Beyond the Pipes: Planning for Sustainable Stormwater Management in the City of Toronto

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Abstract

Significant flooding in urban areas from strong storms and heavy rainfall has increased concerns about the ability of municipalities to manage the stormwater generated during these events and thereby protect infrastructure, properties, and public health and safety. Traditional stormwater management infrastructure has been successful in handling smaller storms but the infrastructure is aging and lacks the capacity to handle the large volumes of stormwater associated with these increasingly intense storms.

Sustainable stormwater management emphasizes natural solutions that combine function and performance with environmental, economic, and social benefits. Despite these advantages, integrating sustainable stormwater management practices into existing stormwater systems is a difficult process where the entrenched reliance on traditional solutions contributes to the multiple barriers to implementation.

The City of Toronto is a unique case study where political and fragmented administrative barriers have been addressed and a framework of policy, bylaws, and guidelines to encourage implementation of sustainable stormwater management practices has been established. Although several programs and projects have been initiated, financial, technical, and social barriers continue to slow progress in widespread implementation. The general lack of knowledge and understanding of stormwater as well as negative perceptions of stormwater must be overcome to encourage facilitation while lack of funding and incentives, and concerns about the operation and maintenance of sustainable stormwater management practices must also be addressed. The experiences of the City of Toronto show that although it is possible to overcome institutional barriers and ingrained beliefs, they have not yet been adapted to the current state of affairs.

Social, financial, and technical barriers must be dealt with for widespread implementation of sustainable stormwater management.

Foreword

This Major Paper (MP) fulfills the requirements of the Master of Environmental Studies degree by integrating the components that comprise my area of concentration of stormwater management and environmental planning to further investigate new perspectives. Understanding stormwater management in urban areas requires knowledge of the role and impacts of land use planning, as well as recognizing the increasing influence of the concept of sustainability in all areas of urban planning.

My research focuses on the barriers to implementing sustainable stormwater management in urban areas, integrating the components of stormwater management and flooding, land use planning, and sustainability. The MP meets the objectives for the stormwater management and flooding component through the investigation of the relationship between planning and stormwater management, including the role of urbanization in altering the hydrological cycle and increasing the risks of flooding, and an overview of the traditional and sustainable stormwater management practices that are in use.

While the objectives for the component of land use planning were primarily met through coursework, the MP presented the opportunity to explore the environmental impacts from urbanization that are often overlooked in planning. Various components of urban planning such as transportation and housing all generate stormwater runoff that can contribute to problems such as urban flooding or poor water quality if stormwater management is inadequate. Since the volume of runoff is a direct consequence of urbanization, good urban planning is crucial as a proactive step to minimizing the impacts of stormwater runoff.

The third component of sustainability is addressed by understanding sustainability in the context of stormwater management and identifying the environmental, economic, political, and social factors that influence the implementation of sustainable stormwater management. The overview of sustainable stormwater management practices such as low impact development provides further insight into the diverse ways in how sustainability is defined and expressed in different areas.

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Introduction

In the past few years, unusually strong storms and heavy rainfall have caused significant flooding in urban areas, heightening concerns about the ability of municipalities to manage the volume of stormwater generated during these increasingly intense storm events. Urban flooding is a serious issue because the concentration of individuals and developments can magnify the total destruction and economic losses from one flooding event (Jha *et al*, 2012). Effective stormwater management is needed to lessen the impacts of storms and their associated rainfall, thereby protecting municipal infrastructure, land and property, and public health and safety. While traditional methods of stormwater management are successful in handling smaller storms, it is apparent that the existing stormwater infrastructure may not have the capacity to meet the large storms predicted to occur as a result of climate change. Furthermore, aging stormwater infrastructure and limited funding creates additional challenges in addressing this issue.

As seen in other areas of planning and practice, the concept of sustainability and its principle of balancing current and future needs while considering environmental, economic, political, and social influences and impacts has been integrated into stormwater management to provide viable options that combine function and performance. Sustainable stormwater management emphasizes natural on-site solutions that offer ecological and social benefits, can be easy to implement, and are often more economical than engineered stormwater infrastructure. Despite these advantages, integrating sustainable stormwater management into the existing stormwater systems has been a difficult process with multiple barriers to implementation for various cities in Australia, the United States, the United Kingdom, and other countries. Since the entrenched reliance on traditional solutions contributes to these barriers, bringing sustainable stormwater management into the mainstream requires overcoming traditional perspectives and solutions for managing stormwater and broadening the perceptions of water in urban areas.

This research paper begins with a description of the hydrological cycle and how urbanization alters the natural processes to enhance stormwater runoff, followed by an overview of traditional stormwater management and sustainable stormwater management. The City of Toronto is used as a case study to explore the various barriers to implementing sustainable stormwater management as its unique circumstances provide a different perspective and experience from other jurisdictions. In the past decade, the City of Toronto has worked to integrate sustainability into its practices, including the development of a framework and policies to encourage sustainable stormwater management. However, implementation appears to be limited suggesting the presence of barriers to integrating sustainable stormwater management practices. A discussion of the barriers is followed by recommendations to increase implementation in the City of Toronto.

Research Methodology

The research was conducted using primary and secondary literature and interviews. Primary literature includes legislation from the provincial government such as the Planning Act, 1990, and planning documents such as the Provincial Policy Statement, 2014, and the Growth Plan for the Greater Golden Horseshoe, 2006. The City of Toronto was also a source for primary literature, particularly the Official Plan, the Wet Weather Flow Master Plan (WWFMP) and associated Guidelines, and the Toronto Green

Standard. Provincial and municipal government and agency websites were also consulted for current information related to stormwater management that has not been published in formal documents. Key secondary literature primarily includes technical guidance manuals released by governments and agencies, such as the Toronto and Region Conservation Authority and Credit Valley Conservation Authority's Low Impact Development Stormwater Management Planning and Design Guide and the United States Environmental Protection Agency's Using Smart Growth Techniques as Stormwater Best Management Practices. Peer-reviewed journal articles and books were also used to provide an academic perspective to the research.

Six candidates from a range of backgrounds were contacted for an interview. Candidates from the community and the private sector who were involved in stormwater management in some capacity did not respond to multiple interview requests. A Senior Engineer at Toronto Water declined to be interviewed but provided an alternate contact name. Of the three candidates who agreed to an interview, one interviewee is a Policy Advisor at Toronto Water and is currently working on updates to the WWFMP and Guidelines while another interviewee is a Senior Manager in Water Resources at the Toronto and Region Conservation Authority. The third interviewee is a consultant who was involved in the development of the WWFMP.

The Hydrological Cycle

Water balance in the air, land, and water is maintained through the natural processes of the hydrological cycle. In watersheds, the vegetation, topography, and subsurface of the land strongly influence the amount of water that is captured, stored, evaporated, and released into the watercourses. Surface water from precipitation flows as runoff in the watershed and eventually converges at an area of lower elevation, flowing into another water body (Ministry of the Environment (MOE), 2003b). During its movement to the tributaries and river, water may be temporarily stored in the vegetation and soils or in snowpacks in cold weather and then slowly released. Water may also infiltrate groundwater, allowing for groundwater recharge in the subsurface.

The geophysical character of a watershed influences the drainage of surface water and consequently the volume of runoff that flows in the watershed from precipitation (Barbosa *et al*, 2012). The speed at which water flows downslope is affected by the surface topography of the watershed (Price, 2011). In areas with little or no vegetative cover, water flows more quickly from the land into the rivers, thereby stripping the topsoil and causing erosion. However, in forested or vegetated areas, water can be absorbed by the vegetation and then slowly released back into the watershed through the process of evapotranspiration. The type and thickness of the soil also influences the volume of water that is absorbed. Thicker layers of soils comprised of fine particles will retain more moisture whereas coarse, thin soils will convey water more easily and store lower volumes of water (Price, 2011).

Below the soil layer, the topography of the subsurface can also influence the water storage and flow pathways in the watershed. Confining layers in the subsurface prevent infiltration of the water into deeper layers and instead promote shallow water storage (Price, 2011). This can decrease the volume of water that the watershed can absorb and handle during heavy precipitation. Furthermore, the geology of the watershed may also affect the drainage network of the hydrology in the basin (Price, 2011). Permeable or fractured bedrock may store higher volumes of water in comparison to bedrock that has minor fractures and stores small volumes of water for short periods. Depending on the connectivity of the bedrock, it may even funnel the water into subsurface storage.

Role of urbanization in flooding

Urbanization alters the normal hydrological processes in a watershed that enable the proper functioning of the hydrologic cycle (Parker, 1995). The physical environment is transformed such that the water balance is disrupted, the hydrological processes are obstructed, and the natural mechanisms that can manage high volumes of water are lost and replaced with urban surfaces and structures that cannot perform the same functions to a similar level (Figure 1). According to Karvonen, “urbanized areas have significantly less infiltrative capacity, resulting in larger volumes of runoff that change the hydrologic cycle from a largely vertical flowpath to a largely horizontal one” (p.10).

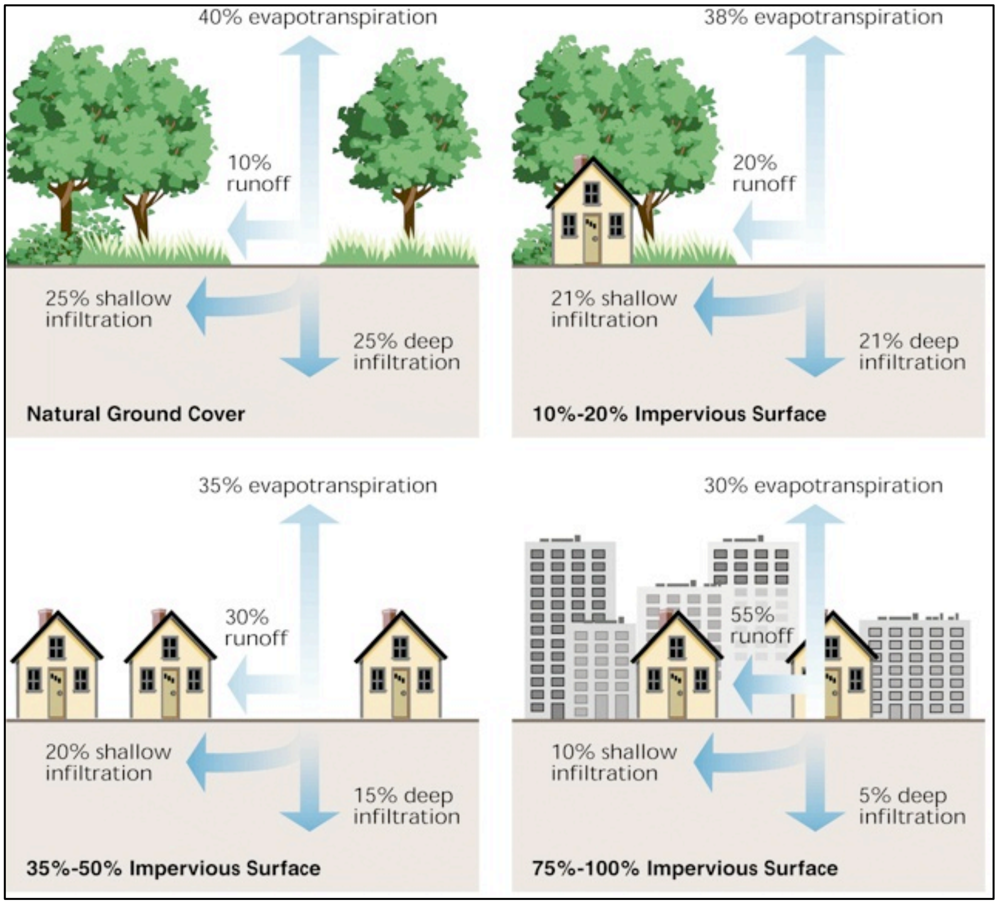

Figure 1: Comparison of the processes involved in water balance, pre-development and post-development (Source: Federal Interagency Stream Restoration Working Group, 1998)

The frequency and intensity of flooding events are increased as a result of these hydrological changes that generate more stormwater runoff (Stone and Bullen, 2006; Parker, 1995). According to Miguez *et al* (2009), "when the urbanization is not adequately planned, the negative consequences of that process are greater, more extensive, and more critical and may cause severe tangible and intangible losses as well as social problems of different magnitudes" (p.101).

The runoff generated in urban areas accumulates, causing higher volumes of runoff and discharge peaks, increasing the velocity of the flow and consequently altering the geomorphic properties of the streams (Barbosa *et al*, 2012). Stormwater runoff can trigger a rise in the number and/or intensity of flooding events because of these greater volumes of water, faster rate of flow and shorter duration of peak flow (Brody *et al*, 2007; MOE, 2003b). The magnitude of a flood may be higher because floods can peak more quickly due to the shortened time difference between the point of maximum precipitation volume and the point of maximum run-off volume (Brody *et al*, 2008). In addition to its impacts on flooding, stormwater runoff carries various organic and inorganic pollutants, including suspended solids, heavy metals, pathogenic microbes, and nutrients that can negatively impact water quality, thus disrupting and degrading aquatic ecosystems (Barbosa *et al*, 2012). Precipitation washes and transports the pollutants, untreated, from the urban areas and into the watercourse.

The fundamental problems leading to increased runoff that are created by urban development are specifically the reduction of water infiltration into the land and evapotranspiration from vegetation removed for development (Echols, 2008). The impact of urbanization begins as soon as the trees and vegetation are cleared from the land and the land is graded for the structures that will be built (Davis and McCuen, 2005). Removal of the trees and vegetation results in the loss of sources of water storage and the natural mechanism of evapotranspiration where vegetation releases water vapour back into the hydrologic cycle. The process of evapotranspiration can remove large quantities of water and, in some areas of the United States, is responsible for "dissipat[ing] nearly half of [the] annual rainfall volume" (Echols, 2008, p.205). Grading of the land fills in any water-holding depressions and also compacts the soil so that infiltration of water into the soil and subsurface is drastically reduced.

Impervious areas, a key feature of urbanization, have been identified as a major contributor to stormwater runoff and flooding, impeding infiltration and increasing the volumes of runoff, peak flow, and rates of flow (Brody *et al*, 2008). Impervious surfaces are considered to be surfaces such as the roofs of buildings that do not allow any water infiltration or roads, driveways, parking lots, and sidewalks that allow minimal infiltration through cracks or small holes. Since water cannot infiltrate impervious surfaces, it becomes surface runoff and is collected in stormwater sewers that divert the runoff into the watercourse. Although the majority of residential lots have lawns, these are typically landscaped and graded such that limited infiltration occurs and the lawns can thus be considered as impervious surfaces (Davis and McCuen 2005). Furthermore, the grass typically used on these landscaped lawns cannot store much water and thus excess precipitation becomes runoff. It is estimated that 80% of precipitation becomes runoff in areas with high density housing and impervious surfaces (Davis and McCuen, 2005). Research also suggests that severe negative impacts are evident when one-tenth of the area of a watershed is covered with impervious cover (Rogers and DeFee, 2005). Furthermore, a 10 to 20% increase of impervious cover in the watershed corresponds to a twofold increase in runoff (Brody *et al*, 2008).

Urbanization has also led to the intense development of land that was historically left untouched to accommodate seasonal flooding of rivers and streams, or low-lying lands susceptible to coastal tides. As an urban area continues to develop and grow, it becomes established as a flourishing urban centre that attracts migrating populations seeking a better life (Miguez *et al*, 2009). Since new development is constricted by the amount of land available, in order to accommodate the increased population and demand,

and economic pressures, municipalities have approved the intense development of low-lying lands (Wheater and Evans, 2009; Rogers and DeFee, 2005). The floodplains of rivers function as natural storage for excess water, thus lessening the potential for and impacts of flooding. By developing on the floodplains, the natural functions of this land are lost, thereby increasing the risks of flooding for the people, property, and infrastructure in these areas. Development in floodplains is often incremental, however once development begins, it is difficult to prevent further development thus the floodplains become intensely developed (Parker, 1995).

Traditional Stormwater Management

Urban stormwater management focuses on preventing localized flooding, protecting existing infrastructure and properties, and maintaining public health and safety (Winz *et al*, 2011). Large-scale engineered stormwater infrastructure has historically been regarded as the most effective way to meet these objectives. The guiding theories in stormwater management have been conveyance of the runoff away from the area at risk and storage of the runoff (Echols, 2008). To facilitate conveyance, modifications to the watercourses or construction of engineered drainage systems may be used. The natural paths of streams and rivers in developed and urbanized areas may be modified through straightening of the watercourse or installing artificial channels to reduce the flood risk at a particular location (Jha *et al*, 2012). These modifications cause increased rates of flow and flow capacity of the channel but can result in reduced storage, which ultimately increases the flood risk for downstream locations.

Runoff can also be directed through systems of drainage pipes that carry it from the impervious surfaces to water bodies (Burns *et al*, 2012). The runoff moves more quickly through the pipes to the receiving watercourse, creating higher flows and peak flows that can cause flooding (Jha *et al*, 2012). Furthermore, inadequate drainage systems can also cause localized flash flooding if they cannot handle high volumes of runoff (Parker, 1995). Although the runoff is redirected away from areas at risk of flooding, such drainage systems cannot replace the natural hydrological processes (Echols, 2008). The fundamental issues of reduced infiltration and evapotranspiration from urbanization still exist and the flooding risk is simply transferred to another area.

Detention or storage of the runoff was initially implemented to address the negative consequences of conveyance (Echols, 2008). By storing the excess runoff and then controlling its release, the peak flows could be reduced and thus minimize downstream flooding (Jha *et al*, 2012). Artificial storage facilities such as dams and reservoirs, retention and detention ponds are constructed to hold the runoff, and often include a flood control system with outlets and spillways or overflow, to manage the release of the water when necessary. Underground storage basins for detention to decrease flooding and sewer overflow discharges have also been constructed (Barbosa *et al*, 2012). However, detention basins designed for runoff from large storm events cannot successfully manage the runoff from the smaller but more frequent storms (Echols, 2008). Furthermore, the extended high flow rates of the runoff released into the streams have resulted in erosion of the stream banks. To address the smaller runoff volumes, overflow retention systems are used to retain the excess runoff and thereby reduce peak flows.

Sustainable stormwater management

Historically, stormwater runoff was considered to be "a hazard to be temporarily contained and then discarded as an unwanted byproduct of urban development" (Echols, 2008, p.205). Water was an unruly force that needed to be continuously constrained and regulated in a "repressive rather than productive" disciplinary approach in order to sustain urban life (Jones and Macdonald, 2007, p.535). Urban stormwater management relies "heavily, if not entirely, on engineered systems to collect and convey runoff to nearby receiving waters" (Donofrio *et al*, 2009, p.179). In response to the need to handle a greater capacity of water, the "traditional response to this has been to produce an ever harsher disciplinary regime – more and bigger pipes attempting to move water around ever faster" (Jones and Macdonald, 2007, p.536). Ultimately, urban areas become dependent on the engineered infrastructure in a self-reinforcing feedback loop where the drainage systems installed to prevent flooding increase the velocity and volume of water, thus increasing the potential for downstream flooding that is typically mitigated with installation of more pipes to prevent flooding (Winz *et al,* 2011). The stormwater management systems themselves can also contribute to flooding if the structures fail or the capacity of the drainage system is overwhelmed, thus leading to overflowing storm sewers (Wheater and Evans, 2009). According to Jones and Macdonald (2007), "repressive disciplinary mechanisms tend to exacerbate the impact of water's unruliness when those mechanisms are finally breached" (p.536).

Since the majority of stormwater management infrastructure has been placed underground, "both water and the repressive disciplinary infrastructure systems that contain it are now completely taken for granted by the general population" (Jones and

Macdonald, 2007, p.536). Stormwater engineering has focused on "approaches to size drainage networks and convey stormwater from cities as quickly as possible, a logic that can be summarized as "end of pipe, out of sight, out of mind" (Karvonen, 2011, p.7). Despite the protective benefits of traditional engineering infrastructure, it lessens our exposure to nature and understanding of nature (Winz *et al,* 2011). This results in a disconnection between people and the local environment thus "creating a modified 'static' aesthetic for previously living, dynamic ecosystems" (Winz *et al,* 2011, p.337). Burying stormwater management from the public eye weakens not only the general understanding of the role of municipal infrastructure but more importantly, the value of the environment's functions and services.

As cities continue to grow, increased demands and pressure are placed on existing and aging municipal stormwater systems. It is economically unfeasible to design and construct a drainage system capable of handling the range of precipitation volumes from all storms, especially when considering the growing intensity of storm events (Jones and Macdonald, 2007). The sunk costs in constructing and operating this infrastructure are substantial thus adopting other technologies can seem daunting (Winz *et al,* 2011). However, the costs of repairing or replacing this infrastructure can force some cities "to replace aged systems with a more integrated approach to accomplish multiple goals in water supply and wastewater management while realizing cost benefits" (Donofrio *et al*, 2009, p.180).

As a result, "new forms of water management are beginning to arise which attempt a more regulated, productive form of discipline attempting to work with water's more unruly characteristics rather than trying to suppress them outright" (Jones and

Macdonald, 2007, p.536). The approach towards stormwater management is evolving to focus instead on long-term sustainability, resilience, and cost efficiency (Donofrio *et al*, 2009). Known as low impact development (LID) in Canada and the United States, water sensitive urban design (WSUD) in Australia, and sustainable drainage systems (SuDS) in the United Kingdom, this new approach is an "integrated water management system that encompasses low-impact design, water conservation and recycling, water quality management, and urban ecology" (Donofrio *et al*, 2009, p.179). Through the integration of urban planning with sustainable water resource management, LID aims to simultaneously manage stormwater using sustainable methods and protect water resources to create resilient communities that are better able to deal with increasing demands and stressors. The key principles of this approach are to:

- use the natural systems as the framework when planning for development and protect natural features involved in hydrological processes
- emphasize the prevention of runoff
- encourage pollution prevention by treating stormwater at its source
- create landscapes with multiple uses and benefits
- provide education on stormwater management and ensure ongoing operation and maintenance of stormwater management systems (Davis and McCuen, 2005; Toronto and Region Conservation Authority (TRCA) and Credit Valley Conservation Authority (CVC), 2010)

The goal of LID is to "plan, design, construct and maintain a site such that the quantity and quality of the runoff that leaves the site replicate pre-development characteristics" (Davis and McCuen, 2005, p. 337). LID emphasizes maintaining and enhancing the natural processes of the hydrological cycle, aiming to achieve the pre-development hydrological and water quality characteristics "by increasing retention, detention, infiltration, and treatment of stormwater runoff at its source" rather than directing runoff off-site as quickly as possible (Donofrio *et al*, 2009, p.183).

Implementation of LID practices can reduce flooding and erosion of streambanks, and improve groundwater recharge, water quality, and aquatic habitats (TRCA and CVC, 2010).

LID can be integrated into various sites from new developments to infill developments, in rural areas and existing cities, and across a scale ranging from single lots to subdivisions to municipal systems (Davis and McCuen, 2005). In areas that have already been developed, LID practices can be used as retrofits to enhance and/or replace the existing stormwater management infrastructure by reducing the volume of runoff and pollutant loadings, thereby lessening the burdens on the system (Stovin *et al*, 2013). Although LID alone is not intended to serve as the basis for flood control, the implementation of multiple LID practices can provide additive reductions in the volume of runoff generated from the source area thus potentially reducing the peak flows and the overall impacts of larger storm events (TRCA and CVC, 2010).

In addition to the benefits of reduced runoff volumes and lower pollutant loadings, LID can provide direct social benefits to the community. Site design LID practices such as preservation of open spaces and forested areas can improve natural habitat, provide recreational opportunities, and increase the marketing potential of lots on the fringes of the open space and raise property values (United States Environmental Protection Agency (EPA), 2007). LID practices can also improve the aesthetic appeal of the landscape and the quality of life.

The use of LID can reduce total project costs for stormwater management. An analysis of the costs of LID suggests that in the majority of 17 case studies, implementing LID resulted in significant capital cost savings of 15 to 80% because of the lower costs for site grading, stormwater infrastructure, paving, and landscaping (EPA, 2007). Cost savings are achieved due to a reduction in materials for roads, sidewalks, curbs and gutters, and smaller sizes of flood-control structures. Although maintenance costs for certain LID practices may be slightly higher, other LID can be maintained through standard lawn and landscape care.

Structural Low Impact Development

LID incorporates both structural and non-structural techniques to meet the goal of attaining the pre-development water balance and quality of a site. Structural LID includes lot level source control and conveyance practices that can be applied onsite to the buildings or the land (TRCA and CVC, 2010). Source control structural LID such as infiltration basins and trenches, porous pavement, green roofs, rain gardens, cisterns, and rainwater barrels, minimize the amount of runoff and pollutants onsite through infiltration or storage for reuse, evaporation, or irrigation (Donofrio *et al*, 2009; EPA, 2007). Treatment control structural LID typically rely on filtration practices to capture or treat the pollutants that can impact the receiving watercourses and includes measures such as buffer strips, vegetated filter strips, bioswales, bioretention areas, constructed wetlands, and tree pits.

Multiple small-scale source control practices can be incorporated throughout a site to maximize opportunities for the infiltration of runoff (Davis and McCuen, 2005). The type and number of LID practices that are constructed on a site is dependent on factors including the land use, topography of the site, soils, geology, and groundwater levels and uses (TRCA and CVC, 2010). To supplement LID, appropriate design and landscaping can increase infiltration and attenuate the flow of the runoff through meandering flowpaths and highly permeable soil, and promote retention and evapotranspiration with suitable vegetation (Davis and McCuen, 2005).

Non-structural Low Impact Development

Non-structural LID uses site design and planning principles to minimize the urbanization of undeveloped land and the use of stormwater systems (TRCA and CVC, 2010). These strategies focus on reducing the amount of impervious area, using appropriate site layouts and dimensions, preserving natural hydrological functions, and using natural drainage to achieve the LID objectives. Site design strategies are typically more economical, efficient, and visually attractive than the traditional end-of-pipe solutions that control and treat stormwater.

Since impervious areas have been linked to runoff, reducing the amount of impervious area is an evidence-based planning strategy to reduce the volume of runoff. In the United States, some local governments have implemented regulations that limit the ratio of impervious surface on a site to the total site area in an effort to maintain natural infiltration across a watershed (Sung *et al*, 2013). However, Jones *et al* (2005) suggest that regulatory measures that impose maximum limits on impervious cover in one area of a watershed may inadvertently lead to the distribution of impervious areas and their impacts throughout a watershed as a result of development pressures.

The negative impacts of impervious areas are more directly related to the arrangement of impervious surfaces and their connections to the storm sewer system rather than the total amount of impervious cover across a watershed. The effective impervious area (EIA), defined as the impervious surfaces that drain directly into the storm sewer system for further drainage into surface water, is considered to be a major source of runoff in an urbanized watershed (Yang *et al*, 2011; Lee and Heaney, 2003). Runoff from non-EIA drains into pervious surfaces and infiltrates the ground. Therefore, minimizing EIA through disconnections from storm sewers is needed to reduce the volume of runoff.

Stormwater runoff can be managed through planning practices that are designed to reduce the volume of runoff generated from impervious surfaces or encourage infiltration of runoff. Planning at the site, neighbourhood and regional levels can have significant impacts on the quantity and quality of stormwater runoff. Regional planning is considered to be one of the strongest approaches to coordinating growth, development, and conservation in a watershed through comprehensive planning across more than one jurisdiction (United States Environmental Protection Agency (EPA), 2005). Impervious areas can be minimized at the watershed level by redirecting development away from ecological and open space areas and focusing development on previously developed sites and areas with existing infrastructure in the watershed.

Smart growth principles can address the impacts of stormwater through improved site design criteria and compact development (EPA, 2005). The mixed land use, variety of housing types, highly connected and multimodal transportation network, preservation of open space, and emphasis on development within existing communities, encourages a smaller development footprint that also results in generating lower volumes of runoff. Infill development and redevelopment also take advantage of the existing infrastructure and do not require the development of exurban or environmentally sensitive areas. Development districts with coordinated planning, infrastructure, and investment can result in the creation of an efficient site plan that incorporates various smart growth techniques and comprehensively addresses stormwater management. Community and stakeholder collaboration can provide opportunities for education on stormwater and to develop mutually agreeable solutions that consider community values such as aesthetic designs that complement the surrounding neighbourhood (Crabtree, 2010).

The layout of a neighbourhood contributes to the amount of impervious area and subsequently, the volume of runoff generated. Grid layouts produce less runoff compared to communities with expansive paved cul-de-sacs and dead-end streets (Stone, Jr., 2004). Furthermore, grids with their rectangular block and parcel structure can limit the building footprint thus encouraging multistory developments. Through comparative modeling of various types of residential developments, larger developed areas of single family dwellings on large lots and wide roads have a greater negative impact on the watershed with higher peak flows and runoff volumes, and earlier times for peak flow to be reached (Zheng and Baetz, 1999). Compact designs with smaller lots and road widths, dedicated open spaces, and a variety of housing including single family and semidetached dwellings, townhouses, and apartment buildings, have the lowest impacts on runoff volume and peak flows. At the subwatershed level, sustainable suburban design can significantly lower the volume of runoff.

Density also influences runoff as higher density areas are associated with lower runoff volumes and lower density parcels typically have more impervious areas and lawn areas that can increase runoff (Stone and Bullen, 2006). If the impervious area is held constant, high density and compact development generates approximately 40% less runoff than low density development (Yang and Li, 2011). When considered on a per capita basis, the total runoff volume decreases when simply doubling the suburban density from 3-5 dwelling units per acre to 8 dwelling units per acre (Jacob and Lopez, 2009). This reduction is considered to be the result of clustered development as the smaller size of the developed area is sufficient to offset the increased runoff from higher density areas.

At the site level, programs and regulations that can be used in stormwater management include smaller lot sizes and dimensions and setting maximum setbacks (Stone, Jr., 2004). Reducing the size and dimensions of single residential parcels is considered to be the most effective practice to regulating the amount of impervious cover in residential areas. The volume of stormwater runoff as a result of development has been found to correspond to increasing lot size and thus the amount of impervious cover, which includes the footprint of the structures, areas of the driveway and sidewalk, and street allotment (Stone and Bullen, 2006). Smaller impervious areas from reducing the lot size, lot frontage, and street width, and setting maximum front-yard setbacks, can all lead to significant reductions of stormwater. Lots with smaller frontages would subsequently reduce the street allotment needed to service the lot and also increase the likelihood of constructing a multistory building and reducing the building footprint (Stone, Jr., 2004). The street allotment can account for nearly one-third of the average parcel impervious area and across communities, paved streets comprise a substantial area of total impervious cover.

Protecting the physical environment helps to maintain the natural hydrologic functions that efficiently and capably manage stormwater runoff. Stream buffers, undisturbed natural areas, and trees all play crucial roles in the hydrological cycle through the processes of infiltration, filtration, and evapotranspiration (TRCA and CVC, 2010). The preservation of open spaces is a multipurpose land use planning strategy that protects natural areas such as wetlands and riparian corridors that can aid stormwater management through water retention and detention, separates conflicting land uses, and can serve as park and recreation areas (Brody and Highfield, 2013). By protecting wetlands, riparian areas, and open spaces that are prone to flooding from development, the natural water storage capacity is maintained and the associated risks and damages from flooding are minimized. This strategy of avoidance is considered to be one of the most effective approaches such that more communities are protecting floodplains from development to reduce flood damages. In addition to the direct benefits to reducing runoff and flood risk, open spaces also provide for habitat protection, improved water quality, and opportunities for recreation.

Non-structural LID also favours preserving areas with highly permeable soils and avoiding development in order to maintain the natural infiltration and drainage capacities (TRCA and CVC, 2010). Natural drainage patterns with extended or meandering flow paths are emphasized to slow down the velocity of the runoff and delay peak flows, and to maximize the opportunity for runoff to filtrate into the soil and vegetation (TRCA and CVC, 2010; EPA, 2007). Site grading is avoided in favour of retaining or creating the topography of natural dips and mounds on a site. Impervious areas such as roofs and downspouts, driveways, and parking lots, are disconnected from the storm sewers by redirecting the flow to pervious areas for infiltration and filtration.

One of the most successful examples of a community planned with LID strategies is The Woodlands, a master-planned community north of Houston, Texas, of seven residential villages mixed with commercial and retail developments (Galatas, 2004). The

Woodlands was developed in 1974 using an ecological planning approach where "community design was conceived in 'harmony with nature,' employing a functional natural drainage concept and extensive tree preservation" (Galatas, 2004, p.174). Soil permeability was used to determine the locations for particular land uses and development thus land with highly permeable soils was protected as open space and higher density residential or commercial developments were located on land with poor draining soils (Galatas, 2004; Yang and Li, 2011). Throughout the development of The Woodlands, natural drainage patterns and vegetation were preserved to retain the natural hydrological processes (Doubleday *et al*, 2013). Roads and individual parcels were carefully planned and designed for stormwater management where streets and yards were constructed at the same level, curbs, gutters, and storm sewers were banned and roadside ditches were installed alongside major collector streets (Galatas, 2004). Dams for retaining the runoff were also designed and integrated into areas where the topography and grading would maximize infiltration and groundwater recharge (Yang and Li, 2010).

The natural drainage approach of The Woodlands was incorporated into its first suburban village, Grogan's Mill, and part of its second village, Panther Creek but subsequent villages were constructed as conventional suburbs to suit the preferences of the homeowners who preferred graded sites and the visual appeal of curbs and gutters on the roads (Galatas, 2004; Yang and Li, 2011). In 1979 and 1994, the Woodlands was hit by storms in excess of the 100-year level but was protected from flooding, which was attributed to the natural drainage system (Yang and Li, 2010). Major storm events in 2000 and 2008 caused heavy flooding in villages constructed after 1997, but the villages with open drainage were unscathed (Yang and Li, 2011). The natural drainage features were effective in flood mitigation as water could infiltrate the ground surface into the permeable soils, even during intense storms with heavy rainfall.

Provincial Direction on Stormwater Management

In Ontario, stormwater is governed by a top-down approach where the province sets policies and guidelines that municipalities must follow when addressing stormwater management. The Ministry of the Environment (MOE) directly oversees stormwater management through policy and legislative tools, and also provides technical guidance and funding programs. The Ministry of Municipal Affairs and Housing (MMAH) provides indirect oversight of stormwater management through policy and legislation in land use planning and development.

Ministry of the Environment: Environmental Legislation

For the MOE, the primary legislative and policy tools for stormwater are the Ontario Water Resources Act, 1990, and the Certificate of Approval process (Binstock, 2011). The purpose of the Water Resources Act is "to provide for the conservation, protection and management of Ontario's waters and for their efficient and sustainable use, in order to promote Ontario's long-term environmental, social and economic well-being" (Ontario Water Resources Act, RSO 1990, s 0.1). The Act, under section 31, prohibits or regulates the discharge of sewage, including stormwater, into any waters and under section 32, allows for the ministry to require owners and operators of sewage works, water works or other facilities discharging contaminants into water to implement measures that would prevent, reduce or alleviate negative impacts on water quality. Certificates of Approval with respect to sewage works are legislated in section 53 where environmental compliance approvals are required “to use, operate, establish, alter, extend or replace new or existing sewage works” (Ontario Water Resources Act, RSO. 1990, s. 53(1)) and more broadly by Part II of the Environmental Protection Act, 1990 where approval must be sought to engage in an activity that may discharge a contaminant into the environment (Environmental Protection Act, RSO. 1990). Both the Water Resources Act and the Environmental Protection Act are generally used together to address sources of water pollution and protect surface water and groundwater.

Ministry of the Environment: Guidance and funding programs

Technical guidance on planning, designing, and reviewing stormwater management practices is currently available in the Stormwater Management Planning and Design Manual. Initially published in 1994, this manual was last updated in 2003 to reflect the evolution in stormwater management including information on the watershed planning process, incorporating principles such as water quantity, water quality, and water balance into the selection and design process, infill developments, and design examples of stormwater management practices (Ministry of the Environment, 2003a). The manual covers topics such as land use and environmental planning, environmental criteria to consider, examples of stormwater management practices and their design, operation and maintenance, monitoring, and costs, and also serves as the basis for approvals of stormwater management systems. To supplement this manual, the Ministry also produced a primer on concepts in stormwater management such as the importance of the hydrologic cycle, integrated environmental and land use planning, pollution prevention, relationship to flooding, and examples of stormwater management practices and their challenges (MOE, 2003b).

In recognition of the impacts of urban areas on stormwater, the MOE also collaborated with the Toronto and Region Conservation Authority (TRCA) and others, on the Stormwater Pollution Prevention Handbook in 2001. This handbook provides guidance primarily to municipalities on preventing pollution and reducing flow with respect to stormwater runoff and the combined sewer overflows (CSOs) that occur when the flow exceeds the capacity of the combined sewers (Toronto and Region Conservation Authority *et al*, 2001). The handbook describes the issues of urban runoff and pollution, and discusses pollution prevention planning for municipalities.

The MOE currently provides funding to water systems through the Showcasing Water Innovation program to support innovative and economical solutions for managing drinking water, stormwater and wastewater (Ministry of the Environment, 2014a). Thirty-two projects were selected from applicants across Ontario in 2011, of which 16 demonstration projects focus on stormwater management. These projects include rainwater harvesting, adaptive stormwater infrastructure, stormwater facility retrofits, stormwater sediment reuse, floating wetlands, and more (MOE, 2014b). All of the funded stormwater demonstration projects are located outside of the City of Toronto.

Ministry of Municipal Affairs and Housing: Planning-related Legislation

Land use planning in Ontario is guided by planning policies and legislation that consider appropriate development and land use along with the natural environment, public health and safety, and other provincial interests. The Planning Act, 1990, is the principal legislation for land use planning, establishing the guidelines for managing land use and identifying the authorities and their responsibilities in land use (Planning Act, RSO. 1990). In addition to the Planning Act, planning matters and decisions must be consistent with the Provincial Policy Statement, 2014, and any other provincial policies and plans that are in effect.

In the Planning Act, stormwater is only referred to in the context of site plan control areas. Municipalities may require applicants seeking approval of site plans to provide information on "grading or alteration in elevation or contour of the land and provision for the disposal of storm, surface and waste water from the land and from any buildings or structures thereon" (Planning Act, RSO. 1990. s. 41(7)(a)9). If the area is in an upper-tier municipality and the land abuts a highway, the applicant may be asked to provide information on "grading or alteration in elevation or contour of the land in relation to the elevation of the highway and provision for disposal of storm and surface water from the land" (Planning Act, RSO. 1990. s. 41(8)(a)(iv)). Ontario Regulation 544/06 under the Planning Act, dictates that applicants for plans of subdivision are required to identify "whether storm drainage will be provided by sewers, ditches, swales or other means" (Ontario Regulation 544/06, Schedule 1, s. 25).

The Provincial Policy Statement, 2014 (PPS), provides long-term policy direction for land use planning and development in the province while considering provincial interests and resources, public health and safety, and the natural and built environment (Ministry of Municipal Affairs and Housing (MMAH), 2014b). Policies favour development and land use that is compact and cost-effective to minimize sprawl and servicing costs, and to consider the impacts of climate change on settled areas. Unlike the Planning Act, the PPS provides explicit policy direction in stormwater management. In Section 2.2.1.h, planning authorities are directed to "ensur[e] stormwater management practices minimize stormwater volumes and contaminant loads, and maintain or increase the extent of vegetative and pervious surfaces (MMAH, 2014b, p. 24). The PPS was updated in 2014 to include further direction on stormwater management that incorporates consideration of sustainable solutions:

1.6.6.7 Planning for stormwater management shall:
> a) minimize, or, where possible, prevent increases in contaminant loads;
> b) minimize changes in water balance and erosion;
> c) not increase risks to human health and safety and property damage;
> d) maximize the extent and function of vegetative and pervious surfaces; and
> e) promote stormwater management best practices, including stormwater attenuation and re-use, and low impact development (MMAH, 2014b, p. 17)

Furthermore, the PPS now directs that "planning authorities should promote green infrastructure to complement infrastructure" (MMAH, 2014b, p. 15). Since the purpose of the PPS is to simply provide policy direction, the policy language is likely more lenient to account for a range of locations and circumstances across the province. While all decisions on land use planning and development in Ontario must be consistent with the PPS, it is not a regulation and does not have any mechanisms for implementation.

The Growth Plan for the Greater Golden Horseshoe, 2006, provides policy direction to manage growth and development across the region as the population in this area is anticipated to increase from 7.8 million people in 2001 to 11.5 million people by 2031 (Ministry of Municipal Affairs and Housing (MMAH), 2014a). The plan addresses areas for growth and intensification, infrastructure such as transportation, water and wastewater systems, and the natural environment. A holistic and cooperative perspective towards stormwater management is encouraged by the Growth Plan, which states that "municipalities that share an inland water source and/or receiving water body, should co-ordinate their planning for potable water, stormwater, and wastewater systems to ensure that water quality and quantity is maintained or improved" and that "municipalities, in conjunction with conservation authorities, are encouraged to prepare watershed plans and use such plans to guide development decisions and water and wastewater servicing decisions" (MMAH, 2014a, p. 27). The Growth Plan further supports alternative stormwater management solutions since "municipalities are encouraged to implement and support innovative stormwater management actions as part of redevelopment and intensification" (MMAH, 2014a, p. 27). Similar to the PPS, the Growth Plan provides policy direction for development in which municipal planning decisions must be consistent with Growth Plan policies, thus softer language is used to capture the various circumstances of municipalities in the Greater Golden Horseshoe Area.

Toronto and Region Conservation Authority

The province also provides additional oversight through the Conservation Authorities Act, 1990, which enables the formation of community-based agencies that represent municipalities using watershed boundaries to delineate their jurisdiction (Conservation Ontario, 2014). Conservation authorities aim to establish a balance between human needs and the natural environment across watersheds through resource management, watershed planning, and promoting conservation. Activities focus on environmental protection, management of water resources across the watershed, environmental education, and participation in municipal planning processes.

The Toronto and Region Conservation Authority (TRCA) covers nine watersheds across six municipalities: the City of Toronto, the Regional Municipality of Durham, the Regional Municipality of Peel, the Regional Municipality of York, the Township of Adjala-Tosorontio, and the Town of Mono (Toronto and Region Conservation Authority, 2014a). Working with governments, businesses, and the public, the TRCA provides expertise on ecology, biodiversity, and water resources, sustainable community development including land use, development, and construction, as well as environmental education. In the planning and development process, the municipality forwards the applications and plans for proposals located next to natural areas or the waterfront to the TRCA for review (Toronto and Region Conservation Authority, 2014b). The TRCA provides comments and advice on areas such as stormwater management, flood control, and conservation of natural features and functions. Applicants must satisfy the TRCA's concerns before approval is granted and the application can then move forward in the municipal approvals process.

Toronto and Region Conservation Authority: Guidance and Projects

The Stormwater Management Criteria document provides guidance for planning and designing stormwater management infrastructure that meets the stormwater management requirements for development approvals (Toronto and Region Conservation Authority, 2012). Environmental design criteria for runoff volume, water quality, water balance and erosion control are provided along with an outline of the procedure for stormwater management planning. The TRCA's Low Impact Development Stormwater Management Planning and Design Guide describes the principles of LID, the design process, and guidance on selecting appropriate LID practices (TRCA and CVC, 2010).

In addition to the guidance, the TRCA leads several programs that encourage the use of sustainable stormwater management measures. The Sustainable Neighbourhood Retrofit Action Plan (SNAP) is a pilot program that addresses urban environmental issues by developing action plans at the neighbourhood scale in areas such as stormwater management, water use and conservation, natural heritage, and energy (Toronto and

Region Conservation Authority, 2014c). The program aims to make sustainable changes through retrofits, green infrastructure, and by encouraging changes in behaviour.

The TRCA also leads the Sustainable Technologies Evaluation Program (STEP) where the objective is to support the broader implementation of sustainable technologies and practices (Sustainable Technologies Evaluation Program, 2014a). STEP gathers performance data on clean water, air and energy technologies, develops guidance and policies, assesses barriers and opportunities for implementation, and promotes these technologies. Projects in urban runoff and green infrastructure include studies on LID, conventional stormwater management, preservation and restoration of natural features, and pollution prevention (Sustainable Technologies Evaluation Program, 2014b).

City of Toronto

The City of Toronto oversees stormwater management broadly through urban growth and development policies in the Official Plan and Toronto Green Standard, and directly through the Wet Weather Flow Management Plan by specifically targeting improvements to water quality and flow. As previously discussed, the work of the TRCA also complements the city's efforts by providing expertise in stormwater management and supporting programs that encourage sustainable stormwater management.

Official Plan

Toronto's Official Plan lays out a vision for the future of the city by building on its existing foundations to accommodate anticipated growth and create a city and quality of life that meets the needs of the residents. The Official Plan establishes policies that address infrastructure, land use, and transportation, as well as policies that guide decisions targeting the built environment, natural environment, economic growth, and cultural and social environment (City of Toronto, 2010). On the issue of water, the City's collaboration with neighbouring municipalities and the province is expected to result in improved water quality and the use of watershed principles as the basis for stormwater and wastewater management.

In consideration of the anticipated growth, the City policy is that "water, wastewater and stormwater management infrastructure will be maintained and developed to support the city-building objectives of this Plan" (City of Toronto, 2010, p. 2-6). The City would be responsible for the provision and maintenance of the facilities, acquire land if possible, to implement stormwater management measures or ensure ravines and watercourses remain in their natural state, and support and implement actions to reduce stormwater runoff and improve water quality.

The Official Plan is grounded in the concept of sustainability, basing it on "social equity and inclusion, environmental protection, good governance and city-building" and allowing for the consideration of environmental, economic, and social impacts as a whole (City of Toronto, 2010, p. 1-2). To promote sustainability in the context of stormwater management, the Official Plan encourages green building design, construction practices, and improvements to naturalization and landscaping, and the use of innovative and sustainable technologies to reduce stormwater flow (City of Toronto, 2010). The natural environment is crucial to supporting the City's existing communities, economy, and overall wellbeing thus the Official Plan emphasizes the management of the quality and quantity of stormwater and groundwater infiltration and flows, and mitigation of the impacts, preferably through source control. Since the Official Plan is a visionary document that establishes the framework for the City's long-term growth, the policies are broadly discussed so that the City does not limit its options in what it can and cannot feasibly implement. However, by using weak language to describe the policies related to sustainable stormwater management, the Official Plan fails to effectively communicate the City's support for implementing sustainable stormwater management practices.

Unlike the weak language used in its broad discussion of sustainable stormwater management practices, the Official Plan is decisive in stating that "new development will include stormwater management in accordance with best management practices…and should include source control and on-site facilities to manage stormwater where rain and snow fall, and to ensure it does not produce a net increase in stormwater flows or degrade stormwater quality" (City of Toronto, 2010, p.3-26). The City has implemented this policy as stormwater management plans are currently required for new development applications and are subject to reviews and approvals. The decisive language that "new developments will include stormwater management…" implies greater support and commitment from the City to ensure that the policy is actually implemented rather than overlooked and ignored. However, the weaker language in the following direction that stormwater management "should include source control and on-site facilities" again undermines the City's support for sustainable stormwater management practices.

To meet the stormwater-related objectives outlined in the Official Plan, the broader plans and strategies include the acquisition of relevant watercourses to enhance stormwater management and ensuring the continuous implementation of the Wet Weather Flow Management Master Plan, which addresses the negative impacts of wet weather flow such as poor water quality and the risks of flooding (City of Toronto, 2010). At the lot level, planning applications related to a zoning bylaw, plan of subdivision, plan of condominium, consent to sever, and site plan control all require stormwater management and servicing reports, providing an opportunity to ensure that the objectives of the Official Plan are upheld.

Toronto Green Standard

The Toronto Green Standard (TGS) is a set of environmental performance measures that promote sustainability in all new developments, thereby easing demands on city infrastructure and the natural environment (City of Toronto, 2013). Performance measures for air quality, greenhouse gas emissions and energy efficiency, water quality, quantity and efficiency, ecology, and solid waste are established through policy, guidelines, and regulations, while implementation is achieved through existing land use planning processes. Through the TGS, broader environmental policy objectives identified in the Official Plan are implemented and growing concerns about adapting to climate change in Toronto are addressed.

As of January 31, 2010, all applications for new developments are subject to the mandatory Tier 1 standards with the option to adopt the voluntary Tier 2 standards (City of Toronto, 2013). Tier 1 standards are considered to be the minimum level of environmental performance measures. Meeting the Tier 2 standards requires a higher level of environmental performance thus a refund of 20% of the development charge rewards developments that are committed to resource efficiency and exert less pressure on existing infrastructure and servicing.

All capital projects are required to meet Tier 1 performance standards and new buildings must comply with the green roof bylaw. For new private developments, the

Tier 1 and 2 performance requirements for stormwater balance, retention and reuse are associated with the type of development and the dimensions of the site (Table 1).

Table 1: Toronto Green Standards: Tier 1 and 2 Standards for Stormwater

	Stormwater balance	Stormwater retention and reuse
Tier 1		
Low-rise residential developments	For sites larger than 0.1 ha, retain stormwater on-site to same level of annual volume of overland runoff allowable under pre-development conditions	For sites larger than 0.1 ha, retain at least 5 mm from each rainfall through reuse, on-site infiltration, and evapotranspiration or ensure maximum allowable annual runoff volume from development site is no more than 50% of total average annual rainfall depth
Mid to high-rise residential, industrial, commercial and institutional developments	Retain stormwater on-site to same level of annual volume of overland runoff allowable under pre-development conditions	Retain at least 5 mm from each rainfall through reuse, on-site infiltration and evapotranspiration or ensure maximum allowable annual runoff volume from development site is no more than 50% of total average annual rainfall depth
Tier 2		
Low-rise residential developments, mid to high-rise residential, industrial, commercial and institutional developments		Retain 10 mm of each 24 hour rainfall event, or 70% of total average annual rainfall depth, for reuse, on-site infiltration and/or evapotranspiration

(City of Toronto, 2013)

Wet Weather Flow Master Plan

Wet weather flow is comprised of stormwater, combined sewer overflows, and inflow and infiltration, all of which can contribute to issues of runoff volume and water quality (City of Toronto, 1998). In 1987, the City of Toronto was identified by the International Joint Commission as an area of concern around the Great Lakes because of the degraded water quality that resulted from untreated stormwater and combined sewer overflows being discharged into the lake (City of Toronto, 2006). Although numerous efforts in the 1980s and 1990s had been made to address wet weather flow, little progress was achieved in part due to the lack of a watershed-based approach. In 1994 when reviewing the City of Toronto's proposal for the Western Beaches Storage Tunnel to improve the quality of water discharged into the lake, the provincial Environmental Assessment Advisory Committee report identified the need for watershed-based planning to address wet weather flow and poor water quality in Toronto's watercourses (City of Toronto, 2006). Subsequently, in recognition of the poor water quality and the need to address the sources of its degradation, the MOE granted approval to construct the Western Beaches Storage Tunnel on the condition that the City of Toronto develop a plan to manage wet weather flow using a watershed-based approach. A comprehensive master plan was needed because of "the complexity of the wet weather flow problem and the different individual management strategies taken within Toronto and the upstream municipalities" (City of Toronto, 1998, p. ii).

The Wet Weather Flow Master Plan (WWFMP) is a 25-year plan "to reduce and ultimately eliminate the adverse impacts of wet weather flow on the built and natural environment in a timely and sustainable manner and to achieve a measurable improvement in ecosystem health of the watersheds" (City of Toronto, 2003a, p.10). This plan is based on the principles of using an ecosystem watershed-based approach to manage wet weather flow, recognizing rainwater and snowmelt as a resource and managing rainwater at the lot level before it enters the sewer system, using the treatment train approach to manage wet weather flow, and educating the public on wet weather flow and involving communities in finding solutions (City of Toronto, 2003b, p.6). The cost to implement the entire WWFMP is estimated to be $1.047 billion plus an additional $233 million for operations and maintenance (D'Andrea *et al*, 2004).

The objectives of the plan are grouped into three components that impact management of wet weather flow in Toronto. The Institutional Objective seeks to have "wet weather flow issues…be recognized in the City's Strategic Plan, Official Plan policies, zoning by-laws and Environment Plan, and the City… use both by-laws and incentives to achieve its goals" (City of Toronto, 2003a, p. 10). Furthermore, it emphasizes a cooperative and collaborative approach to managing wet weather flow activities and issues among the City of Toronto, the TRCA, other government agencies and municipalities, and the community. The Financial Objective states that "both the generators of pollution and the beneficiaries of a clean environment should contribute equitably to the financing of wet weather flow management initiatives" and identifies developers as the responsible parties for "the costs of protecting the environment against potential pollution from new development" (City of Toronto, 2003a, p. 10).

Thirteen Technical Objectives are grouped into four categories that address water quality, water quantity, natural areas and wildlife, and sewer systems (City of Toronto, 2003a). Under Water Quality, the objectives are to meet the water and sediment quality guidelines, implement pollution prevention to virtually eliminate toxic substances, improve the water quality in Toronto's rivers and the Lake Ontario waterfront, and improve the aesthetics of the water. Water Quantity objectives aim to maintain a natural hydrological cycle, reduce the impacts of erosion on natural habitat and property, and minimize the impacts of flooding on property and life. Technical objectives for Natural

Areas and Wildlife include healthy aquatic ecosystems, reduced contamination of fish, and the protection and restoration of the functions and features of natural areas. Finally, the technical objectives for sewer systems aim to reduce infiltration and inflow of wet weather flow into the sanitary sewers, elimination of sewage discharges from sanitary sewers, and reduction of incidents of basement flooding.

Through the integration of a natural system approach with a traditional engineering system, the plan incorporates a range of projects, plans, and activities to achieve its objectives (Table 2).

Table 2: Summary of Wet Weather Flow Management Plan

Project or program	Activities
Source controls	Implement mandatory downspout disconnection program Green roof incentive pilot program Rainwater harvesting demonstration project to show non-potable uses of diverted rainwater Tree planting
Conveyance controls	Protect existing ditch network or install 'leaky' storm sewers to 25% of the system to allow stormwater to seep into surrounding soil
End-of-pipe facilities	Construct 175 ponds and wetlands, 175 subsurface stormwater management facilities such as storage tanks and tunnels, and 44 storage and treatment facilities for combined sewer overflows
Beach water quality improvements	Capture and treat stormwater at end-of-pipe facilities before release into the lake
Basement flooding protection	In areas vulnerable to flooding, replace sewers where possible, install isolation valves that automatically close when the sewer backs up, and provide reimbursement for disconnected downspouts
Cross connections	Locate connections between plumbing fixtures and storm sewers and correct the connection to the wastewater system
Stream and aquatic habitat restoration	Restore degraded areas through re-vegetation of streambanks, reforestation, wetland creation, and removal of fish barriers in streams
Public education	Raise awareness about the WWFMP, projects, and programs
Monitoring	Ensure monitoring of projects to gather data on performance measures and assess projects for effectiveness

(City of Toronto, 2014e)

Implementation of the Wet Weather Flow Master Plan

Since the WWFMP was approved in 2003, progress has been achieved in several areas. The Wet Weather Flow Management Guidelines were released in 2006 to provide practical guidance for stormwater management plans for new and infill development and to establish performance objectives for runoff volume, water quality, and flood management (City of Toronto, 2006). Specifically, the guidelines provide direction on "the design and implementation of stormwater management measures at source necessary to achieve the long-term goal and objectives of the Wet Weather Flow Management Plan", "harmonize stormwater management policies and practices of former municipalities", and "provide guidance on stormwater management practices and approval requirements" (City of Toronto, 2006, p.1).

The Earl Bales Stormwater Management Pond was built in 2011 to manage and treat runoff from a 550 ha catchment area of residential and industrial development (City of Toronto, 2014b). Designed to blend into the natural environment, the stormwater pond improves water quality by capturing and treating 90% of the annual runoff in the catchment, prevents erosion and tree loss in the ravine system, reuses stormwater for irrigation and snow-making, and revives a former utility site. The city has also completed Class Environmental Assessments for a number of large projects including the Don River and Central Waterfront Project, Don Valley Parkway Stormwater Runoff, Etobicoke Waterfront Stormwater Management Facilities, Eastern Beaches Storm Sewer Outfalls Control, and Scarborough Waterfront CSO and Stormwater Outfalls Control (City of Toronto, 2014a).

City Council approved the Mandatory Downspout Disconnection Program and its related bylaw in 2007 requiring property owners to disconnect the downspout from the drainpipe and divert the water into the ground (City of Toronto, 2009). The program will be implemented in three phases: combined sewer service areas in 2011, chronic basement flooding areas in 2013, and the remainder of the city in 2016. The city also initiated the Basement Flooding Protection Program where environmental assessments in 41 basement flooding study areas are conducted to examine the sewer system and overland flow paths for their ability to safely convey runoff during intense storms (City of Toronto, 2014d). These assessments will identify vulnerable infrastructure and areas, and recommend how the city can address and resolve these problems. Mitigation for stream erosion has also been undertaken at a section of Highland Creek that suffered major erosion and damage to infrastructure and streambed reconstruction has been performed in the Birkdale Ravine (City of Toronto, 2009).

Analysis of Barriers to Implementation

The City of Toronto faces various challenges in its efforts to effectively manage stormwater and reduce the potential impacts of flooding. The existing stormwater management infrastructure is aging and needs to be replaced or repaired, or updated to be more sustainable (Consultant, personal communication, July 9, 2014). Some of the older communities developed before the current regulations and the creation of the conservation authorities were established in flood-prone areas and are thus vulnerable to flooding (Senior Manager, personal communication, July 8, 2014). Toronto's intense urbanization also makes stormwater management more difficult to address in comparison to less developed areas (Policy Advisor, personal communication, June 13, 2014). Simply put, the issues can be described as “big city, big problems, old infrastructure” (Consultant, personal communication, July 9, 2014).

Despite these challenges, the City of Toronto is working towards managing stormwater in a more sustainable manner with policies and programs such as the WWFMP and Toronto Green Standard. Initiatives including the downspout disconnections program, green roof bylaw, and the Earl Bales Stormwater Management Pond are well regarded (Senior Manager, personal communication, July 8, 2014). However, implementation of sustainable stormwater management practices seems to be limited and a Consultant suggests that more implementation of the WWFMP is needed (Consultant, personal communication, July 9, 2014).

It can be challenging to implement new techniques for handling problems that already have widely accepted solutions. Jurisdictions including Australia, Ireland, the United Kingdom, Germany, and the United States have all experienced institutional, social, financial and technical impediments in their efforts to implement LID more broadly. Toronto is in a unique position in that the existing regulatory framework and support from the province has lowered the institutional barriers found in other jurisdictions but nonetheless, recognizing these barriers is crucial to understanding their influence on implementation. The primary challenges in the City of Toronto tend to be social, financial, and technical barriers.

Institutional barriers

Institutional barriers are considered to be one of the two foremost impediments to implementing sustainable stormwater management. Such barriers are considered to be “difficult to overcome for they are systemic and embedded within organisational cultures, practices and processes" (Brown and Farrelly, 2009a, p.659). Brown and Farrelly (2009a) describe institutions as being "expression[s] of the formal and informal rules and norms that shape the interactions of humans with each other and with the environment" (p.654) and note that in the context of water management, institutions are "subjective, path dependent, hierarchical and nested both structurally and spatially, and embedded within the cultural, social, economic and political context" (Brown and Farrelly, 2009b, p.840). As a result, institutional barriers "arise from political, social, legal or managerial constraints" (Brown and Farrelly, 2009b, p.840).

Compared to the existing literature on the experiences of other jurisdictions in implementing sustainable stormwater management, the City of Toronto seems to have encountered few institutional barriers that have plagued jurisdictions in Australia, the United States, and Ireland. Although political constraints are experienced in other jurisdictions, more specifically as issues with the legislative mandate and priorities of multiple municipal, state, and federal governments, the City of Toronto benefits from having a more formalized structure of policies, bylaws, and guidelines to direct stormwater management and encourage movement towards sustainable solutions. According to a Senior Manager at the TRCA, having the right policies in place is important for uptake of sustainable stormwater management (Senior Manager, personal communication, July 8, 2014). A municipal Policy Advisor indicated that the provincial and municipal approach of policies, guidelines, and technical guidance has been "effective in certain respects" as "people try to adhere to guidelines if they (the guidelines) exist"(Policy Advisor, personal communication, June 13, 2014). Both the WWFMP Guidelines and Toronto Green Standards also include monetary penalties to encourage compliance. However, in Australia, the experience was that the lack of strict requirements resulted in limited ability to encourage implementation of WSUD (Roy *et al*, 2008). Without a regulatory framework, policies, or guidelines, it is more difficult for governments to promote implementation of sustainable stormwater management.

This existing framework provides the foundation to strengthen stormwater management in Toronto by easing the path for mainstreaming sustainable solutions as integral practices. The political will to deal with stormwater management was translated to some degree into plans and guidelines such as the WWFMP and the Toronto Green Standard, thus the focus could shift to achieving the environmental objectives rather than fighting for recognition of stormwater management as an issue. According to a consultant who was involved in developing the WWFMP, political will strongly influenced the work and direction of the WWFMP (Consultant, personal communication, July 9, 2014).

Political support is a crucial factor in encouraging sustainable stormwater management as the process itself can move forward more easily (Senior Manager, personal communication, July 8, 2014). Although City Council has been responsive to stormwater management and the increasingly intense storm events, resulting in a shift in the focus of the WWFMP from water quality to water quantity (Policy Advisor, personal communication, June 13, 2014), Council has not yet shown any indication of going further in mandating sustainable stormwater management solutions. Given Council's previous decisions to approve the WWFMP and other environmentally sustainable measures, it seems that there is the political will for flexible guidelines rather than strict requirements. Political endorsement was identified as crucial to increasing the prospects for uptake of sustainable stormwater management in Ireland (O'Sullivan *et al*, 2011). In

Australia and Germany, long-term political will and perseverance were considered to be instrumental for integrating various agencies and securing their commitment to sustainable stormwater management (Brown and Farrelly, 2009b; Nickel *et al,* 2014).

The more commonly cited institutional barriers to implementation of sustainable stormwater management in other jurisdictions concern the institutions themselves that are tasked with carrying out the directions of government. Since stormwater management is increasingly considered on a watershed basis, multiple institutions across various levels of government are typically involved in planning and implementing strategies to manage stormwater. A fragmented administrative framework where multiple organizations have overlapping or unclear responsibilities hinders coordination of the various organizations thus preventing progress towards implementation (Keeley *et al*, 2013). In Ontario, the roles and responsibilities of the municipalities and agencies such as the conservation authorities, are established by the Province through the existing legislative framework. With the responsibilities clearly defined, the City of Toronto and other participating government ministries and agencies can concentrate on discussing stormwater rather than formulating a framework on their respective administrative responsibilities.

In other jurisdictions, the fragmented administration may instead be illustrated by management of the different components of the water cycle (e.g. water, wastewater, and stormwater) in separate municipal departments (Roy *et al*, 2008). This may lead to a lack of clarity over which department or level of government is responsible for overseeing and maintaining the stormwater management infrastructure. At the City of Toronto, drinking water, wastewater, and stormwater, are all under the division of Toronto Water. Although each component is separately addressed in various subdivisions, the fact that all three components fall under Toronto Water clarifies the oversight for water services and the responsibilities for operations and maintenance, as well as contributes to the likelihood of more effective and efficient coordination.

Brown (2005) suggests that the constraints of the fragmented administrative framework on implementation can also result in restricting the development of institutional learning. By limiting these opportunities, organizational inertia continues to flourish in institutional structures that are "known to constrain integration and innovation" (Brown and Farrelly, 2009a, as cited in Mitchell, 2004, p.654). This inertia or resistance to change has been identified as an obstacle across jurisdictions in the United States and Australia (Keeley *et al,* 2013; Brown and Farrelly, 2009a). As a result of this inertia, change occurs slowly and the status quo of stormwater management "perpetuates the inefficient use of resources and continuing waterway degradation, but also continues to reinforce this so-called institutional inertia" (Brown and Farrelly, 2009b, p.840).

Another possible cause for the institutional inertia with respect to sustainable stormwater management is risk and an aversion to the risks of using relatively new solutions (Roy *et al,* 2008). Municipalities may be unwilling to bear the risk of failure and higher maintenance, engineers may be uncertain of the functionality, while the public health division may be concerned with the potential increase and spread of mosquito-borne disease in LID practices that have standing water. Institutional inertia may also be attributed to the limited capacity of the institutions that have insufficient funding and personnel who have the skills, knowledge, and experience to support and execute programs to implement sustainable stormwater management (Roy *et al*, 2008; Brown and Farrelly, 2009a; Sharma *et al*, 2012).

Since fragmented administrative frameworks can lead to institutional inertia, the combination of the existing legislative framework and the political will to address stormwater management through watershed-based plans is likely a key reason for the weaker institutional inertia in Toronto. The stormwater-related policies and programs for developers, property owners, and the community, as well as for capital projects suggest that the City and the TRCA are engaged in institutional learning and also willing to bear the risks of sustainable stormwater management. Both the City and the TRCA emphasize the use of LID practices, indicating an evolution in how these institutions currently approach stormwater management when compared to previous years.

Social barriers

Social barriers are considered to be the second major impediment to mainstreaming sustainable stormwater management in various jurisdictions. The Policy Advisor (personal communication, June 13, 2014) believes that "as with many environmental issues, I don't think people spend a lot of time thinking about stormwater management until it affects them". However, there is a correlation between personal experiences with flooding and public interest in stormwater management as seen in the increased public support to fund projects such as the Basement Flooding Protection Program (Policy Advisor, personal communication, June 13, 2014). Usually, the public is not involved in stormwater management projects unless they are personally dealing with it on their own site (Senior Manager, personal communication, July 8, 2014).

The lack of public understanding of stormwater management includes limited knowledge and comprehension of the need for stormwater management, unfamiliarity and misconception of LID practices, and failure to understand the relationship between land use and the generation of runoff. Typically, people are unaware of stormwater management which Jones and Macdonald (2007) attribute to the "legacy of an underground, highly repressive system, [that] has… let us forget about the amount of effort which is needed to regulate water's more unruly tendencies – we have tended only [to] think about discipline when those negative controls break down" (p.543). The experiences of the Shettleston floods in July 2002 succeeded in raising awareness of the need to address drainage in Glasgow, Scotland, albeit at a personal cost for many residents (Jones and Macdonald, 2007). Hurricane Hazel's damaging impacts on the residents and infrastructure of Toronto in October 1954 highlighted the issue of flooding and instigated the TRCA's efforts in flood control (Bilton, 2008). Sharma *et al* (2012) suggest that the decentralized nature of sustainable stormwater management requires increased community understanding and involvement to encourage implementation. However, Keeley *et al* (2013) believe the fundamental issue is the common perception that stormwater itself is not a problem. The public does not understand the need for stormwater management or the contributions of the land use on their properties to the overall problem of stormwater runoff. Until the 1980s, urban stormwater was generally believed to simply be a flooding nuisance that had little value socially or ecologically (Brown, 2005). Stormwater was not treated "as a valuable resource but more like a problem to solve, or even worse…as a waste product" (Karvonen, 2011, p.15).

In order to encourage implementation of LID, “new forms of discipline require that we not only modify the behaviour of water, but the behaviour of society, understanding that this discipline is actively performed” (Jones and Macdonald, 2007, p.543). Rauch *et al* (2005) speculate that improved awareness and understanding of stormwater management will subsequently lead to positive changes in social practices and behaviours that in turn, encourage sustainable stormwater management. Many practitioners believe that the use of LID solutions will improve the public perception of the problems related to stormwater management (Keeley *et al*, 2013). However, there may still be resistance to sustainable stormwater management as there have been reports of perceptions that some solutions are considered unattractive or ineffective (Roy *et al*, 2008).

The physical appearances of some sustainable stormwater management solutions are designed to complement the surrounding natural environment, thus their functions and contributions to managing stormwater are often invisible. Therefore, it may be difficult to show progress and justify the costs of constructing these solutions when the outputs of their work are invisible. It is difficult for the public to see money spent on projects or programs unless there is a noticeable payback (Senior Manager, personal communication, July 8, 2014). Bilton (2008) notes that when the Toronto and Region Conservation Authority developed a flood control plan in 1959 after Hurricane Hazel, proposed engineering dams were important for their role in flood control and to have “something to show for the money spent on the projects [as it] was the only tangible way to demonstrate progress to the public” (Bilton, 2008, p.86).

Financial barriers

The financial costs of sustainable stormwater management have also been identified as a challenge in promoting implementation in Toronto. Although "there's good economic sense for stormwater management" from the "good water quality and flooding control [that] contribute to improved quality of life", costs remain a concern for developers and practitioners (Policy Advisor, personal communication, June 13, 2014). Capital, operation, and maintenance costs of structural sustainable stormwater management are frequently cited as burdens and perceived to be higher than traditional infrastructure yet analysis suggests that implementation and use of LID may actually be more cost effective because their use may result in lower costs overall (Roy *et al*, 2008; Sharma *et al*, 2012; O'Sullivan *et al*, 2011; Bowman and Thompson, 2009). Although practitioners in Ireland identified maintenance costs of LID as a deterrent, the role of LID source controls in reducing the maintenance costs of existing stormwater infrastructure was not considered (O'Sullivan *et al*, 2011). A cost analysis of the construction, operation and maintenance over the whole life of sustainable urban drainage systems in the Dunfermline Eastern Expansion mixed development in Scotland suggested that "well designed and maintained SuDS are more cost effective to construct, and cost less to maintain than traditional drainage solutions" (Duffy *et al*, 2008, p.1451). Roy *et al* (2008) acknowledge that there is evidence that sustainable stormwater management solutions are cheaper than traditional stormwater infrastructure but the data is less clear when considering the cost of individual practices.

The financial aspects of sustainable stormwater management affect the economics of developing properties and subdivisions in many jurisdictions. Unless LID is a requirement, developers will use the most cost-effective solution to meet the stormwater quality and quantity standards (Senior Manager, personal communication, July 8, 2014). Requirements to manage stormwater on-site may force developers to build a tank on the property rather than use the land for parking, thus affecting the bottom line (Policy Advisor, personal communication, June 13, 2014). Many developers believe that implementing sustainable stormwater management through green and conservation design and maintaining open spaces are more costly with respect to capital and maintenance costs (Duffy *et al*, 2008; Bowman and Thompson, 2009). However, developers tend to underestimate the demands and preferences of prospective buyers for open spaces and houses with conservation features (Bowman and Thompson, 2009).

In Toronto, many developers are implementing sustainable stormwater management practices in accordance with the WWFMP Guidelines and the assistance of municipal staff (Policy Advisor, personal communication, June 13, 2014). However, it is uncertain as to whether developers are simply meeting the minimum standards of the WWFMP Guidelines or taking steps to further reduce runoff at its source. To reduce the inherent risks of using relatively novel techniques, developers may engage in developer satisficing, where developers rely on options that are proven to only meet, rather than maximize, their goals (Bowman and Thompson, 2009). Toronto developers also have the option of cash-in-lieu of implementing stormwater management solutions to reduce runoff to on-site pre-development levels but this practice is discouraged by city staff and is only accepted when there are no other options (Policy Advisor, personal communication, June 13, 2014). From the Senior Manager's perspective, developers are receptive to incorporating LID in their projects but cities need to understand that developers want credits for LID implementation (Senior Manager, personal communication, July 8, 2014).

Related to the burden of financial costs is the lack of funding and incentives to encourage implementation of LID. In Toronto, there are many 'sticks' such as the regulations, by-laws, and guidelines that comprise the framework to oversee implementation but few 'carrots' in the form of funding and financial incentives (Policy Advisor, personal communication, June 13, 2014). Stormwater management in general already suffers from inadequate funding at all levels of government thus decision-makers and practitioners are likely to prefer established traditional methods rather than test the relatively novel sustainable solutions (Brown, 2005). To some practitioners, funding is the critical element in encouraging implementation since without funding, other potential barriers such as institutional or community resistance, fragmented administration and organization, or uncertainty with technical aspects, become irrelevant (Keeley *et al*, 2013).

Incentives can be used to promote LID practices by providing financial rewards that acknowledge the benefits of implementing sustainable stormwater management. Water professionals and other stakeholders indicated that the lack of incentives such as rebates that recognize subsequent benefits such as reduced pressure and demand on sewer infrastructure and services can discourage implementation (Sharma *et al*, 2012). If financial incentives are to be used, rebates and discounts should be in amounts that are high enough to influence changes in behaviour (Roy *et al*, 2008). Nickel *et al* (2014) suggest that direct financial incentives such as subsidies and grant programmes should be given to early adopters to promote the use of green infrastructure. As a result, new technologies can be tested and these experiences can lead to further understanding that subsequently adds to the knowledge base of sustainable stormwater management. Once sustainable stormwater management solutions are established, planning instruments, non-financial incentives, stormwater fees and regulations are the dominant methods in incentivizing uptake.

Technical barriers

For the City of Toronto's municipal stormwater responsibilities, the focus is on finding suitable stormwater management solutions to meet the water quality and quantity objectives of the WWFMP rather than on using particular techniques (Policy Advisor, personal communication, June 13, 2014). The Senior Manager emphasizes site-specific stormwater management and the treatment train approach where traditional infrastructure and LID practices are used as multiple solutions to manage stormwater (Senior Manager, personal communication, July 8, 2014). Although the city emphasizes LID for improving water quality, such techniques are not considered to adequately address the issue of water quantity (Policy Advisor, personal communication, June 13, 2014). To manage municipal stormwater, the city relies on grey infrastructure such as the traditional drainage system to handle the quantity of stormwater runoff. Despite the efficiency of piped infrastructure in conveying stormwater to the lake, grey infrastructure is expensive to install and maintain, and does not address the quality of the water thus further treatment is needed.

From the perspective of the Senior Manager at the TRCA, concerns about the operation and maintenance are influential in the broader implementation of LID (Senior Manager, personal communication, July 8, 2014). Unlike the traditional stormwater management methods that are well known and established, the LID practices must be proven to perform effectively and information on its operation and maintenance requirements must be available. Municipalities are concerned about the performance of LID so even if LID is implemented, some municipalities still want to install proven solutions as a backup system that will perform the same functions.

Lack of knowledge about the standards and guidelines of each LID technique and their operation and maintenance requirements, discourages practitioners from suggesting their use (Sharma *et al*, 2012). When considering the depth of knowledge acquired from decades of experience on the operation, maintenance, and performance of traditional stormwater infrastructure, there may be reluctance to use sustainable stormwater management practices that are comparatively novel and unproven (Sharma *et al*, 2012). Both Roy *et al* (2008) and Sharma *et al* (2012) identify uncertainty in the performance of sustainable stormwater management practices as a barrier to implementation, specifying the lack of data on the performance of the techniques in a range of settings as an impediment. To encourage uptake of sustainable techniques, stormwater managers require verified data and information on the design specifications, performance, and cost of various sustainable stormwater management approaches (Sharma *et al,* 2012).

Even if information on LID practices is available, practitioners must understand LID and be confident in recommending their implementation. Practitioners in Ireland were unaware of the information on the techniques and did not fully understand technical guidance that was publicly available (O'Sullivan et al, 2011). These findings were similar to the experiences in Cleveland, Ohio, and Milwaukee, Wisconsin, where insufficient access to in-house technical expertise and technical assistance were identified as barriers to designing small-scale green infrastructure projects (Keeley *et al*, 2013). However, even if practitioners are knowledgeable in sustainable stormwater management techniques, they may still be averse to recommending installation and use if they lack experience in implementation of these techniques. Sharma *et al* (2012) found that even when knowledge of sustainable stormwater management techniques was well-developed, the lack of practical experience could block uptake of sustainable stormwater management.

The lack of monitoring of individual LID practices also indirectly contributes to the technical barrier in that it fails to provide data and information that could encourage implementation. Long-term monitoring is needed to validate the performance of sustainable stormwater management solutions, could assist in improving the standards and guidelines for their use, and help to refine the regulatory and governance frameworks (Sharma *et al*, 2012). Monitoring the performance measures of various structural and non-structural LID practices could provide further information on the efficacy of each practice as well as clarify the requirements for operation and maintenance. The data gathered from long-term monitoring could provide practitioners and decision-makers with sufficient knowledge and confidence in selecting appropriate techniques.

Recommendations

The experiences of implementing sustainable stormwater management in the City of Toronto shows that it is possible to overcome institutional barriers and create policies, bylaws, and guidelines to facilitate implementation of sustainable stormwater management. Toronto has been able to overcome institutional barriers encountered in other jurisdictions, which can be attributed to the existing legislative framework that define the responsibilities of the governments and agencies, and the political will of the provincial and municipal governments to address stormwater management. Despite this progress, social, financial, and technical barriers still need to be addressed.

While developers and residents need to understand their roles and responsibilities in managing stormwater, the provincial and municipal governments and agencies will likely need to continue to lead the way towards integrating sustainable stormwater management practices into the existing stormwater management systems. Their leadership is crucial to overcoming the social, financial, and technical barriers that continue to impede LID. Governments and their agencies are considered to be sources of funding and their technical expertise and guidance are important resources for developers and the community. However, governments and agencies should continue to engage in collaborative partnerships with developers, consultants, and communities to further promote sustainable stormwater management and foster learning opportunities.

Although the City of Toronto has made progress in its efforts to integrate sustainable practices into stormwater management, it will take some time before these practices are broadly accepted and incorporated as viable options. Since the province of Ontario is the lead on technical guidance related to stormwater management, the Senior Manager emphasizes the importance of an updated Stormwater Management Planning and Design Manual to reflect the current standards and progress in stormwater management since its 2003 publication (Senior Manager, personal communication, July 8, 2014). Revising this manual to strengthen the treatment train approach and integrate resiliency to and best practices for climate change was also endorsed by an MOE review on municipal stormwater management and climate change (Ministry of the Environment

(MOE), 2010). The MOE and TRCA are currently working to update the Stormwater Management Planning and Design Manual.

Pilot projects have also been recommended by MOE to support and encourage municipal stormwater management (MOE, 2010). Demonstrations of sustainable stormwater management practices provide the opportunity to demonstrate new techniques while gathering data on their performance, operation, and maintenance. Increasing the number of LID pilot projects would allow more innovative solutions to be tested and monitored before widespread implementation, and thus build confidence in these techniques. Public awareness of LID and stormwater management is likely to increase if pilot projects are located in easily accessible high traffic areas or events. This could also create educational opportunities on the impacts of stormwater and the benefits of sustainable stormwater management. To emphasize the benefits and build support for LID, the functional performance of the pilot projects should be noticeably linked to its outputs, possibly with on-site signage indicating money saved or samples of the stormwater after filtration for LID practices that address water quality. Developers and residents need to see evidence of LID performance and financial returns.

Temporary financial incentive programs for the public and developers as well as increased funding for municipalities are needed to encourage sustainable stormwater management. MOE has acknowledged that financial incentives are needed for municipal stormwater management (MOE, 2010). The City of Toronto is looking into various methods such as increasing water rates beyond inflation, debenture financing, and stormwater user fees to generate revenue to address the shortfall in funding for stormwater infrastructure and services (Policy Advisor, personal communication, June

13, 2014). Stormwater user fees are based on the premise that owners are charged a fee based on the volume of runoff that is generated by their property. This fee would act as an incentive for owners to save money by reducing their runoff contribution. However, the Senior Manager at the TRCA cautions the difficulties in administrating a stormwater user fee program and the pushback from the public. Stormwater user fees must be implemented wisely with an appropriate formula to calculate the fee and meaningful incentives such as reduced user fees for homeowners who install stormwater management onsite (Senior Manager, personal communication, July 8, 2014).

Lessons Learned

The case study of Toronto suggests that it is possible to modify and update the traditional approach of controlling stormwater with engineered infrastructure to integrate sustainable practices that instead work with water's natural tendencies. In this evolution towards a sustainable approach to stormwater management, the control and discipline of water is lessened thereby allowing water to eventually follow its natural flow paths and drainage patterns. However, the release of stormwater to move in a more natural state arises through human orchestrations. It is through human interference that the unruliness of water is disciplined; it is through further human interference that water is permitted to flow freely in pre-approved conditions. Even if sustainable stormwater management practices are used, water is still tamed and disciplined to serve human needs in urban areas.

Despite the continued control over water's natural tendencies, the use of sustainable stormwater management provides learning opportunities that may transform perceptions on the role of water in urban environments. Bringing forth the issue of stormwater and using sustainable practices can reveal the multi-faceted behaviour of water to a wider audience. The integration of traditional and sustainable stormwater management practices redefines the relationship between water and humans where the absolute control and conveyance of stormwater runoff gives way to an approach that regards stormwater as an important component of the natural environment and in some cases, a potential resource instead of a waste product or threat.

Conclusion

Recent experiences with intense storms and major flooding in urban areas have increased concerns about the capabilities of stormwater management systems in handling excessive volumes of stormwater. Integrating sustainable stormwater management practices can ease the burden on the aging stormwater infrastructure and reduce the risks of flooding yet considerable impediments prevent their widespread implementation. Despite the existing political support for stormwater management in the City of Toronto, social, financial, and technical barriers must still be overcome for LID to be widely accepted and used in stormwater management. LID has a range of environmental, economic, and social benefits, and is expected to become a standard practice in developments (Senior Manager, personal communication, July 8, 2014). Although the transition towards widespread acceptance of LID may take decades, a growing consensus believes that LID “will eventually become the dominant form of stormwater management” (Karvonen, 2011, p.19). Sustainable stormwater management is the natural progression in the evolution of stormwater management in urban areas.

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