Toronto

"a water management experience to think about"

Skyline of Toronto, Canada. Photo credit: ©iStock.com/espiegle

Urban Water Management: City of Toronto a Case Study

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1. Introduction

The City of Toronto, with a population of 2.8 million residents, is Canada's largest city, located on the north shore of Lake Ontario, one of North America's five Great Lakes. The City of Toronto is the capital of the Province of Ontario (one of 10 provinces in Canada), and its municipal boundaries extend across a 640 square kilometer area, spanning six watersheds, where all but one of the watersheds extend beyond the City's municipal boundaries. The City has 11 waterfront beaches, eight of which have been granted the international Blue Flag designation and meet the strict Province of Ontario water quality standard for swimming beaches (Ontario, 1994) through most of the summer.

Toronto Water is a department within the City of Toronto municipal government, solely responsible for the provision of safe and reliable drinking water, the collection and treatment of wastewater, and stormwater management. Toronto Water is the largest supplier of municipal drinking water and wastewater treatment in Canada. Toronto Water was formed following the 1998 amalgamation of the former Metropolitan Toronto regional government with six former local municipalities. Prior to amalgamation, the regional government was responsible for the treatment and transmission of drinking water, trunk sewers and wastewater treatment. The local municipalities were responsible for local water distribution systems and sewers. This two tier governance structure for urban water management is typical across Canada. However, in addition to Toronto Water, Calgary Water Services and Halifax Water (a utility owned and operated by the Halifax Regional Municipality, and the only publicly owned water utility in Canada) are other Canadian examples of municipalities which have adopted the best practice of an integrated approach to urban water management. Integrating all water related operations under one organizational unit, ensures that the limited available funding is properly apportioned across all water service areas (drinking water, wastewater and stormwater) to meet the daily operational needs; and capital investment necessary to address the competing priorities of infrastructure renewal, urban growth servicing requirements, increasing regulatory requirements, protection of the environment, and climate change adaptation.

In Toronto, revenue obtained through metered water consumption supports Toronto Water's operating expenses and annual investment in infrastructure. Toronto Water operates and maintains infrastructure valued at over $28 billion CAD which includes 4 wastewater treatment plants, 4 water treatment plants, nearly 6,000 kilometres of transmission and watermains; and over 10,400 kilometres of sewers.

2. Governance

From a water governance perspective, it is important to recognize the regulatory and legislative framework under which the municipal governments in the province of Ontario operate their water systems. The Province of Ontario, through legislation, governs the provision of safe and reliable drinking water and the collection and treatment of wastewater. The Ontario Water Resources Act (Ontario, 1990a) is arguably the most important law protecting water quality and quantity for both surface and groundwater, and through which water supply and the discharge from municipal wastewater treatment facilities, stormwater management, and combined sewer overflows and treatment facilities are regulated. Complementing this Act is the Ontario Environmental Protection Act (Ontario, 1990b) which prohibits the discharge of contaminants into the natural environment unless an Environmental Compliance Approval has been issued specifying the allowable flow and concentration limits. These discharge limits are generally set, giving regard to Provincial Water Quality Objectives (Ontario, 1994), established to protect aquatic life; and recreational water use based on public health protection.

The most stringent requirements governing the discharge of wastewater effluent are captured within the Government of Canada's Fisheries Act (Fisheries Act, 1985), which prohibits the discharge of deleterious substances which would degrade or alter water quality such that it could be harmful to fish or fish habitat. Most recently, the Wastewater Systems Effluent Regulations (2012) were released under the Fisheries Act which specifically address municipal wastewater treatment plant effluents and impose strict limits for effluent quality, not previously regulated by the Province of Ontario, as well as requirements governing the annual reporting of combined sewer overflow discharges.

In Ontario, all upgrades or new municipal water, wastewater and stormwater system projects must adhere to the requirements of the Province of Ontario's primary environmental planning legislation: Environmental Assessment Act (Ontario, 1990c). This Act prescribes the process to be followed in consideration of options for these types of undertakings, incorporating public consultation. The options under consideration are evaluated based on ecological, social, cultural and economic impacts, which then frame the selection of the recommended preferred option for implementation. A guidance document produced by the Municipal Engineers Association (2011), provides a proven decision-making framework for various classes of projects (depending on their characteristics and significance) in compliance with the requirements of the Environmental Assessment Act.

An important piece of legislation governing watershed planning is the Province of Ontario's Conservation Authorities Act (Ontario, 1990d). The Act was first introduced in 1946 to enable the province and municipalities to join and form a conservation authority within a specified watershed based geographic area, to manage the province's watershed resources and protect lives and property from flooding and erosion. In 1956, following the devastating impact of Hurricane Hazel in 1954 where 81 lives were lost, thousands left homeless and massive economic losses were associated with widespread public and private property damage in the Toronto area, amendments were made to the Act. These amendments empowered the Conservation Authorities to prohibit filling of valley lands and floodplains, implement proper land use planning prohibiting urban development within flood-hazard areas such as floodplains, and the implementation of flood protection works such as dams, reservoirs, flood control channels and erosion control works.

In 2002, following the tainting of the municipal drinking water system for the small town of

Walkerton, Ontario, northwest of the City of Toronto, resulting in the tragic deaths of seven residents and over 2300 people becoming ill due to the contaminated water, the Province of Ontario passed the Safe Drinking Water Act (Ontario, 2002). The ultimate objective of this legislation was to protect human health through the control and regulation of drinking water systems, which include specific requirements governing operator training, standards for testing and reporting of drinking water quality. Licenses to operate drinking water systems are granted, conditional on the submission of sustainable drinking water financial plans. The financial plans, which must be approved by the governing municipal council, must demonstrate financial sustainability for both the utility's operations and longer term capital investment to address regulatory requirements, urban growth needs and infrastructure renewal. Toronto Water's 2010-2015 Drinking Water System Financial Plan also identifies all sources of funding for planned capital infrastructure projects (Toronto, 2010).

Complementing the Safe Drinking Water Act, the Province of Ontario enacted the Clean Water Act (Ontario, 2006) to protect drinking water, adopting a multi-barrier approach to prevent contaminants from entering sources of drinking water: groundwater and surface water. The Clean Water Act requires the establishment of multi-stakeholder Source Protection Committees, which include affected municipal water departments supplying water, the area conservation authorities, and affected industry sectors such as agricultural and land development. The Committees' overarching roles are to assess existing and potential water quantity and quality threats to drinking water sources; and to develop actions to reduce or eliminate the threats, embodied within formalized Source Protection Plans, developed with broad community consultation. Recently, a comprehensive Source Protection Plan (CTC, 2014), for an area extending over 10,000 square kilometres around the City of Toronto, directed at protecting 66 municipal groundwater supply wells and 16 municipal surface water intakes in Lake Ontario including the City of Toronto's four intakes has been completed and is awaiting formal approval from the Province of Ontario. The development of this Plan included undertaking a technical assessment of current municipal water sources to identify vulnerable areas; and existing and future water quality and quantity threats which may impair the long-term sustainability of the source. The Plan contains policies which address significant drinking water threats to ensure the protection of the drinking water sources, and identifies the responsible authorities to implement each policy.

To help support the financing of new or upgraded municipal infrastructure, including water, wastewater and stormwater systems required to service new urban growth, the Province of Ontario's Development Charges Act (Ontario, 1997) provides for the levying, by the municipality, of development charges to help pay for growth related off-site costs associated with the development. On-site costs are the responsibility of the developer. The Act requires that a ten year forecast of capital needs or upgrades are identified, which serves as the basis for the calculation of the charge. The funding accrued by municipalities through this legislation has supported significant upgrades and expansions in water systems across the Province of Ontario. In Toronto, funding accrued through Development Charges has supported Toronto Water infrastructure capital projects which ultimately support the servicing of future urban growth, as captured in Toronto Water's Drinking Water System Financial Plan (Toronto, 2010).

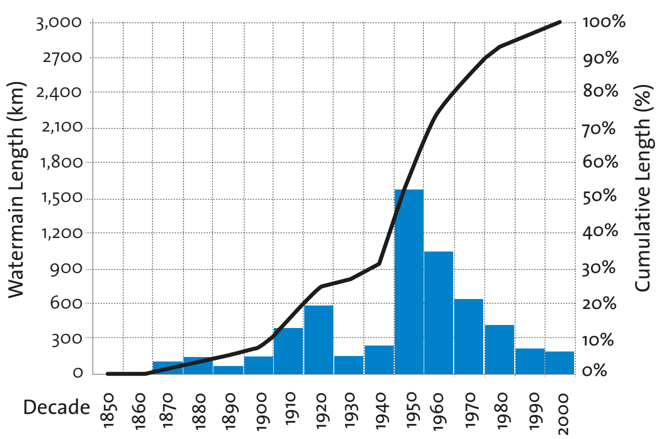
3. Infrastructure deficit / renewal needs

The water, wastewater and stormwater infrastructure renewal needs for older municipalities is a recognized problem across North America. The construction of this infrastructure has typically tracked urban development cycles; and much of this infrastructure is now at or nearing the end of its service life. In Toronto, an analysis on the longer term water and wastewater infrastructure renewal needs was last completed in 2008 (Toronto, 2008a). The analysis was undertaken by asset class: watermains, sewers, water treatment facilities and sewage treatment facilities.

The City of Toronto's water distribution system of 5,850 kilometres of pipe was estimated to have a replacement value of $5.9 billion CAD.

The construction of the water distribution system, dating back to the 1850s, is shown in Figure 1, by decade of construction. The Figure shows that the growth of the system tracks the urban development cycles in North America of the late 1800s, early 1900s and the major growth cycles of the 1950s, 1960s and 1970s. The average age of the system was estimated at just over 50 years, and where over 20% of the system was estimated to be 80 years of age or older, considered to be at the theoretical end of service life for this asset class.

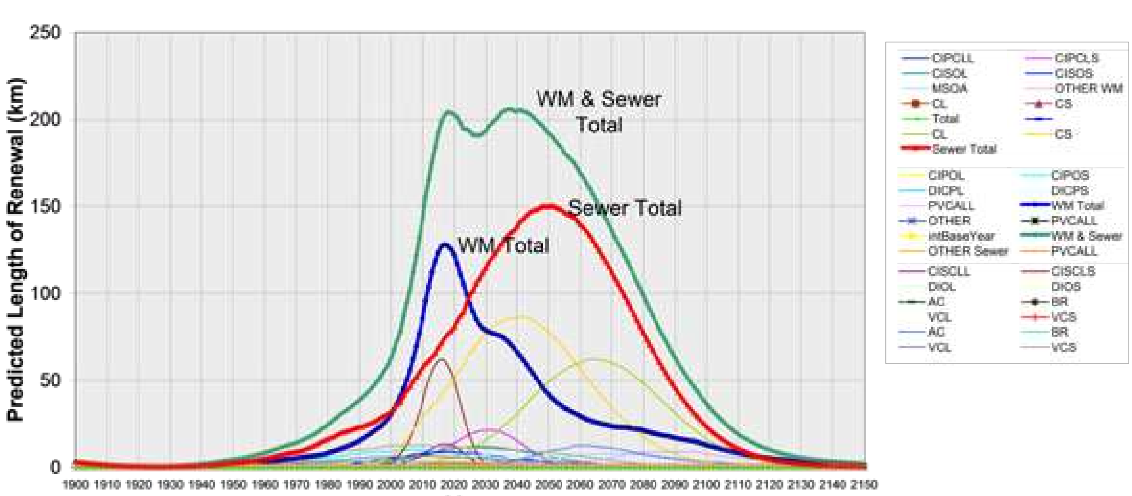
Figure 1. Watermain Infrastructure Construction History in the City of Toronto (Toronto, 2008)



By comparison, the City's sewer system of almost 10,600 kilometres of pipe was estimated to have a replacement value of $13.3 billion CAD. While the growth of this system followed similar construction cycles shown for watermains, some of the City's sewers date back to the early 1800s; and because combined sewers were constructed well into the 1950s, the age of the entire system is skewed by the fact that both storm and sanitary sewers were constructed subsequently, and therefore the overall age of this infrastructure class is somewhat newer than watermains, with the average age to be about 50 years, and 11% of the system was estimated to be 80 years of age or older.

To help assess the infrastructure renewal backlog and future renewal needs, the Water Research Foundation's KANEW model (Deb et al., 1998) was used. The KANEW model provided a methodology and software for predicting "survival" rates for cohorts of asset classes. The cohorts were established based on factors such as pipe type, age and material. A total of 12 and 8 cohorts were established for the watermain and sewer assets, respectively (Toronto, 2008a). The model was then used to generate predictions of annual infrastructure renewal needs. A summary of the modelling results, showing annual renewal rates for each cohort, all watermains, all sewers, and all pipes (watermains and sewers combined) is presented in Figure 2.

Figure 2. Predicted Annual Renewal Length by Year for: a) Watermains (WM); b) Sewers; and c) Total Watermains and Sewer Infrastructure (Toronto, 2008a)



Using this approach, the total watermain and sewer infrastructure renewal backlog was estimated to be 760 kilometres and 1,035 kilometres respectively, equating to a total renewal (defined as replacement and rehabilitation using trenchless structural lining technologies) need of $1.3 billion CAD, representing about 10% of the replacement value for these assets. However, if no additional investment is made in infrastructure renewal, each successive year adds to the renewal backlog. Based on the KANEW analysis, an estimated 70 to 130 kilometres (i.e. 1.2 to 2 percent) and 50 to 70 kilometres (i.e. 0.5 to 0.7 percent) of watermains and sewers, respectively, will be reaching the end of their service life and will need to be renewed annually, so as not to add to the backlog. Combined, this represented an annual investment of an estimated $110 million CAD, which includes pipe replacement and trenchless technologies such as the insertion of structural liners (examples can be found in D'Andrea, 2013) which can reduce overall costs and minimize disruption to the community.

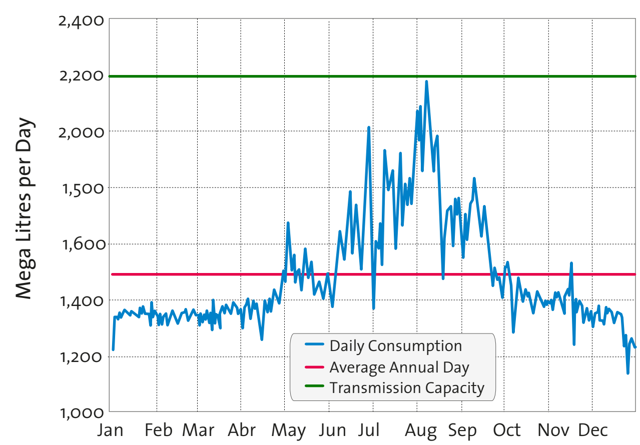
To address these needs, and the infrastructure renewal backlog at the City of Toronto's four secondary wastewater treatment plants (with a combined treatment capacity of 1.5 billion litres per day) and four water treatment plants (with a combined treatment capacity of over 2.7 billion litres per day), a longer term infrastructure renewal plan was developed, and is updated on an annual basis, as part of Toronto Water's annual capital budget submission.

4. Servicing future growth (water efficiency plan)

The City of Toronto's innovative Water Efficiency Plan (Toronto, 2002), approved by City Council in 2003, was directed at reducing water consumption across the City to create "in-system" capacity, to meet the short term projected population and employment growth (expected to increase by 10 to 12 percent, by 2011). The conventional approach was to expand water treatment and supply infrastructure which would have to supply peak day demand flows during summer months for outdoor water use (e.g. lawn watering); and wastewater collection and treatment infrastructure to support the additional wastewater flows generated.

In 2001, the typical annual water consumption profile for the City of Toronto with an average estimated consumption of 1260 ML/d and supply to York Region (a regional municipality north of Toronto) with an additional estimated annual average demand of 230 ML/d is presented in Figure 3. The figure shows a combined peak day demand of 2,210 ML/d, approaching the system's transmission capacity. The Toronto peak day demand represented an estimated 60% increase to the base (October to April) consumption of 1,155 ML/d in 2001.

Figure 3. 2001 Daily Water Consumption (ML/d) – (Toronto, 2002)



The Water Efficiency Plan's objectives were to reduce overall water consumption by 15% through the implementation of more water efficient fixtures and measures city-wide, to create capacity within the existing infrastructure and thereby defer costly infrastructure expansion, while decreasing energy use for pumping and corresponding CO_2 emissions, chemical usage at water and wastewater treatment facilities, and wastewater treatment plant effluent discharges. The underlying premise of the Plan was based on changing consumer behavior and influencing the purchase and implementation of more water efficient fixtures and measures by offering financial incentives. Measure specific financial incentives were derived based on a "capacity buy-back principle", where the value of the incentive provided was less than the cost of building the equivalent level of water and wastewater infrastructure: typically one-third the cost.

At the time the Plan was being developed, water used for toilet flushing and clothes washing represented nearly 30% and 22% of the average indoor water use, respectively (Toronto, 2002). While the Ontario Building Code mandated the use of ultra-low flush volume toilets for new home construction, high water consumption (13 litre) toilets were still being sold, typically at a much lower price point than the counterpart 6 litre and dual flush toilets. To help ensure success for the Toilet Rebate Program, which was a cornerstone of the Plan, and to address past criticism of first generation low flush toilets which often required multiple flushes to expel solids, toilet rebates were only offered for the purchase of specific toilets which met Toronto's minimum acceptable bulk solids removal requirements based on the standardized Maximum Performance (MaP) toilet testing protocol (Alliance for Water Efficiency, 2014).

The implementation of the Plan was estimated at $74 million CAD, and represented good value at one third the estimated $220 million CAD required for the equivalent expansion in water and wastewater infrastructure (Toronto, 2003a).

A number of water conservation/efficiency measures were identified for implementation by "water use sector": single family residential, multi-unit residential, industrial/commercial/institutional, and municipal; and included watermain system leak and water loss reduction; toilet replacement (to ultra low 6 litres or less flush volumes);industrial/commercial/institutional capacity buy-back program; outdoor water audits; computer controlled irrigation; and public education and community outreach.

Details regarding the methodology and derivation of the sector the specific financial incentives are contained within the Water Efficiency Plan (Toronto, 2002), which also sets out an implementation and monitoring plan. A water loss assessment and leak detection study was also undertaken, in support of the Plan development. The study found that water losses were in the order of eight to ten percent of the production totals, estimated at an annual value of $30 million CAD in treatment and transmission costs. Using the International Water Association (IWA) water audit methodology, and infrastructure leakage index (ILI) recognized as an international performance measure by which water utilities can objectively assess the level of water loss (AwwaRF, 2007), the City of Toronto was found to have an ILI of 4.2. As shown in Figure 4, the City of Toronto's results are in the middle of the range when benchmarked against municipalities across North America and internationally, respectively. Further, the study showed that an ILI of 2.5 is economically viable for Toronto and could achieve a leakage reduction of an estimated 49 MLD, valued at an estimated $15.8 million in treatment and transmission costs. To advance this initiative, the City of Toronto has developed a multi-facetted City-Wide Water Loss Reduction and Leak Detection Program, which is currently being implemented (Toronto, 2011a).

Water demands, measured as annual average daily demand (AADD) for Toronto, were analyzed and compared against the reductions forecasted through the implementation of the Water Efficiency Plan and the increases forecasted through the projected urban growth without water conservation, are presented in Figure 5. As noted, the actual water consumption reductions have exceeded the original Water Efficiency Plan projections, where the 2010 consumption dropped 14% from 2001 levels, notwithstanding that there was an estimated increase in population growth of 52,000 residents during this period.

While a number of factors have contributed to the lower than expected water consumption, including annual water rate increases, implemented to fund an aggressive infrastructure renewal program summarized below, the effectiveness of the Plan implementation must be acknowledged. Over 410,000 financial incentives (e.g. over 350,00 toilet rebates and over 60,000 rebates for high efficiency front load clothes washers) were issued at a cost of $37 million CAD, achieving a reduction in water consumption estimated at over 81 MLD, valued at an estimated $91 million in infrastructure expansion based on unit costs derived when the Plan was approved. However, based on actual construction cost escalations, this cost was re-assessed at an estimated $180 million CAD (Toronto, 2011a), representing an estimated 480% of the value of the financial incentives. Given the success of the program, changes in market conditions where the sale and promotion of water efficient fixtures and appliances have become the norm, and increased public awareness and support for conservation, most of the programs, particularly those offering financial incentives to consumers, were discontinued in 2011 (Toronto, 2011a).

Figure 4. Infrastructure Leakage Index (ILI) comparison across: a) North America; and b) Internationally (Toronto, 2011a)

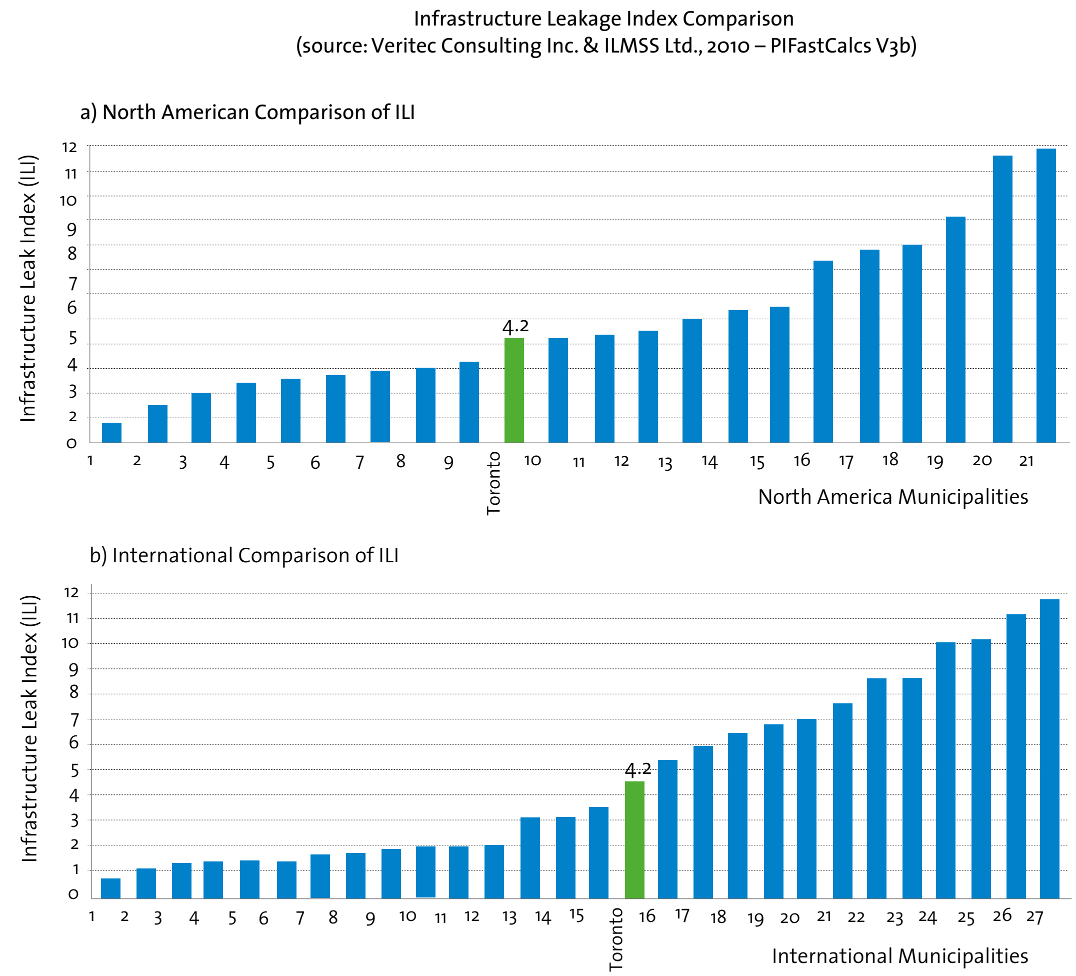
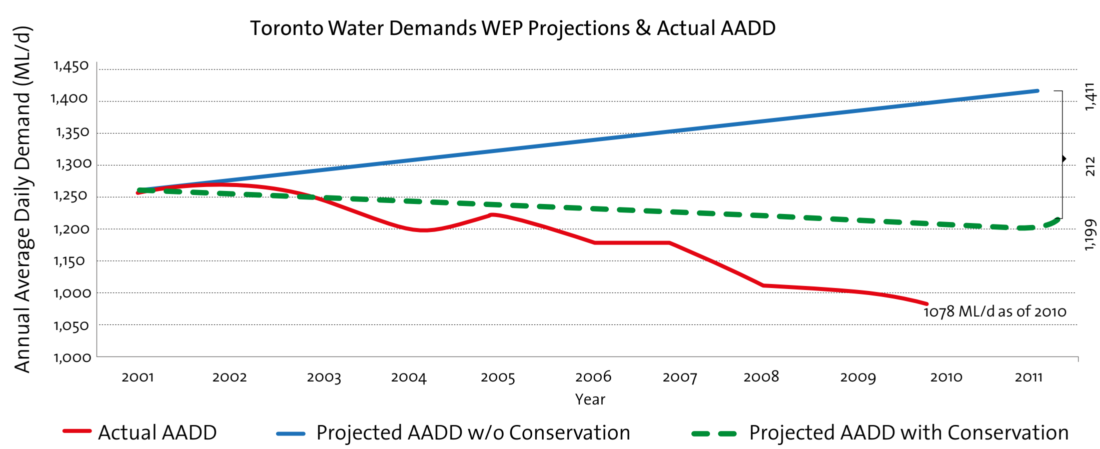
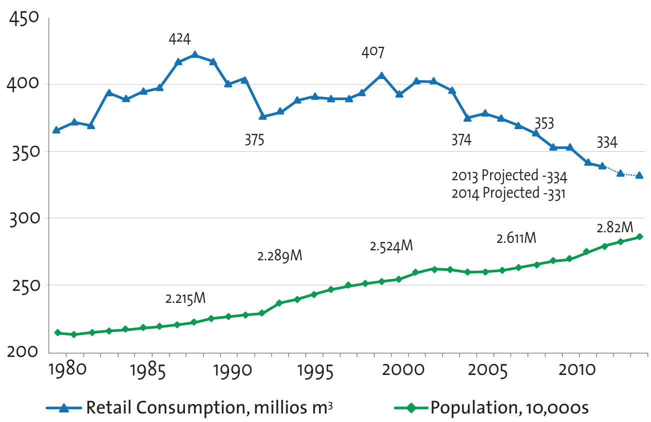


Figure 5. Toronto Water Demands: Water Efficiency Plan Projections and Actuals (MLD) – (Toronto, 2011a)



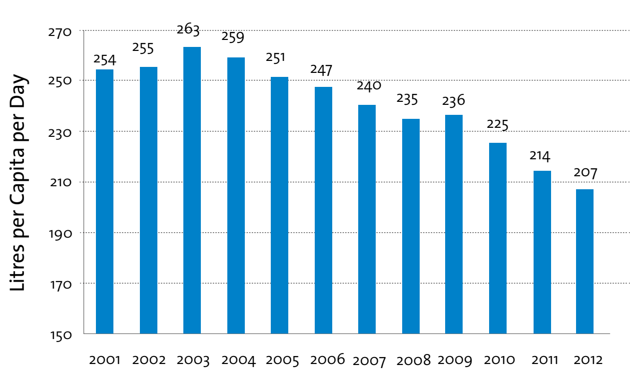
A recent summary (Toronto, 2013a) shows a more striking and continuing trend, where despite a significant population growth of an almost 8% (217,000 population) experienced between 2005 and 2013, water consumption has actually dropped an estimated 12% over this same period as shown in Figure 6.

Figure 6. Population Growth and Water Consumption: 1980 to 2013 (Toronto, 2013a)



Further, a steady drop in average residential per capita base (non summer) demand of about 2% per year, over the last 10 years, continues to be observed, as shown in Figure 7. With this trend, average per capita consumption is expected to drop to about 150 litres per capita per year by 2025.

Figure 7. Average Residential Per Capita Base Demand (Toronto, 2012)



Similarly, annual peak day water consumption associated with outdoor water use, largely for lawn watering, has also steadily declined to an estimated 1420 MLD in 2010, down an estimated 24% from the estimated 1850 MLD peak day consumption in 2001 (Toronto, 2011a).

While the reductions in consumption have been tremendously successful, this has had a profound negative impact on revenue, affecting Toronto Water's longer term infrastructure renewal plans, and water rate forecast predictions, which is discussed in more detail below.

5. Dealing with impacts of urban runoff (wet weather flow master plan)

Urban development within the City of Toronto and surrounding area has resulted in intense pressures on the ecosystem, and the alteration of the natural environment and hydrologic cycle, adversely effecting wet weather flows. In Toronto, this also results in increased stormwater runoff and polluted storm sewer discharges; combined sewer overflows (CSOs) from the combined sewer system which extends across about 25 percent of the city; and infiltration and inflows to the sanitary sewer system leading to wastewater treatment plant by-passes; which all contributed to degraded water quality in area watercourses and the Lake Ontario waterfront. The impacts of these wet weather flows have contributed to Toronto's designation as one of 43 polluted areas of concern in the Great Lakes Basin (Environment Canada, et. al., 1989). While past water pollution abatement measures focused on known pollution sources such as combined sewer overflow discharges, stormwater discharges in urban areas have also been found to be significant pollution sources. In Toronto, extensive studies of these discharges showed that event mean concentrations for storm sewer discharges were comparable to combined sewer overflow discharges (Figure 8). As shown in Figure 8, when compared against the Provincial Water Quality Objectives (PWQOs), the water quality constituent concentrations in these discharges is typically two to four orders of magnitude greater; and for E.Coli bacteria which is used as the beach water quality standard in Ontario, these discharges are typically three to four orders of magnitude than the PWQO of 100 counts/dL.

Figure 8. Event Mean Constituent Concentrations in Storm Sewer and Combined Sewer

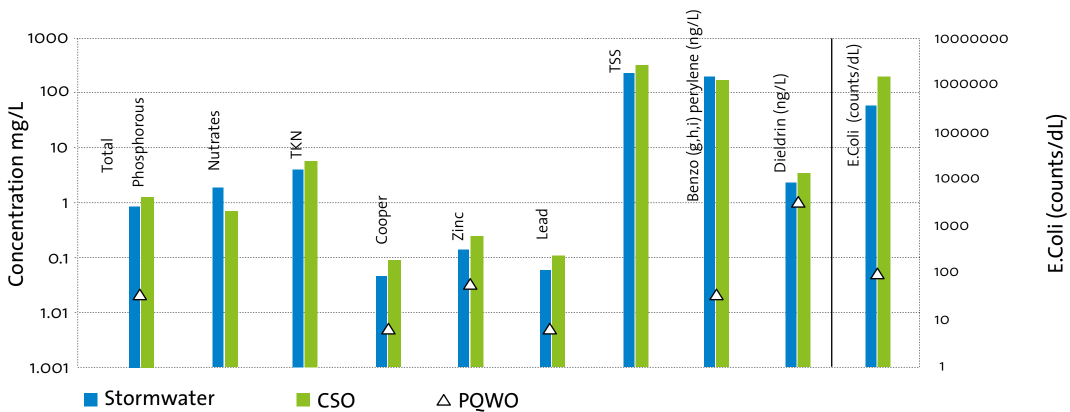
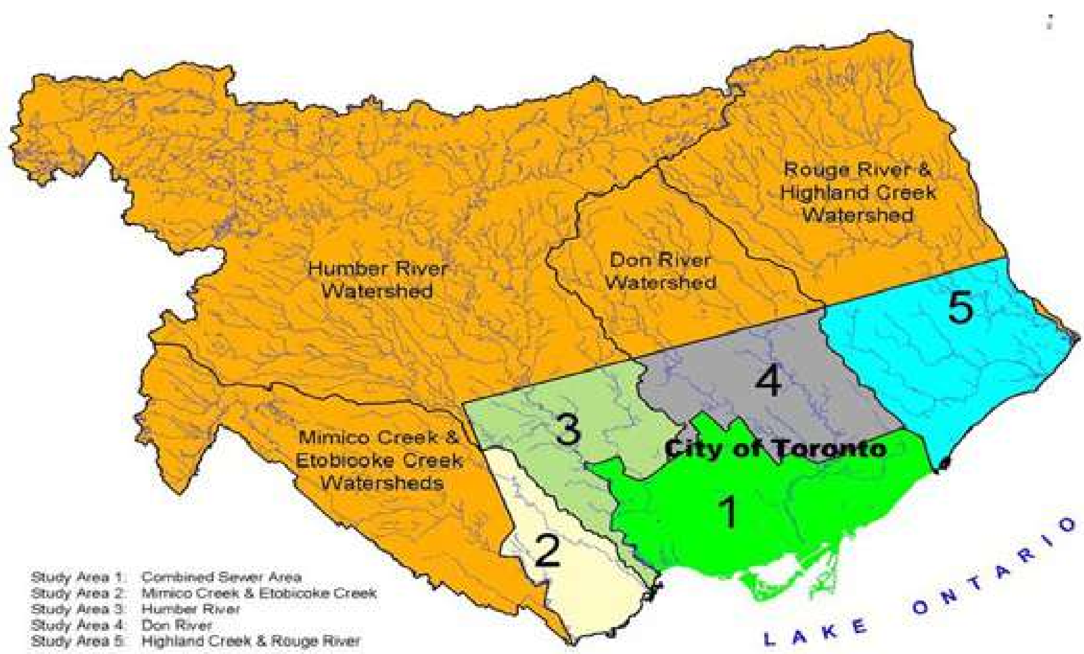


Figure 9. Study area for City of Toronto Wet Weather Flow Master Plan (D'Andrea, et. al, 2004a)



Further, more recently with the increased frequency of intense rainfall events exceeding the design capacity of the City's sewer system (typically during the summer months with characteristic high intensity shorter duration storms), the overloaded sewer systems lead to sewer back-ups and basement flooding (i.e. most homes in Toronto also have basements which provide below grade living space with floor drains connected to the sewer system).

In the Province of Ontario, new urban developments must prepare stormwater management plans as conditions of approval, in accordance with the Stormwater Management Planning and Design Manual (Ontario, 2003). In the absence of a regulatory requirement to deal with the adverse effects of wet weather flows in existing urban areas, previous wet weather flow initiatives in Toronto were driven, in large part, by the need to deal with localized flooding issues and water quality impacts on recreational beach areas. While source control options had been considered, the problems were generally addressed with hard infrastructure, and "end-of-pipe" solutions. Although these actions were significant and provided local environmental improvements, it was recognized that a comprehensive, watershed based approach was necessary across the entire City. This spawned the development of the City of Toronto's progressive Wet Weather Flow Master Plan which was approved by City Council in 2003. Consistent with the planning principles of the Province of Ontario's Environmental Assessment Act (Ontario, 1990c) and following the Master Planning process outlined in the Municipal Municipal Engineers Association (2011), the Plan was aimed at achieving set receiving water quality targets, in consideration of the Provincial Water Quality Objectives (Ontario, 1994) and incorporating broad public consultation at key decision points. Details of the Plan development, including the integration of sewer system, watershed and lake circulation receiving water computer simulation modelling to help assess the effectiveness of various options in achieving the end water quality objectives are summarized in D'Andrea et. al. (2004a) and D'Andrea et. al. (2004b). The Plan is considered the largest planning initiative of its type in Canada.

A new philosophy was adopted in the development of the Plan, which emphasized control of stormwater runoff at source. Further, following the stormwater pathway from individual property parcels to the receiving waters, a hierarchical approach to stormwater management was embodied in the Plan with measures and controls considered starting from source (lot level), followed by conveyance system controls, and then finally end-of-pipe. In parallel, a Wet Weather Flow Management Policy to guide new urban development/redevelopment and municipal works and operations was also developed.

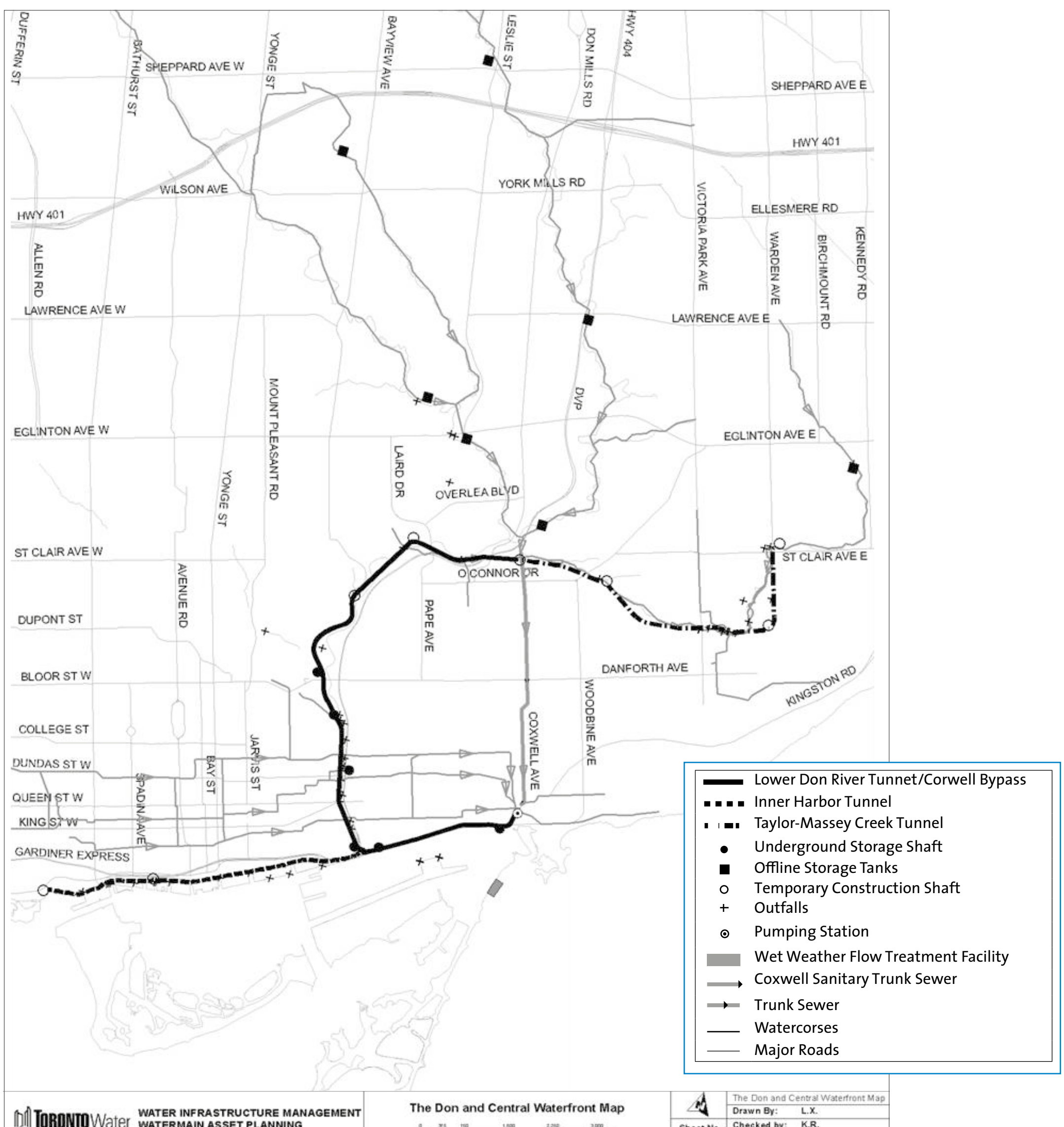
While the study area focused on the 640 km2 area contained within the City of Toronto boundaries, the study extended to include all six major watersheds (i.e. all but one of the watersheds extend beyond the City boundaries) which cut through the City, effectively representing a 2,100 km2 area (Figure 9), following an ecosystem management approach on a watershed basis (WEF/ASCE, 1998).

In developing the Plan, 13 objectives were developed, grouped into four major categories: water quality, water quantity, natural areas and wildlife, and sewer system (D'Andrea, et. al., 2004b). A number of strategies were developed, which represented a mix and varied level of implementation for the categories within the hierarchical framework of stormwater management: source, conveyance and end-of-pipe controls. Through computer simulation modelling, the effectiveness of the strategies in achieving the previously defined water quality objectives were assessed, and the costs estimated. A 25 year implementation Plan was developed, following extensive public consultation, based on the preferred strategy. The implementation of the comprehensive Plan (Toronto, 2003b), was estimated at over $1 billion CAD, and contained the following elements: public education and community outreach; enhanced municipal operations including a dry weather discharge remediation program, shoreline management, source controls (which led to the mandatory disconnection of all residential downspouts affecting an estimated 350,000 properties), conveyance controls (e.g. protecting and enhancing the City's extensive ditched road drainage systems, and construction of infiltration systems where appropriate through ongoing renewal of the City's aging sewer system) , end-of-pipe controls (e.g. including the construction of an estimated 180 stormwater ponds where sufficient open space was available; and underground storage systems for stormwater and CSOs in space constrained areas such as the downtown core), basement flooding protection works (which were expanded in scope subsequently and described in more detail below), stream restoration works (e.g. using natural channel design principles where possible); and environmental monitoring. In support of the Plan, a Wet Weather Flow Management Policy was also developed to guide actions and planning by the City on wet weather flow issues, particularly in regards to the servicing and requirements for new and redevelopment areas (Toronto, 2003c). Subsequently, Wet Weather Flow Management Guidelines were produced to direct prescribed levels of water quantity and quality control for new development (Toronto, 2006a). A summary of the progress made in implementing the Plan and priorities on a go forward basis can be found in Toronto (2011b).

One of the most significant projects contained within the Plan is the Don River and Central Waterfront Project, aimed at addressing most of the

City's remaining CSOs, and ultimately leading to the "delisting" of Toronto as an Area of Concern in the Great Lakes Basin. This project uses a "systems integration" approach to address the wet weather flow needs identified in the Plan, the longer term wastewater collection servicing needs supporting urban growth within the Don Sanitary Trunk Sewer System (the City's largest trunk sewer system, servicing an estimated 750,000 population), and along the Central Waterfront area, as one comprehensive project. The complete system (Figure 10) incorporates a 22 kilometre system of deep tunnels, underground storage elements, real time control for an existing trunk sewer, and a high-rate treatment facility to treat the flows captured (Toronto, 2011b). The project is in the engineering design phase and construction is expected to begin in 2017.

Figure 10. Don River and Central Waterfront Project Elements (Toronto, 2011b)



6. Climate change adaptation to address urban flooding: basement flooding protection program

In developing the Wet Weather Flow Master Plan, measures and system upgrades were included to address areas of the City which had recently experienced sewer backups leading to basement flooding. However, there was no consideration given to the urban flooding impacts from more frequent extreme storms resulting from climate change.

In August 2005, an intense rainfall with over 150 mm of rainfall over a two to three hour period resulted in over 4,000 basement flooding complaints across the newer areas of the City (serviced by separated storm and sanitary sewers); and caused significant damage to the City's infrastructure including the complete washout of an arterial road, a washout of a section of a sanitary trunk sewer, and extensive stream bank erosion damage. These impacts exposed the need to develop a plan for and effectively deal with the impacts of climate change. The impacts of this storm and the work plan which ensued are presented in D'Andrea (2011) and Toronto (2006b and 2008b).

A typical, post 1950s Toronto residential property has two sewer connections (i.e. previously only a single sewer connection was required to connect to combined sewers servicing the older areas of the City): one sanitary sewer lateral servicing the internal wastewater plumbing and basement floor drains; and one storm sewer lateral servicing the buildings foundation drains (although some homes have foundation drains connected to the sanitary sewer lateral instead) and downspouts (in cases where they are still connected). During periods of heavy rain (in excess of the sewer system design capacity), the sewer systems are overloaded and surcharge leading to sewer back-ups and wastewater flow into the basements, typically through the floor drains which are at the lowest elevation within the home.

Historically, there have been several instances where intense storms have resulted in widespread basement flooding. For the most part, incidents of basement flooding resulting from sewer backups had largely been eliminated except for extreme storm events, as a result of infrastructure improvements made to address this problem. In the areas of the City serviced by combined sewers, separate storm sewers to intercept road drainage were constructed to reduce flows to and surcharging of the combined sewers. In separated sewer areas, improvements were typically made to the sanitary sewer system by upsizing sewers to eliminate hydraulic bottlenecks, and constructing in-system storage facilities to address the increased levels of infiltration and inflows of stormwater to the system. Unfortunately, these upgrades were insufficient to accommodate the deluge from the 2005 storm.

A detailed engineering review was therefore undertaken to identify the problems contributing to the widespread flooding, and the upgrades necessary to reduce the risk of future flooding from extreme storms (Toronto, 2006b). The review found that the existing sewer systems were in generally good structural condition and performed as per their original design. The storm sewers, for example, were designed to intercept primarily road drainage for storms of a one in two, to a one in five, year return frequency. The storm of August 2005, was determined to have a return frequency in excess of one in 100 years, which completely overloaded the storm sewers, and contributed to a much higher than designed level of infiltration and inflow to the sanitary sewers.

As noted earlier, past attempts to alleviate basement flooding focused on the sanitary and combined sewer systems; and the storm drainage systems, both minor (sewers) and major (overland flow) were rarely reviewed. Most of the City of Toronto was serviced without a proper major drainage system, such that when the storm flows exceeds the design capacity of the storm sewer system, the stormwater remains on the road surface and flows to a low point where, ideally, it outlets via an overland flow route to the nearest watercourse. However, many areas of the City are very flat or have low points with no place for the water to outlet and therefore, during extreme storm events, significant ponding occurs on the street, often overtopping curbs and flowing onto private property (see Figures 11 and 12). Further compounding the problem, in many areas, the individual properties are poorly graded (in many cases toward the house) and, in some cases, the homes have reverse sloped driveways in which stormwater is conveyed directly to the house. As a result, this creates several opportunities for stormwater to enter the sanitary sewer system: a) within the road way, sanitary sewer access covers located in low lying areas prone to ponding provide a direct access point; b) stormwater ponding around the foundation walls of individual homes can enter through windows, doors, cracks in the wall, etc., and then ultimately to floor drains connected to the sanitary sewer; and c) where foundation drains are connected to the sanitary sewer saturated ground conditions will increase flows to the sanitary sewer, as shown in Figure 12.

Consistent with the Wet Weather Flow Master Plan, an integrated approach was used to develop the City's Basement Flooding Protection Program, to address the adverse impacts of extreme storms, which subsequently formed the City's climate change adaptation strategy dealing with urban flooding.

Figure 11. Overland Flow Paths in Residential Area of Toronto (D'Andrea, 2011)

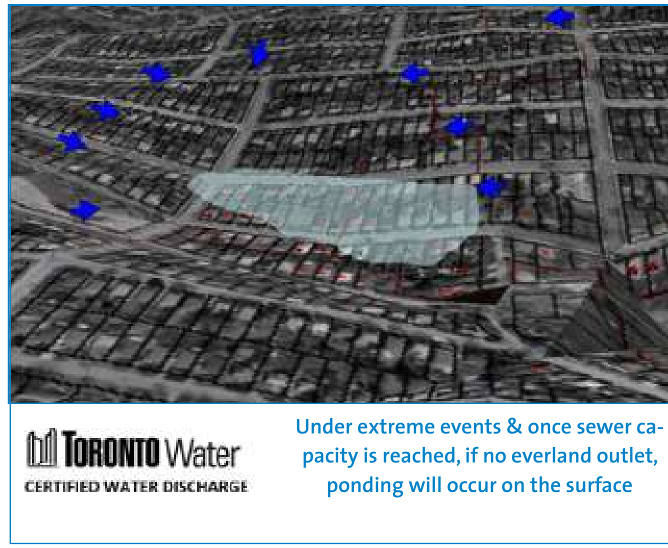
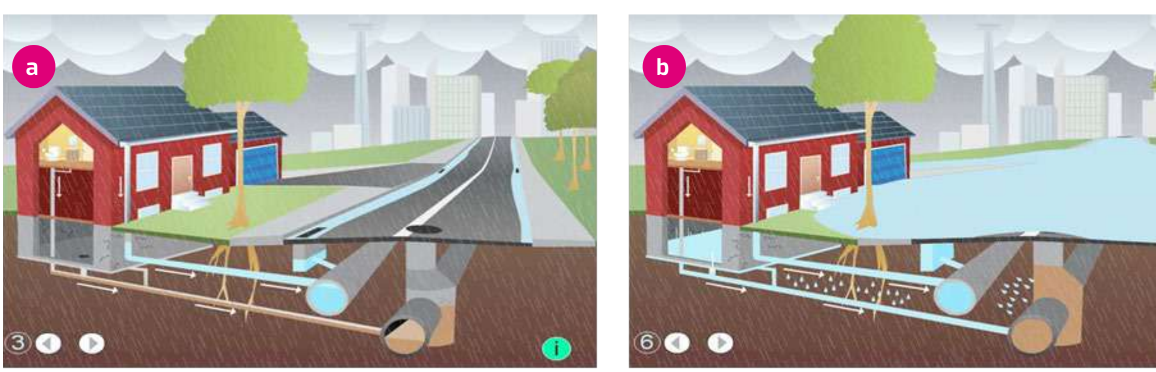


Figure 12. Separated Sewer System Schematic: a) normal function when storm flows are within sewer design flows; b) when storm sewer system is overloaded (D'Andrea, 2011)



The key elements of the program consisted of:

a. Source control measures: promoting the installation of backwater valves on the sanitary lateral servicing residential properties and the disconnection of foundation drains from the sewer system, and having them connected to a sump pump instead, wherein the City provides a financial subsidy to help entice the installation of both; mandating the disconnection of roof downspouts through regulation; promoting proper lot grading, repairing of cracks and leaks in foundation walls, windows, doors; and promoting soft-surface landscaping that help reduce the amount of stormwater runoff generated;
b. Sanitary sewer system improvements: increasing the service standard for sanitary sewers permitting a greater level of infiltration/inflow than conventional sanitary sewer design in basement flooding prone areas; and
c. Storm sewer system improvements: increasing the service standard for storm drainage systems to a one in 100 year storm event, where feasible, where a proper major (overland flow) drainage

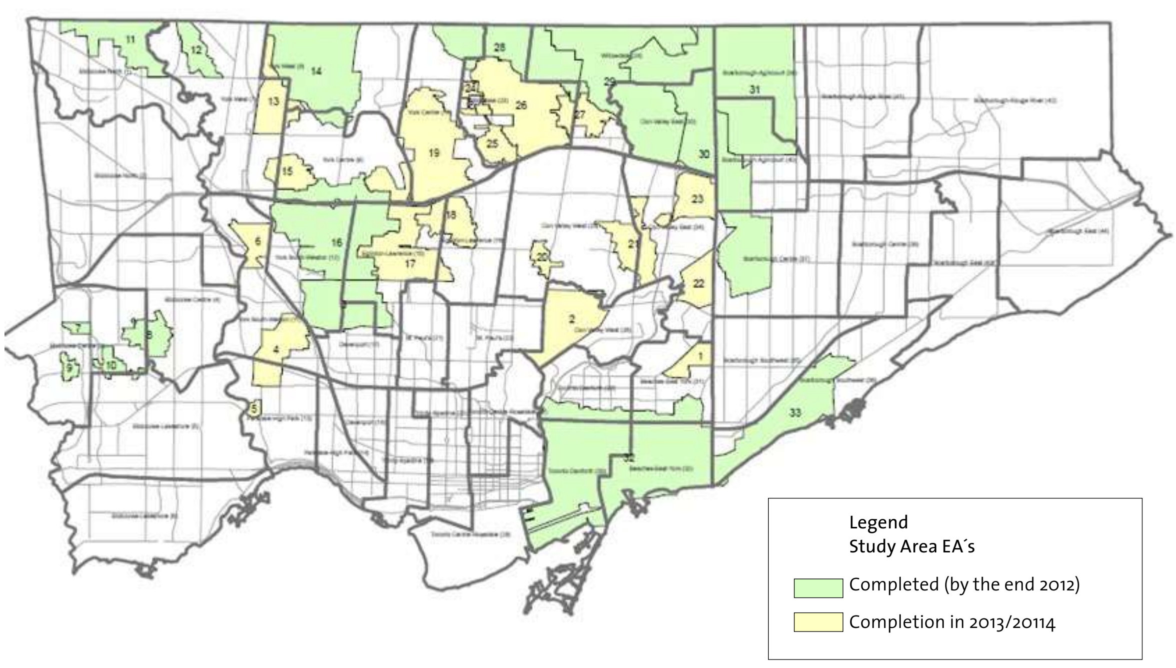
system does not exist. This typically involves construction of additional inlets in low lying areas with stormwater dry ponds where open space is available; and/or underground storage tanks or oversize pipes.

The Program was applied, initially, to 31 chronic basement flooding prone areas across the City (Figure 13), wherein environmental assessments with broad public consultation are used to identify and evaluate various options to help reduce the risk of flooding. As summarized, in Toronto (2008b), the environmental assessments were completed for the first four study areas, and consistent with the approach above, of the $230 million CAD identified in infrastructure improvements, only $20 million CAD were earmarked for sanitary sewer upgrades, the remainder was directed at storm drainage and storm sewer improvement works. Given the pent up demand and continued frustration by residents as extreme storms have continued to hit the City, where most recently in July 2013, more than 4,700 homes experienced basement flooding, the Program has grown to include an additional four study areas, and Toronto Water's ten year capital program has earmarked an estimated $1 billion CAD (Toronto, 2013a) for the implementation of infrastructure improvements emanating from the studies noted above.

7. Integrating and funding urban water management infrastructure needs

To fund the above-noted programs, the City of Toronto, through the Toronto Water Division, prepares an annual capital budget which includes a ten year plan of capital infrastructure projects and programs, necessary to meet the above-noted programs, and other projects across its three service areas: water treatment and supply, wastewater collection and treatment, and stormwater management. The projects are categorized in the following priorities: health and safety; legislated

Figure 13. Basement Flooding Protection Program - Environmental Assessment Study Areas (D'Andrea, 2011)



(e.g. projects aimed at complying with the Federal Fisheries Act -Wastewater Systems Effluent Regulations); state of good repair (e.g. infrastructure renewal); service improvement (e.g. the Basement Flooding Protection Program); and growth related (e.g. implementation of the Water Efficiency Plan and infrastructure upgrades). A summary of the infrastructure renewal and upgrades planned for 2014 and to the year 2023, by category, is presented in Toronto (2013a).

Toronto Water's 2014 approved capital budget was $613 million CAD; and the 10 year 2014 to 2023 Capital Budget and Plan was estimated at $8.97 billion CAD, of which 56, 24, 11 and 8 percent is directed at: state of good repair, service improvement, legislated and growth, respectively.

In Toronto, the capital budget submission is complemented with the submission of an annual water and wastewater rates report which contains a financial analysis of forecasted water consumption; corresponding revenue projections based on proposed rate increases; and a projection of the capital reserve balance from which the capital program is funded. The corresponding 2014 Water and Wastewater Rates and Service Fees report, supporting the 2014 to 2023 Capital Budget and Plan is presented in Toronto (2013b).

Early after the amalgamation of the City of Toronto, in 1998, annual water rates were generally set near the rate of inflation, but the revenue generated was insufficient to deal with the increasing capital program needs (Toronto, 2005). Annual rates were subsequently raised by nine percent and then six percent, respectively, however, capital reserve balances continued to be insufficient to fund the program requirements. In 2006, Toronto embarked on a nine for nine (nine percent per year – for nine years) water rate increase campaign, where all additional revenue generated was directed to funding the ever expanding capital program, with a priority placed on the ageing infrastructure renewal (Toronto, 2005). As noted earlier, a comprehensive analysis completed in 2008, across all infrastructure asset classes, estimated the infrastructure renewal backlog at $1.8 billion CAD. With the increased revenue and concerted investment in infrastructure renewal, at a rate greater than the rate of decay, by the end of 2014, the renewal backlog was estimated to be $1.6 billion CAD and with the continued planned investment, is projected to be eliminated by 2023 (Toronto, 2013a).

Toronto Water has been funded on a "pay as you go basis", where most of the funding to support its operations and capital program is funded through metered water consumption, without reliance on borrowing or debt financing. A two block rate structure is used for setting water rates: Block 1 includes all consumers including industrial consumption for the first 6,000 cubic metres per year; and Block 2 includes industrial process use water with consumption greater than 6,000 cubic metres per year with rates set as a Council approved policy at 30 percent reduction of the Block 1 rate. In 2014, the Block 1 and Block 2 rates were set at $2.96 and $2.07 CAD per cubic metre, respectively. The average annual single family residential household consumption is estimated at 300 cubic metres, representing an average annual cost of $814 CAD.

As noted earlier, despite the increase in population, total water consumption has been trending downward. Although weather conditions, particularly during the summer months affect outdoor water use (e.g. lawn watering), the steady decline is largely attributed to the continued implementation of water efficiency measures and economic factors. Currently, water consumption is estimated at 200 litres per capita per day, and if current trends continue, is expected to drop to 150 litres per capita per day by 2025. This has resulted in a significant reduction in forecasted revenue, limiting the available funding for capital project priorities, and the longer term capital program. As noted in Toronto (2013b), the current capital plan is facing a shortfall of over $1 billion CAD over the next 10 years, and additional funding needs to be raised to maintain current levels of service and to accelerate Council priority programs such as the Wet Weather Flow Master Plan and Basement Flooding Protection Program.

More recently, Toronto Water has begun exploring various options, including the introduction of a stormwater utility charge, which would create a dedicated funding source for all wet weather related projects (Toronto,2013c). In Canada, this type of charge has already been introduced in cities such as Calgary, Edmonton, Regina, London, Kitchener and Halifax.

8. References

AwwaRF, 2007. American Water Works Association Research Foundation Report 91163 Evaluating Water Loss and Planning Loss Reduction Strategies.

Alliance for Water Efficiency, 2014. Maximum Performance (MaP) Testing. http://www.allianceforwaterefficiency.org/Maximum_Performance_(MaP)_Testing.aspx

CTC, 2014. CTC Source Protection Region – Source Protection Plan (Amended). http://www.ctcswp.ca/wp-content/uploads/2012/10/20141215_CTCSourceProtectionPlan.pdf

D'Andrea, M., Snodgrass W.J., Chessie, P.D., 2004a. Development of a Wet Weather Flow Management Master Plan for the City of Toronto. Water Quality Research Journal Canada. Volume 39, No. 4, 417-431.

D'Andrea, M., Snodgrass, W., Chessie, P.D., 2004b. City of Toronto Wet Weather Flow Management Master Plan, Enhancing Urban Environment by Environmental Upgrading and Restoration, 57-78. J. Marsalek et al. (eds.), Kluwer Academic Publishers.

D'Andrea, 2011. A Climate Change Adaptation Strategy to Address Urban Flooding – The City of Toronto's Basement Flooding Protection Program. Presentation at the ICLR Basement Flooding Symposium, Toronto, Canada. http://www.iclr.org/images/MD-ICLR-110526b.pdf

D'Andrea, 2013. Big City Water Woes – Innovating the Fix. Canadian Water Network Conference, Connecting Water Resources – Changing the Water Paradigm, Ottawa, Canada. http://www.cwn-rce.ca/assets/resources/powerpoint/CWR-2013-Presentations/DAndrea-Michael-FINAL.pdf

Deb, A., R. Herz, Y. Hasit, and F. Grablutz. 1998. Quantifying Future Rehabilitation and Replacement Needs of Water Mains. AwwaRF, Denver, CO.

Environment Canada et al. 1989. [Environment Canada, Ontario Ministry of Environment, Ontario Ministry of Natural Resources, Metropolitan Toronto and Region Conservation Authority]. Metro Toronto and Region Remedial Action Plan. Stage I. Environmental conditions and problem definition.

Fisheries Act, 1985. Fisheries Development Act, R.S.C. 1985, c. F-14 Consolidated Statutes of Canada. http://laws-lois.justice.gc.ca/eng/acts/F-14/FullText.html

Municipal Engineers Association, 2011. Municipal Class Environmental Assessment. http://www.municipalclassea.ca/

Ontario, 1990a. Ontario Water Resources Act. http://www.e-laws.gov.on.ca/html/statutes/english/elaws_statutes_90o40_e.htm

Ontario, 1990b. Province of Ontario, Environmental Protection Act. http://www.elaws.gov.on.ca/html/statutes/english/elaws_statutes_90e19_e.htm

Ontario, 1990c. Province of Ontario, Environmental Assessment Act. http://www.e-laws.gov.on.ca/html/statutes/english/elaws_statutes_90e18_e.htm

Ontario, 1990d. Province of Ontario, Conservation Authorities Act. http://www.e-laws.gov.on.ca/html/statutes/english/elaws_statutes_90c27_e.htm

Ontario, 1994. Water Management Policies Guidelines Provincial Water Quality Objectives. Ontario Ministry of the Environment and Energy. https://www.ontario.ca/environment-and-energy/water-management-policies-guidelines-provincial-water-quality-objectives

Ontario, 1997. Province of Ontario, Development Charges Act. http://www.e-laws.gov.on.ca/html/regs/english/elaws_regs_980082_e.htm

Ontario, 2002. Safe Drinking Water Act. http://www.e-laws.gov.on.ca/html/statutes/english/elaws_statutes_02s32_e.htm

Ontario, 2003. Stormwater Management Planning and Design Manual, Ontario Ministry of the Environment. http://www.ontario.ca/environment-and-energy/stormwater-management-planning-and-design-manual

Ontario, 2006. Clean Water Act. http://www.e-laws.gov.on.ca/html/statutes/english/elaws_statutes_06c22_e.htm

Toronto, 2002. Water Efficiency Plan. http://www1.toronto.ca/City%20Of%20Toronto/Toronto%20Water/Files/pdf/W/WEP_final.pdf

Toronto, 2003a. Water Efficiency Plan – Staff Report. http://www.toronto.ca/legdocs/2003/agendas/council/cc030204/pof1rpt/cl029.pdf

Toronto, 2003b. Wet Weather Flow Management Master Plan - Overview and implementation plan -- Implementation schedule 2003-2027.

Toronto, 2003c. Wet Weather Flow Management Policy. http://www1.toronto.ca/city_of_toronto/toronto_water/files/pdf/wwfmmp_policy.pdf

Toronto, 2005. 2006 Water and Wastewater Rate Increase and Rate Projections for 2007-2015. http://www.toronto.ca/legdocs/2005/agendas/council/cc051208/pof12rpt/cl002.pdf

Toronto, 2006a, Wet Weather Flow Management Guidelines. http://www1.toronto.ca/city_of_toronto/toronto_water/files/pdf/wwfm_guidelines_2006-11.pdf

Toronto, 2006b. Work Plan for the Engineering Review Addressing Basement Flooding (City-wide). http://www.toronto.ca/legdocs/2006/agendas/council/cc060425/wks2rpt/cl016.pdf

Toronto, 2008a. Toronto Water's Infrastructure RenewalBacklog.http://www.toronto.ca/legdocs/mmis/2008/ex/bgrd/backgroundfile-16566.pdf

Toronto, 2008b. Update on the Engineering Review Addressing Basement Flooding. http://www.toronto.ca/legdocs/mmis/2008/ex/bgrd/backgroundfile-15074.pdf

Toronto, 2010. City of Toronto's Drinking Water System Financial Plan (2010-2015). http://www1.toronto.ca/city_of_toronto/toronto_water/files/pdf/council_approved_financial_plan.pdf

Toronto, 2011a. Water Efficiency Plan Update – 2011. http://www.toronto.ca/legdocs/mmis/2011/bu/bgrd/backgroundfile-34918.pdf

Toronto, 2011b. Wet Weather Flow Master Plan and Basement Flooding Protection Program Update. http://www.toronto.ca/legdocs/mmis/2011/pw/bgrd/backgroundfile-40671.pdf

Toronto, 2012. 2013 Water and Wastewater Water Rates and Service Fees. http://www1.toronto.ca/static_files/budget/2013/pdf/Report_2013_Water_Rates.pdf

Toronto, 2013a. Capital Budget Analyst Notes: Toronto Water 2014-2023 Capital Budget and Plan. https://www1.toronto.ca/City%20Of%20Toronto/Strategic%20Communications/City%20Budget/2014/PDFs/CA%20Capital%20Analyst%20Notes/Toronto%20Water%20-%202014%20Public%20Book-Capital%20Analyst%20Notes.pdf

Toronto, 2013b. 2014 Water and Wastewater Rates and Service Fees. http://www.toronto.ca/legdocs/mmis/2013/bu/bgrd/backgroundfile-63584.pdf

Toronto, 2013c. Future Options and Public Attitudes for Paying for Water, Wastewater and Stormwater Infrastructure and Services. http://www.toronto.ca/legdocs/mmis/2013/ex/bgrd/backgroundfile-62753.pdf

Wastewater Systems Effluent Regulations, 2012. http://laws-lois.justice.gc.ca/eng/regulations/SOR-2012-139/index.html

WEF/ASCE. 1998 Urban runoff quality management. WEF Manual of Practice No 23. ASCE Manual and Report on Engineering Practice No 87.ISBN 1 – 57278-039-8. 259 pp.