	Exhibition Place, Toronto	220 Cowan Ave. (Parkdale), Toronto	601 Christie St., Toronto
Description of Building	17,000 m^2 warehouse with parcel-sorting equipment, adjoining office & truck loading docks 6 hectare site	8 storey office building	12,260 m^2 printing facility, office space, truck loading docks, parking	16 storeys	71,000 sq.ft. Approximately 600 students		Large community centre, sloped roof	
Description of Rainwater Harvesting System	•Large, flat, built-up roof •Water is collected from ½ of roof (85,000 sq.ft.) •44 m^3 underground cistern •no treatment	•Rainwater collected from inverted roof & above-ground terraces •4 tanks totaling 40,000 L in lower level of building •filters •pumps & pressurized tanks	•950 m^2 roof collection area •18 m^3 cistern (12m^3 water draw tank & 6 m^3 settling tank) •tank float switch triggers when low to allow municipal water to fill tank •4 pressurization tanks	•21.7m^3 cistern in u/g parking (14.5 m^3 lower portion for RWH, 7.2 m^3 upper for stormwater detention) •float switch triggers valve when low to allow municipal water to fill tank •sand filter •small pump	•2,879 m^2 roof collection area •45 m^3 cistern (28m^3 water draw tank & 17m^3 settling tank) •2 large pumps, one small expansion tank	•12,000 gallon cistern •filter prior to cistern •Supplemented by raw lake water (existing irrigation system) or municipal supply in winter	•large metal roof •1,550-gallon (5,867 L) plastic elevated above-ground tank •gravity-fed into the HOPE Community Food Garden	•30,000 sq. ft. roof collection area •24,000 gallon cistern under floor slab •pumps •filters
Use of Rainwater	Toilets & urinals, irrigation	Toilets & urinals	6 toilets and 2 external hose bibs	3 toilets, irrigation	Over 20 toilets, irrigation	Toilets & urinals (8 washrooms)	Irrigation for community garden	38 toilets, garden irrigation
Cost	Information not available	Information not available	\$18K, excluding piping in building (~\$1/L)	~\$13K (~\$0.89/L)	\$35K (~\$0.77/L)	\$700K - \$935K	\$3K overall cost + in-kind engineering and design, volunteers for installation	Information not available
Reference	Canada Green Building Council 2008 Baker 2008	McDermott 2008	TRCA 2008	TRCA 2008	TRCA 2008 Kim 2007	Di Gironimo 2007 Williams 2008	Greenest City 2008 Hellebust 2008	Kroesen 2008

APPENDIX F – Description of Rainwater Harvesting System Components

A common residential rainwater harvesting system – a rain barrel - consists of a roof catchment area, gutters and downspouts that convey the rainwater, a simple mesh filter to remove debris, and a large plastic or wood container rainbarrel that has spigots or hose connections that can be used to water the garden. These simple systems are used for outdoor irrigation, and typically the cistern has a capacity of 100 to 500 L. Below, we explain components that are involved in a more sophisticated system.

1. Catchment Area

The catchment area is normally the roof, which may be metal, slate, tile, asphalt shingles, wood shingles, or tar and gravel. Note that asphalt and wood shingles, and tar and gravel roofs have toxins and so can not be used for potable water (TWDB 2005).

Different roofs have differing abilities to capture rainwater. Metal and slate roofs catch and transport rainwater efficiently because they are smooth, while clay/concrete tile and asphalt shingles result in ~10% losses due to inefficient flow, evaporation, and texture (TWDB 2005). Flat gravel roofs would have even more losses (Kinkade-Levario 2007). In addition to losses due to evaporation, there are losses to the first-flush system, splash-out or overshoot from gutters during hard rains, and tank overflow during large storms. Usually a capture efficiency of 75%-90% is assumed (TWDB 2005). A rough 80% efficiency factor is often used (Goedken 2006, TWDB 2004). (It is uncertain whether this factor is also applicable to snowmelt collection.)

2. Conveyance System

Buildings with pitched roofs have gutters and downspouts that convey the rainwater to the cistern. The gutters and downspouts are normally made of PVC, vinyl, aluminum or galvanized steel (TWDB 2005). Gutters work by gravity and so must be appropriately sloped. All downspouts must be directed to one cistern if there is only one cistern and there is a desire to collect all the rainwater that lands on the roof. This can be a challenge in a retrofit situation.

Buildings with flat roofs normally have drains that are internal to the building. The roofs are sloped slightly to direct rainwater towards these drain inlets, which are near the centre of the roof. The internal drain is connected to a storm sewer. For a rainwater harvesting system, these internal drains would be directed to the cistern.

3. Filters, First-Flush Divertors, and Roof Washers

Simple mesh filters located at the inlet to the downspout or inlet to the cistern can be used to remove debris. Another option is to add leaf guards (mesh along the top of all the gutters). (TWDB 2005)

First-flush divertors can be used to further improve the quality of the water to be stored. These divertors collect the first 1-2 gallons per 100 sq.ft. (0.4-0.8 L/m^2) of roof area of rainwater that falls on the roof. This first amount of water is not desirable as it contains a lot of the dust, pollen, bird and rodent feces that may have been on the roof as well as contaminants that were in the air (TWDB 2005)

Another way to further improve the quality of the water is to have a roof washer. This is a 30-50 gallon (110-190 L) tank that has a leaf strainer and a fine filter. Rainwater harvesting systems that are to be used for potable use or for drip irrigation should have a roof washer (TWDB 2005) or some other means of filtering out particles.

4. Cistern

The cistern is the key component of the rainwater harvesting system. It can be made of fiberglass, plastic, wood, galvanized sheet metal, concrete or ferrocement. Its size depends on the precipitation volume and length of dry spells in the region, the amount of water demand in the building, the catchment area, budget available and aesthetic and space considerations. (TWDB 2005)

Cisterns can be above-ground or buried. If above-ground, and exposed to sunlight, they should be opaque to inhibit algae growth, have a screen to discourage mosquito breeding, and be made to be non-UV-degradable (TWDB 2005). Should all year-round use be required, an underground fiberglass or concrete cistern must be employed in cold regions as above-ground water would freeze (Hall 2008).

5. Pump and Pressure Tank

Pumping of the water from the cistern to the end uses is required where the end uses require pressurized water and the tank cannot be placed above the end-use to generate pressure from gravity.

One configuration is to have a pump and a pressure tank (typical size 40 gallons (150 L)) with a pressure switch which turns the pump off when pressure tank reaches the required pressure. An alternate configuration is to have an on-demand pump, where the pump and pressure tank are integrated into one unit. This saves money and space as there is no separate pressure tank. (TWDB 2005)

6. Treatment System

If the rainwater is to be used for potable use, treatment is required by regulators. One configuration is to have the following (TWDB 2005):

- a 5-micron fiber cartridge filter (to filter out particles and dust)
- followed by a 3-micron activated charcoal cartridge filter (to filter out microscopic particles and absorb organic molecules)
- followed by UV light (to kill bacteria, virus and cysts)

Other treatment configurations may include ozonation, membrane filtration, or chlorination (TWDB 2005).