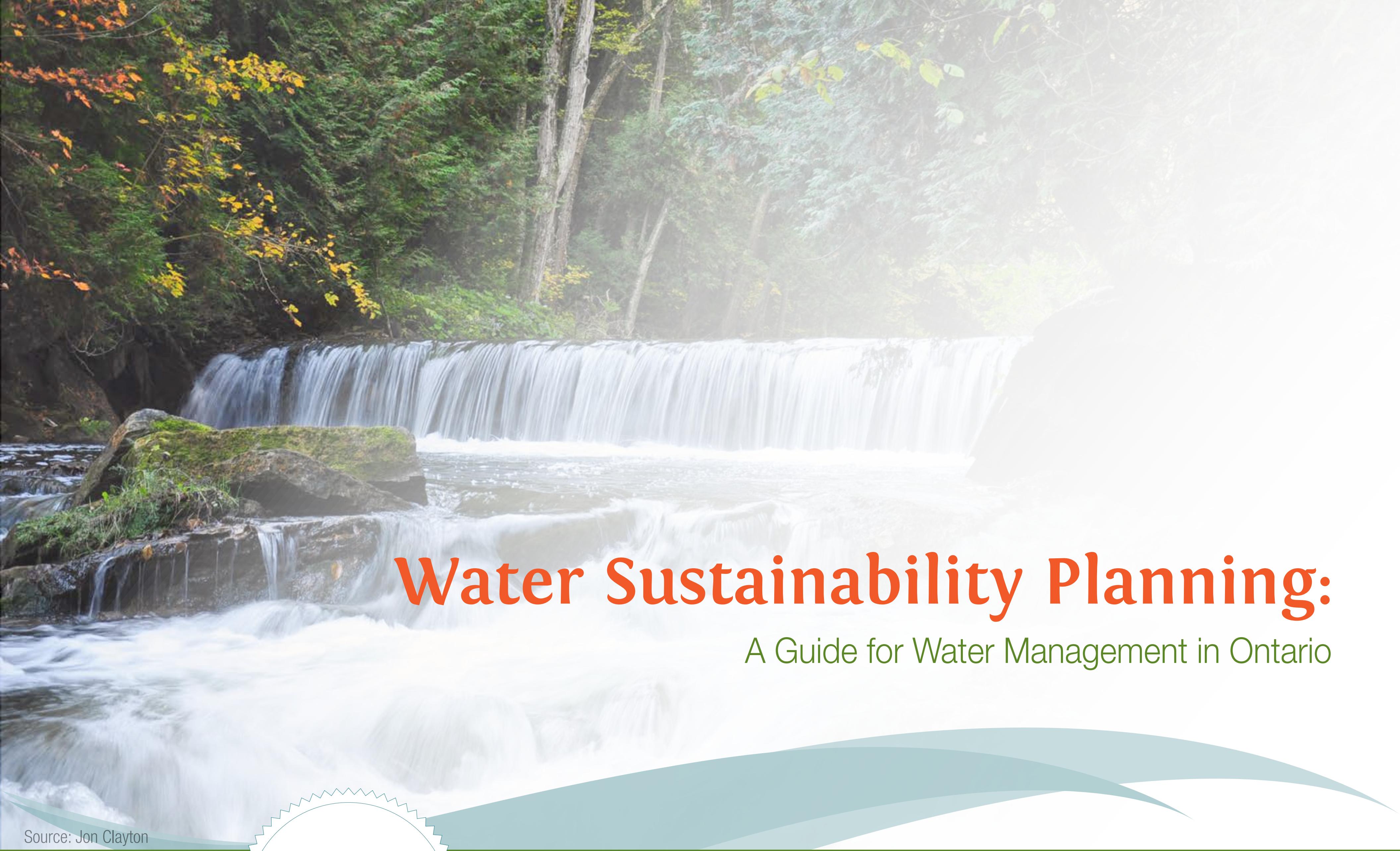

Source: Jon Clayton

# Water Sustainability Planning:

## A Guide for Water Management in Ontario

CREDIT VALLEY CONSERVATION

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# Table of Contents

# 1.0 Introduction

Source: Jon Clayton

This Water Sustainability Planning Guide is a reference for municipal water service providers to use for the purpose of integrating water, wastewater, stormwater and watershed considerations into a water sustainability plan. This guide focuses on how users can take a One Water approach, which considers municipal water management from a watershed perspective. This guide uses case studies and examples to highlight lessons learned from municipalities across Ontario and beyond.

## 1.1 What is a water sustainability plan?

Water management and planning in Ontario is consistent with municipal land-use planning and is currently incorporated in most cases into the master plans, watershed plans, and environmental plans for which municipalities and conservation authorities are responsible.

A water sustainability plan is a document that integrates the various aspects of municipal water management planning within a particular geographical or political study area. Given the nature of water management and services in Ontario, this plan should be undertaken through a collaborative process to meet the specific needs of the individual parties who are responsible for providing water services and water management. The plan provides direction as to the activities that are required to maintain and enhance municipal water services to meet current and future needs, and reduce the impact on Ontario's finite water resources.

These are some of the key components of a water sustainability plan:

- Long-term infrastructure (master) plan
- Asset management plan for all water infrastructure
- Financial plan
- Water conservation plan for municipal water services
- Risk assessment (e.g., of future risks posed by climate change), and
- Strategies to maintain and improve water management services.

Many components of a water sustainability plan already exist under the current municipal master planning and watershed planning processes. The former is generally limited to infrastructure performance and capacity, while the latter focuses on environmental features and functions. This guide presents a water sustainability planning approach that represents the best of both municipal and watershed planning activities. This process is a way to bring together knowledge, information, and best practices in water management and planning.

*There is currently a movement towards more holistic and integrated approaches to water management. This report highlights the changes that need to occur for municipalities to take a One Water approach.*

## One Water approach

Over the last decade, municipalities have begun to look at a more holistic and integrated approach to municipal water management and provision of municipal water services, such as the adoption of Integrated Water Resources Management (IWRM), Integrated Water Management (IWM), or One Water approaches.

For the purpose of this guide, we will refer to the One Water approach. This approach considers built water infrastructure, water services, and natural water systems as one integrated system and incorporates this view into water management and planning.

The ultimate goal of the One Water approach is to mimic the natural hydrologic cycle. Figure 1.1.1 illustrates components of the water cycle in natural and urbanized environments using a One Water approach. In the natural hydrologic cycle, evapotranspiration and infiltration play a large role that results in small amounts of runoff. In urban environments, several variables significantly reduce evapotranspiration and infiltration and produce large amounts of urban runoff. Within the urban water balance, imported potable water and wastewater discharges also needs to be incorporated into the cycle.

Municipalities can use the One Water approach to explore the interconnections between water systems in order to make the most informed decisions regarding water management. They can use the approach to a) ensure that water infrastructure systems deliver appropriate services to human populations, and b) minimize negative impacts on other water systems, including natural systems like aquifers, streams, and lakes.

Making the transition to a new, forward-looking, and sustainable integrated water management framework will support municipalities in addressing a complex system of drivers and risks, including those related to climate change, urban development, and further intensification of existing urban areas.

Failing infrastructure – and the associated costs of repairs and replacement – is one of these risks. In 2007, a Federation of Canadian Municipalities (FCM) and McGill University survey found that the estimated water infrastructure deficit in Canada was $31 billion for existing infrastructure, plus $56.6 billion for new infrastructure needs, including water, wastewater and stormwater systems. Since the One Water approach looks at all water systems as one system, it can help water managers identify cost-effective solutions that can impact and improve multiple systems. It can also help municipalities determine and prioritize investment based on benefits to residents and the watershed.

Rainwater harvesting is one example of a cost-effective solution with multiple benefits. Rainwater harvesting provides an alternative water source for activities that do not require potable water, such as gardening or flushing toilets. In turn, residents use less municipal drinking water – which

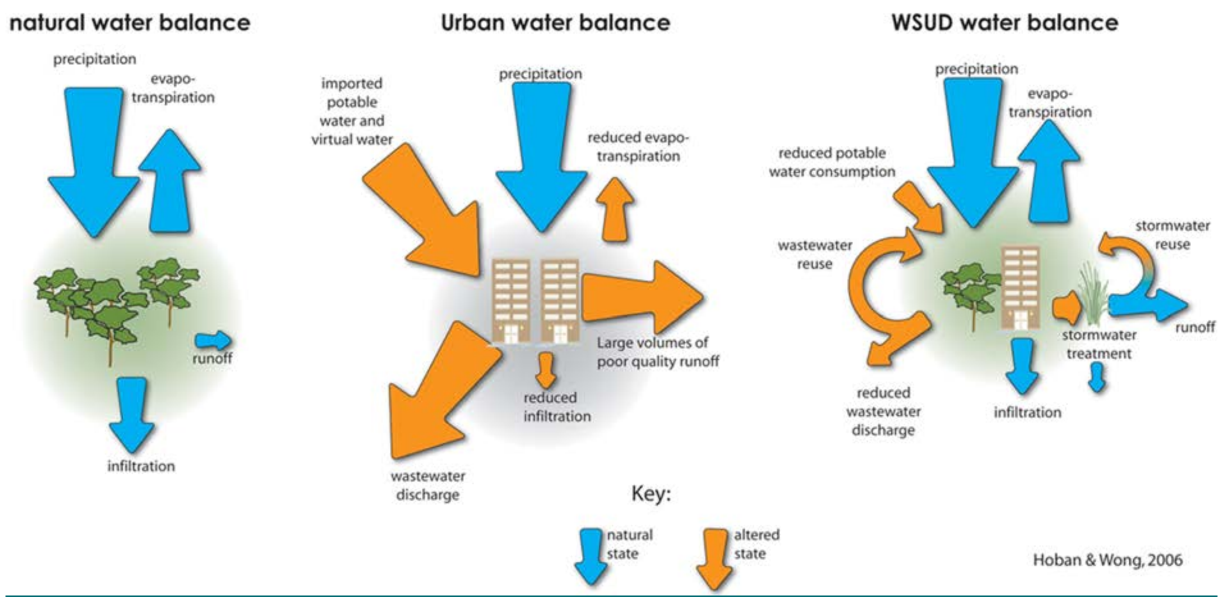



**Figure 1.1.1:** An illustration of three different water balances resulting from land use and water management decisions. (Source: Healthy Waterways)

is expensive and energy (intensive to treat and distribute) for these activities. For some municipalities, including the City of Toronto, Region of Peel, and City of Guelph, treating and distributing water can account for 25% to 60% of total municipal electricity usage[1]. The One Water approach can provide conservation not only of water, but of energy. This relationship is known as the water-energy nexus. Additionally, capturing rainwater decreases the flow of water to municipal stormwater management systems, which can alleviate stress on older systems that lack capacity for high volumes of water, potentially reducing instances of flooding and erosion.

The One Water approach emphasizes solutions that offer multiple benefits. To properly evaluate these solutions, it is helpful to consider water management through the lens of the watershed.

## The watershed perspective

When making the transition to a One Water approach to municipal water planning, it is helpful to start with a "watershed perspective." A watershed perspective reveals the several complex layers of how water systems – natural and built – are connected (see Figure 1.1.2 for an example). Understanding these layers, how they are linked, and how a watershed functions will support cost-effective, holistic municipal water and land management.

It will also reveal risks. For example, a rainfall event might lead to contaminated stormwater runoff draining to drinking water supply intakes. A watershed approach not only identifies these types of risks, but also makes it easier to determine potential solutions to mitigate problems. Efforts to minimize risk can encourage municipalities to work together on integrated planning and management solutions, since watersheds cross political boundaries.

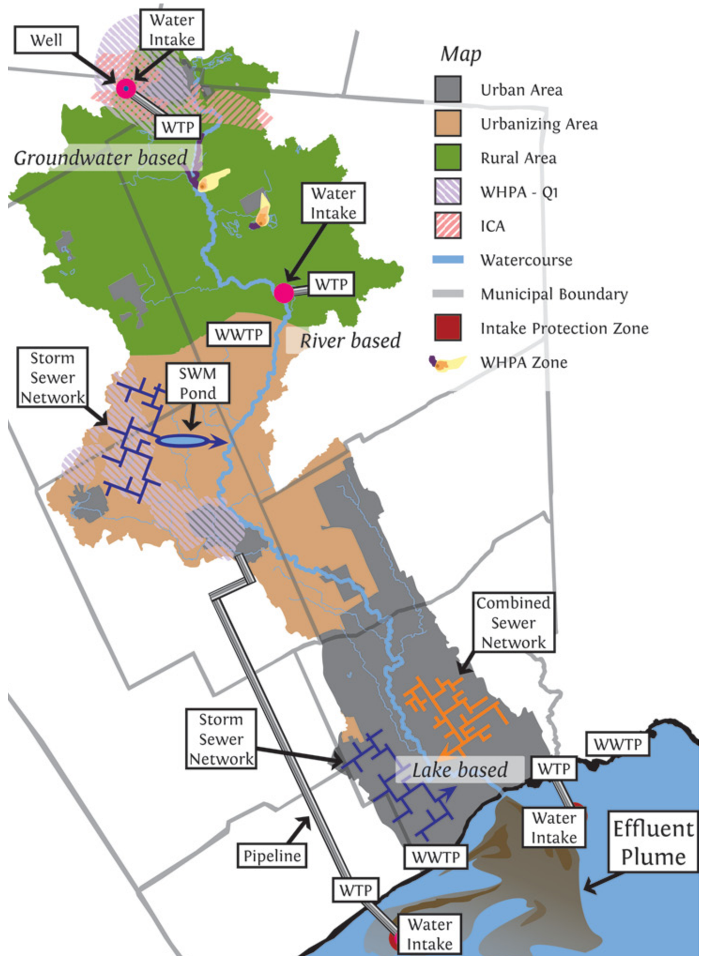



**Figure 1.1.2:** A conceptual imagining of an Ontario watershed demonstrates that the watershed scale reveals the connections between different water management activities, and their reliance on shared water resources. The figure shows areas where stormwater sewers discharge directly to streams and lakes without treatment, and areas where ponds treat stormwater prior to discharge. The figure shows drinking water sourced from groundwater, river, and lake sources, as well as a pipeline to transport drinking water. The figure shows river-based and lake-based wastewater discharge, as well as combined sewers. (Source: CVC)

## 1.2 Objective and scope

The purpose of this guide is to outline a phased approach to completing a water sustainability plan. It is a tool that water managers can use to streamline their planning efforts, reduce costs, and coordinate decisions and management tasks relating to water infrastructure. This guide also includes suggestions on how to expand existing information to fill data gaps in the existing knowledge base within a study area.

There is already extensive guidance for watershed and municipal planning activities. This guide seeks to build upon these resources to include consideration for climate change, asset management, and retrofitting existing urban areas. This guide provides a step-by-step process that municipal water service providers can follow to make more sustainable decisions reflecting the interconnected nature of water resources in Ontario.

The intended audience for this document includes municipal water, wastewater and stormwater management service providers, watershed planners, land use planners and water resources practitioners in Ontario. Implementing the principles outlined in this guide will also require inclusion of other municipal departments, such as parks and recreation, planning, building, transportation and public health, as well as clients of municipal water services such as residents, developers, and businesses.

## 1.3 Policy and legal support

This section provides an overview of relevant policies and legal trends that support the One Water approach.

### Supporting policy

A number of policies in Ontario directly and indirectly relate to water management. The following policies are relevant to and provide support for the water sustainability planning approach outlined in this guide.

#### Provincial Policy Statement

The Provincial Policy Statement states "the watershed is the ecologically meaningful scale for integrated and long-term planning." This guide puts forward the watershed and/or subwatershed as an incredibly useful boundary to consider for water sustainability planning. The Provincial Policy Statement also emphasizes that planning authorities should consider the potential increased natural hazard risk associated with climate change.

#### Water Management: Policies, guidelines, provincial water quality objectives of the Ministry of Environment and Energy

Water management in Ontario is, in part, guided by the policies outlined in this document, also known as the "Blue Book."[2] This document provides direction on management of surface water and groundwater from a quality and quantity perspective. These are the stated goals of the document:

- Ensure water quality is satisfactory for aquatic life and recreation, to preserve groundwater quality to a quality protective of the greatest number of beneficial uses.
- Manage surface water and groundwater quantity to ensure a fair sharing among users, water conservation, and sustainability of the resource.

The Blue Book outlines the Provincial Water Quality Objectives (PWQO), which are numerical and narrative criteria which serve as chemical and physical indicators representing satisfactory level for surface waters and where it discharges to the surface water and groundwater of the Province. The PWQO are a set at a level of water quality that is protective of all forms of requirements aquatic life and recreational use of surface waters.

#### The Safe Drinking Water Act

Under Section 19 of the *Safe Drinking Water Act*, decision-makers for municipal drinking water systems can be held personally liable for failing to act in a reasonable way to ensure the safety of drinking water system user. A water sustainability plan considers potential impacts to drinking water sources and services, and puts forwards a plan to limit those impacts to promote safe and sustainable drinking water services into the future.

### The Ontario Water Resources Act

The *Ontario Water Resources Act* includes provisions for controlling discharge of pollutants into waters that could result in impaired water quality. Section 53 the *Ontario Water Resources Act* requires environmental compliance approvals for sewage works (including stormwater and wastewater works).

### The Environmental Protection Act

The *Environmental Protection Act* governs the discharge of contaminants into the natural environment where that discharge could cause an adverse effect.

### The Environmental Assessment Act

The Ontario *Environmental Assessment Act* provides a process by which the environmental impacts of infrastructure projects, including municipal infrastructure, can be considered and approved by the Ontario Ministry of the Environment and Climate Change. Water, wastewater and stormwater master plans are typically carried out following the class environmental assessment (Class EA) process. If the infrastructure project follows the planning process outlined in the Class EA, it does not need additional approval under the *Environmental Assessment Act*[3].

### The Water Opportunities Act, 2010

The purposes of the *Water Opportunities Act* are to foster innovative water, wastewater, and stormwater technologies, services and practices; to create opportunities for economic development and clean-technology jobs in Ontario; and to conserve and sustain water resources for present and future generations. The Act provides a framework for municipal water sustainability plans, which include asset management, financial, and water conservation plans, as well as risk assessment, and actions to maintain and improve water services.

### The Endangered Species Act

Many municipalities and watersheds in Ontario provide habitat for endangered species. This habitat may include aquatic species that can be impacted by water management activities, such as municipal and wastewater discharge, groundwater taking, and land use changes resulting in altered hydrology. A water sustainability plan should identify sensitive habitats that may require protection to ensure compliance with the *Endangered Species Act* and create a plan for water management activities that enhance and protect that habitat.

## Legal support

In addition to policy, there are legal considerations that influence water management decisions. Liability with respect to water can also come under common (tort) law, the most important of which is negligence, where a duty of care is owed to others, and liability results from a standard of care not being met.[4] Typically, those who construct, operate, and maintain water systems can be found negligent and liable for their actions if they do not meet a standard of care. Recent lawsuits in Canada highlight that policy decisions do not attract negligence, but operational decisions can be seen as negligent.[5] For example, in 1996, a case again the City of Thunder Bay resulted in a finding of negligence over an operational decision. The plaintiffs had experienced basement flooding during a storm event and alleged that the City had known about the problems but acted negligently. The City had passed a by-law requiring downspout disconnection from the sewage system to alleviate capacity issues; however, the City was found negligent for failing to enforce the by-law.

*Recent legal cases in Canada indicate that maintenance of water management infrastructure and enforcement of programs can influence findings regarding negligence.*

## 1.4 Outline

The steps in this guide form a roadmap that municipal service providers can follow when completing a water sustainability plan (see Figure 1.3.1). The remaining chapters will follow each step and identify information to be gathered and decisions to be made.

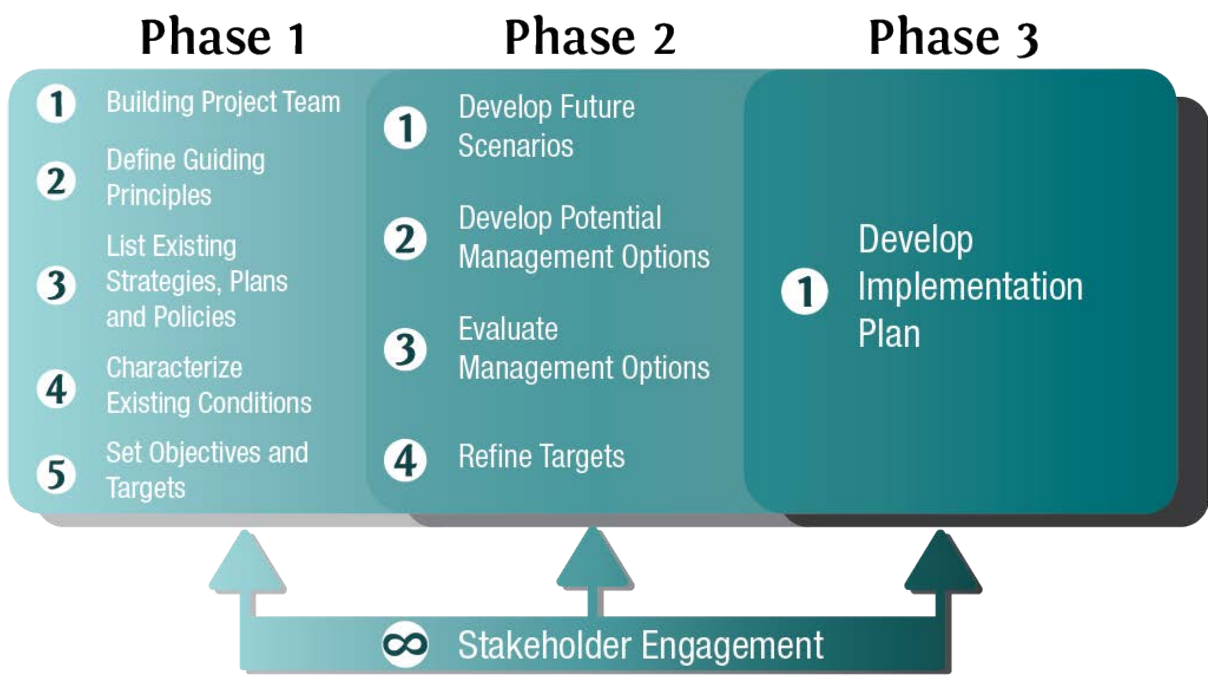
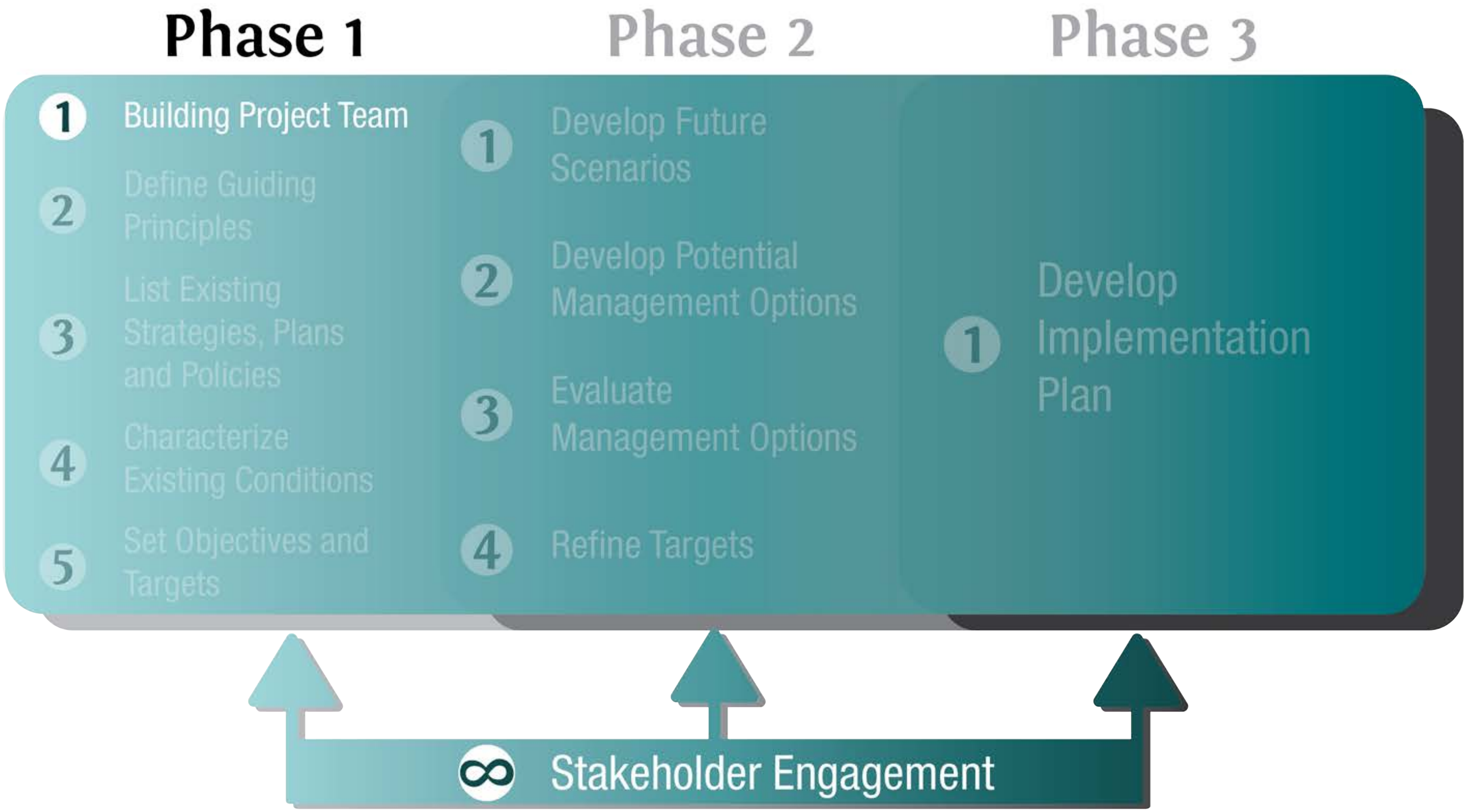



**Figure 1.3.1:** The roadmap to completing a water sustainability plan. (Source: CVC)

# 2.0 Building the Project Team and Scoping the Study Area



The first step in creating a water sustainability plan is to form a project team that represents the water management issues to be included in the plan. This presents a challenge, however, since in most of Ontario no single entity has responsibility for the entire water cycle. The team should then scope the project, including the level of detail and extent of the study area.

Water management in Ontario is carried out by property owners and users (residents, businesses), municipalities, conservation authorities, and provincial ministries using many different governance structures that exist across the province. To create a truly integrated water sustainability plan, the project team should include members representing management of drinking water, stormwater, wastewater and natural assets. Representatives may include a range of practitioners, such as engineers, planners, ecologists, and hydrogeologists. The project team should also consult with users of water services (e.g., the public, businesses).

## 2.1 Building a collaborative team

### Municipalities

Ontario has a two-tier municipal system. The upper-tier municipality is comprised of two or more lower-tier municipalities. Upper-tier municipalities include counties and regional municipalities, while lower-tier municipalities include cities, towns, townships, villages, and municipalities. There are also single-tier municipalities, such as City of Hamilton and City of Toronto. Some single-tier municipalities formed during an amalgamation of former lower-tier municipalities, or are located in an area where there are no upper-tier municipalities, as is the case for much of northern Ontario. Where there are both upper and lower-tier municipalities, powers and responsibilities are divided between the two according to the Ontario *Municipal Act.*[6]

As Table 2.1.1 shows, upper-tier municipalities are exclusively responsible for water production, treatment, and storage, and non-exclusively responsible for sanitary sewage treatment and collection (may be privately provided), as well as stormwater collection and drainage[7]. Where there is non-exclusive responsibility, the lower-tier municipalities often provide the water service. Most upper-tier municipalities do provide some form of municipal water services, and therefore should complete or participate in water sustainability plans for those services in collaboration with lower-tier municipalities in order to integrate their water management and planning processes. Single-tier municipalities, typically have jurisdiction over all aspects of water management.

### Case Study: Cooksville Creek Vulnerability Assessment

In the Cooksville Creek watershed, stormwater is managed by the City of Mississauga (with the exception of regional roads). During an extreme rainfall event on July 8, 2013, many residents experienced basement flooding from sanitary sewer backup, due to stormwater entering the wastewater collection system, which is managed by the Region of Peel. Both municipalities took actions to improve the resiliency and capacity of their respective water management systems to prevent this problem in the future, including the completion of a joint vulnerability assessment for the watershed, with participation from Mississauga, Peel, and CVC staff.

**Table 2.1.1:** Assignment of public utilities in a two-tier municipality. (Source: Ontario Municipal Act, 2001)

| Sphere of Jurisdiction | Part of Sphere Assigned | Upper-Tier Municipality to Which Part of Sphere Assigned | Exclusive or Non-Exclusive Assignments |
|---|---|---|---|
| **Public Utilities** | Sewage treatment | All counties, Niagara, Waterloo, York | Non-exclusive |
| | | Durham, Halton, Muskoka, Oxford, Peel | Exclusive |
| | Collection of sanitary sewage | All counties, Niagara, Waterloo, York | Non-exclusive |
| | Collection of stormwater and other drainage from land | All upper-tier municipalities | Non-exclusive |
| | Water production, treatment, and storage | All upper tier municipalities except counties | Exclusive |
| | Water distribution | Niagara, Waterloo, York | Non-exclusive |
| | | Oxford, Durham, Halton, Muskoka | Exclusive |

## Conservation authorities

In Ontario, 36 conservation authorities conduct watershed management programs and provide services on a watershed basis. One of their primary roles is to protect people and property against the damages of riverine flooding. According to a fact sheet produced by Conservation Ontario, conservation authorities in Ontario manage flood control infrastructure valued at $2.7 billion, including dams, dykes, channels, and erosion control structures.[8]

Local conservation authorities should be included in the development of a water sustainability plan based on their role in water and watershed management and their extensive knowledge of the watershed. Conservation authorities are typically experienced in conducting watershed and subwatershed studies, which are similar in process, scope, and stakeholder engagement to the water sustainability plan process. Conservation authorities also provide review of planning documents for land use and infrastructure projects. The local conservation authority may be a strong choice to lead a water sustainability plan, especially if it has previously led other studies of similar magnitude involving coordination with upper and lower-tier municipalities, NGOs, and developers. For example, CVC led the Credit River Water Management Strategy Update, which was completed in 2007. It involved coordination and collaboration with four upper-tier and ten lower-tier municipalities.

Many conservation authorities manage monitoring programs, including flow monitoring for flood warning programs, watershed health monitoring, including groundwater and surface water monitoring (quality and quantity), and biological and fish monitoring.[9] This information is useful in establishing receiving water objectives and targets for a water sustainability plan with respect to the level of service water management systems should provide.

## Third-party agencies

A number of third-party agencies, including public and administrative agencies, play a role in water management throughout Ontario. For example, the Ontario Clean Water Agency (OCWA) is a Crown agency of the Province of Ontario. OCWA provides water, wastewater, and stormwater operation and management services for some municipalities, First Nations communities, businesses and institutions.

In study areas where third-party agencies play a role in water management activities, these agencies should be involved as members of the project team for a water sustainability plan. Private-sector organizations also operate and manage water and wastewater on a contractual basis with municipalities. Table 2.1.2 shows the organizations, including municipalities, OCWA, and private organizations, that are responsible for water and wastewater management and operations in Ontario.

**Table 2.1.2:** Water and wastewater management in Ontario. (Source: WaterTAP)

| Water Facilities | | Wastewater Facilities | |
|---|---|---|---|
| Operator | No. of facilities | Operator | No. of facilities |
| Municipalities | 467 | Municipalities | 299 |
| OCWA | 160 | OCWA | 157 |
| Other Private Entities | 55 | Other Private Entities | 10 |
| Total: | 680 | Total: | 466 |

## 2.2 Define roles and responsibilities

Once the project team members have been identified, their roles and responsibilities should be clearly defined. Roles for a water sustainability plan team will vary based on the municipalities and conservation authorities involved in the study.

### Leading the study

It is not the intent of this guidance document to identify a single entity or department that should bear the responsibility of leading a water sustainability plan. Rather, this guide provides a number of possible scenarios, with examples where possible, based on the type of municipal and watershed boundaries and water management structures that exist in Ontario.

When the upper-tier and lower-tier municipalities are creating a joint plan, the upper-tier municipality may be able to lead the study most effectively, since it already coordinates planning initiatives with the lower-tier municipalities, and can likely take advantage of existing reporting or communication structures.

*A jointly completed water sustainability plan is a mechanism by which upper and lower-tier municipalities and conservation authorities can collaborate to manage water. A joint water sustainability plan is also a useful way for small and medium-sized municipalities to share resources and complete water management planning activities on a larger scale (such as a watershed scale) in one streamlined document.*

### Case Study: Town of Halton Hills

The Town of Halton Hills has collaborated with both the regional and neighbouring municipalities to survey and maintain their assets. For example, Halton Hills and the Town of Milton have pooled their oil and grit separators into a single large contract for maintenance and cleanout. Another example is the Halton Hills' CCTV partnership with Halton Region, which allows Halton Hills to survey 5 km of storm sewer pipe each year as part of the Region's larger CCTV survey contract. The coordination of these capital programs ensures that taxpayers receive good value for their money.

Depending on municipal and watershed boundaries, it may be easier for a conservation authority to take the lead role in preparing a water sustainability plan, if a number of municipalities are completing a joint plan in which the combined study area falls within (or mostly within) one watershed. The Cooksville Creek watershed case study in Appendix A is an example of a water vulnerability study that led by the local conservation authority (CVC). The study was completed for a watershed located entirely within the CVC's jurisdiction, but involved input from the Region of Peel and City of Mississauga, as well as CVC staff. In this case, the conservation authority was able to coordinate between the upper and lower-tier municipalities, and could bring concerns relating to watershed, stormwater, drinking water, and wastewater vulnerability into the study with equal weight.

### Case Study: Cooksville Creek

In 2014, City of Mississauga staff, the Region of Peel, and CVC decided to use the Cooksville Creek watershed as a case study, due to readily available information about the watershed, and an established understanding of the links between the stormwater and sanitary systems, especially during extreme rainfall events such as the July 8, 2013 storm. The group decided that studying this watershed would provide an opportunity to understand how integrating and optimizing watershed, stormwater, water and wastewater services can help municipalities prepare for, mitigate, and adapt to the impacts of climate change. Lessons the team learns through the study will support management decisions such as standards and integrated risk management. They will also inform emergency preparedness for the Region, City, and CVC to reduce future risks from extreme rainfall events.

### Review and input

When two-tiered municipalities are not creating a joint plan, all municipalities should still provide input and review throughout the project process, along with any local conservation authorities. Other actors, such as environmental non-governmental organizations (ENGOs), private-sector organizations with interests in water (such as hydropower generators), and businesses and residents who use water services, can provide input into the process and review draft documents.

The project team can conduct this input and review process through workshops, town-hall meetings, scoped meetings with specific parties, and public/online review periods. Effective engagement will ensure stakeholders feel like they are part the process. This in turn can lend to efficient implementation.

## 2.3 Scoping the study

Scoping a water sustainability plan depends on several factors. Municipal boundaries, watershed boundaries, municipality size, environmental stressors, and water management activities can all play a role.

In the case of smaller municipalities facing groundwater and assimilative capacity constraints, the scope of the study may be focused on a selection of integrated management options (e.g. stormwater techniques, such as LID or water conservation practices like watering restrictions) that can help maintain groundwater quantity and quality, as well as stream base flows to optimize both water and wastewater treatment.

## 2.4 Defining the study area

The *Provincial Policy Statement* (2014) identifies the watershed as "the ecologically meaningful scale for integrated and long-term planning, which can be a foundation for considering cumulative impacts of development." By looking at systems from a watershed scale, the project team can understand the full implications of water management decisions made in one part of the watershed on another part of the watershed. For this reason, the ideal study area for a water sustainability plan would be a watershed or subwatershed boundary. However, since municipal planning boundaries generally do not coincide with watershed boundaries, it may not always be feasible to choose the watershed as the boundary for a water sustainability plan. Here are some elements to consider when defining the study area of a water sustainability plan:

- Watershed or subwatershed boundaries
- Municipal boundaries (upper and lower tier)
- Other physical boundaries or features (e.g., lakeshore, nearshore, escarpment, moraine, etc.)
- Existing planning areas (e.g., source water protection plan, water/wastewater master plan).

The following sections provide some of the pros and cons of selecting different study area boundaries.

## Case Study: Headwaters of the Credit River

The Headwaters of the Credit River include the much of the Town of Orangeville, as well as the towns of Caledon, Mono, Amaranth, and East Garafraxa. The drinking water supply in the Headwaters subwatershed comes from groundwater sources. As such, subwatershed study focused on groundwater recharge and impacts of water taking on tributary base flows. The study also looked at the ability of the Credit River to continue to assimilate effluent from the Town of Orangeville water pollution control plant, which discharges to the Credit River. This study provides examples of the links between groundwater taking, land use changes impacting infiltration, stream base flows, and wastewater treatment.

### Watershed boundary

Selecting the watershed (or subwatershed) as the boundary for a water sustainability plan encourages integrated water management and planning, and helps project teams fully understand the downstream consequences of upstream decisions.

*A watershed approach is not new. It has been used by the Metropolitan Sewer District of Greater Cincinnati to identify sources and issues contributing to wet weather issues, including combined sewer overflows.*

By taking this approach, upstream and downstream municipalities and stakeholders are encouraged to work collaboratively to develop integrated planning and management solutions that minimize risks across the watershed. This approach also reframes stormwater management as a resource management problem, rather than a waste management problem, by incorporating the downstream impacts of stormwater management into the water sustainability plan process.

The watershed perspective can make links between water management systems clear. For example, water takings that reduce stream base flow may impact assimilative capacity for a wastewater treatment facility in a downstream municipality, while stormwater management practices that promote infiltration may reduce this impact. By understanding these connections at a watershed scale, a stronger case can be made for investment in one area of water management which will have multiple benefits throughout the watershed.

New York City's Ecosystem Services Strategy provides one example of using the watershed as a boundary. To protect the watershed that is New York City's drinking water source, the City formed a partnership with rural landowners to invest in pollution control measures on farms in the upstream portion of the Catskill watershed. The city-funded program, Whole Farm Planning, empowered farmers to implement pollution control measures which prevented more costly investment (approximately eight times more expensive) on filtration systems.[10] This is an excellent example of upstream investment benefitting a downstream municipality.

In areas of Ontario with conservation authorities (see Figure 2.4.1), water management issues within watershed boundaries are already well understood. Conservation authorities use watershed boundaries to set study limits for watershed plans and studies. Where there are plans and studies, there is plenty of background information on hydrology, hydrogeology, land use, geology, topography, aquatic resources, climate, and more. Using watershed boundaries as study areas for water sustainability plans allows project teams to take advantage of material from previous studies and build on the results. This will not only result in a more robust water sustainability plan, it will save time and effort.

As mentioned earlier, watershed boundaries generally do not coincide with municipal planning boundaries. It may not be feasible to conduct a water sustainability plan over the exact watershed boundary. However, it might be possible to prepare a joint water sustainability plan with other municipalities which approximates the watershed boundary, or includes most of the major water management issues in that watershed.

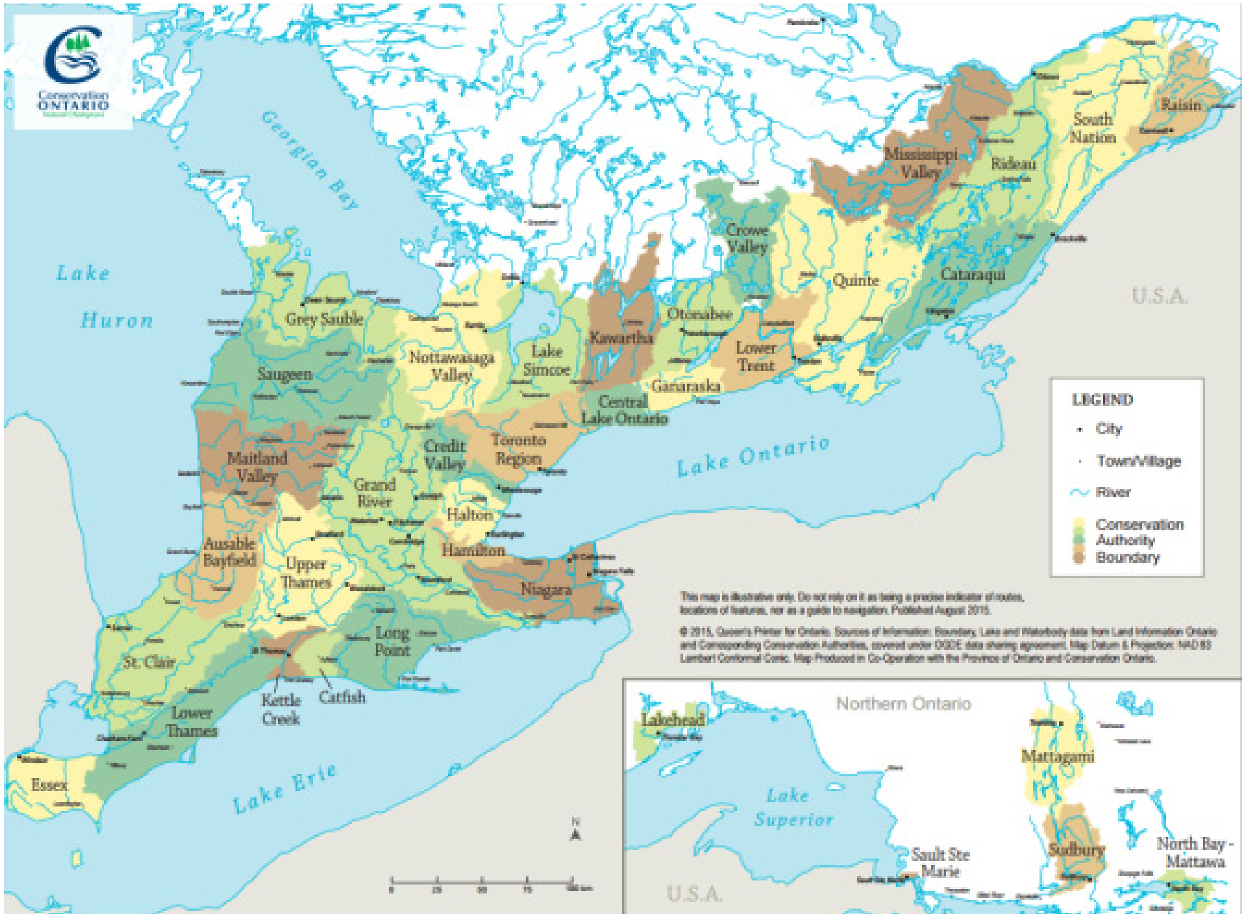



**Figure 2.4.1:** Southern Ontario watersheds are regulated by conservation authorities, as are some watersheds in northern Ontario. (Source: Conservation Ontario)

## Municipal boundaries

Using municipal boundaries to set the study area for a water sustainability plan is an obvious choice. This option is how land use and associated water management and planning activities are generally performed.

In single-tier municipalities, most water management (drinking water, wastewater, stormwater) activities are carried out by the municipality. For this reason, the municipal boundary is an obvious study area boundary for a water sustainability plan. In such a case, consider whether any additional municipalities could be included in a joint water sustainability plan, in order to identify and better understand any upstream or downstream concerns that might impact the single-tier municipality. Project teams can also consult conservation authorities for this purpose. Figure 2.4.2 shows an example of a single-tier municipality and its watersheds.

For two-tier municipalities in which the upper-tier holds responsibility for water management activities, it might be useful to set the regional municipal boundary as the study area for a water sustainability plan, since upper-tier municipalities geographically contain the whole of the lower-tier municipalities within them. Such a study would be a joint plan, with the region or county, lower-tier municipalities, and local conservation authorities. An example is shown in Figure 2.4.3.

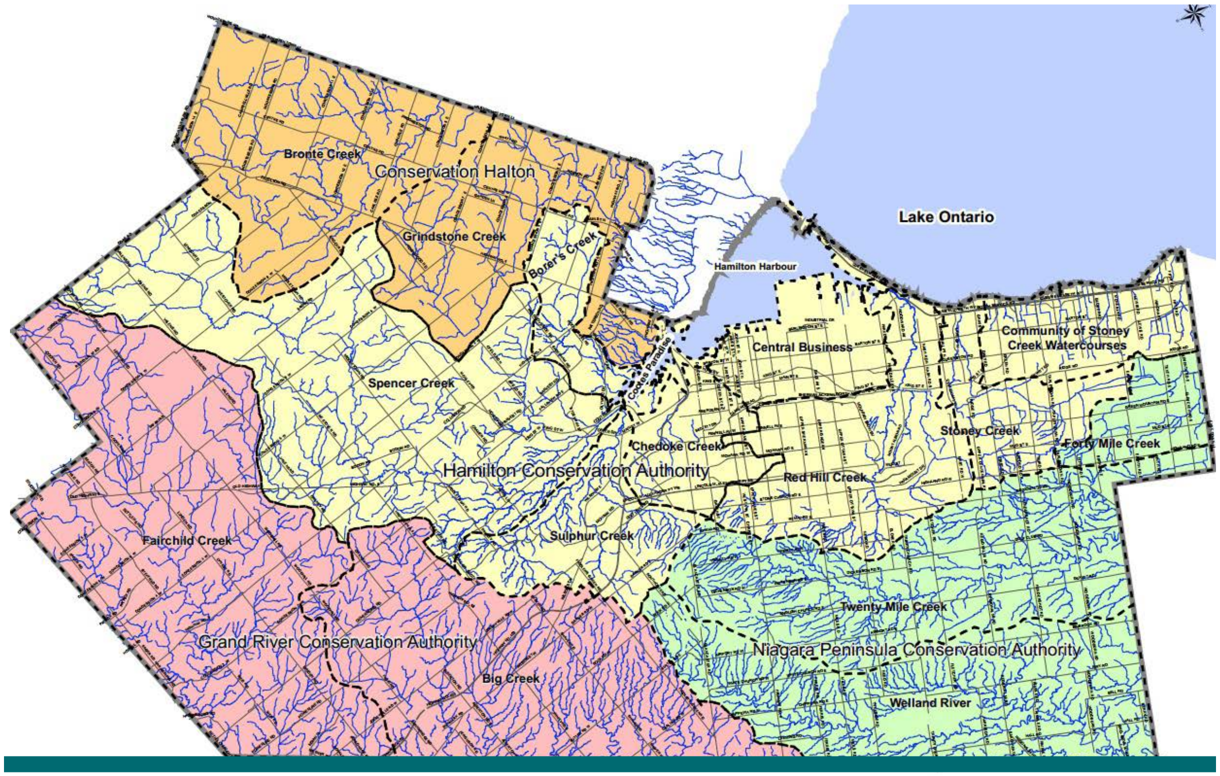



**Figure 2.4.2:** The City of Hamilton is a single-tier municipality that provides drinking water, wastewater, and stormwater services. The City spans several watersheds, including those within the jurisdictions of Conservation Halton, Hamilton Conservation Authority, Grand River Conservation Authority, and Niagara Peninsula Conservation Authority. Drainage from the City of Hamilton flows to the Grand River (Lake Erie), the Niagara River (Lake Ontario), Hamilton Harbour (Lake Ontario) and directly to Lake Ontario through Grindstone Creek and Bronte Creek. A water sustainability plan could be completed over the municipal boundary, with consultation with upstream and downstream municipalities for each of the watersheds in the boundary. (Source: City of Hamilton)

As noted earlier, project teams can also consult municipalities from outside the region to understand potential upstream and downstream issues. This could provide an opportunity to clarify and/or streamline water management roles and responsibilities between the participating parties. In any case, a study using the regional municipal boundaries should include lower-tier municipalities and conservation authorities as partners.

Project teams can also prepare water sustainability plans using lower-tier municipality boundaries. In this case, both the upper-tier municipality and local conservation authority(ies) should be partners in the study. Their roles will vary depending on how water is managed in the study area. In some cases, it may be easier to start with a lower-tier municipal boundary, or even a small watershed or subwatershed boundary, as a pilot water sustainability plan before expanding across the entire upper-tier municipality.

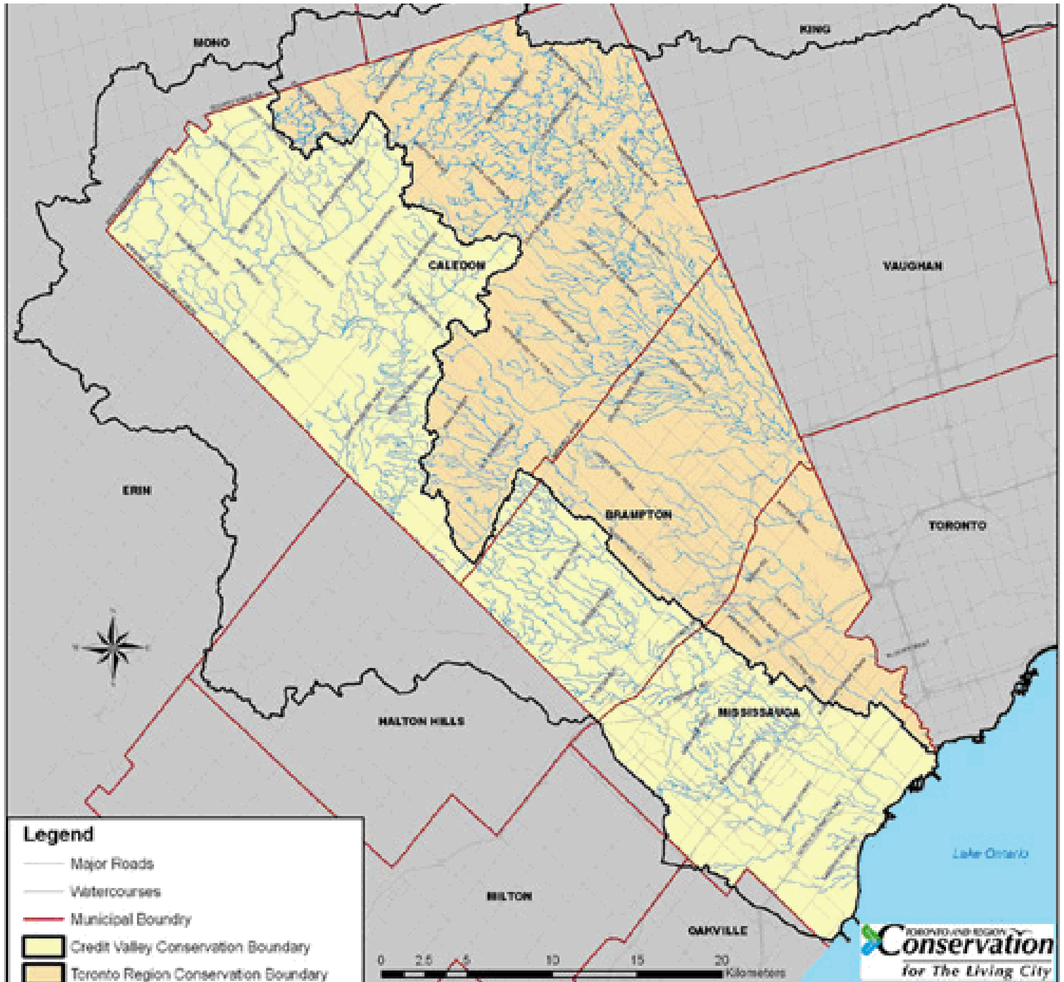



**Figure 2.4.3:** The Region of Peel is an upper-tier municipal that provides drinking water, wastewater and stormwater services (on regional roads only), while three lower-tier municipalities within Peel (Town of Caledon, City of Brampton, and City of Mississauga) provide all other stormwater services. The Region is located within the watersheds of Credit River Conservation, Toronto Region Conservation Authority, and Conservation Halton. (Source: TRCA)

## Case Study: Cooksville Creek Vulnerability Assessment

The Cooksville Creek watershed was selected as a study boundary for a water vulnerability assessment that aimed to integrate different water management systems. Using a physical – rather than political – boundary, helped the project team to understand the physical interactions between different water systems. During the study, the team slightly expanded the boundary to include portions of sanitary sewersheds outside of the watershed, as well as the water and wastewater treatment plants. The team also incorporated interactions between these systems and the surface water and stormwater systems within the watershed. The use of the Cooksville Creek watershed boundary allowed the project team to build on existing information including modelling studies, watershed studies, and a stormwater master plan.

## Other boundaries

In addition to watershed and municipal boundaries, the study area for a water sustainability plan can be set based on previous planning activities and/or other physical boundaries. For example, Figure 2.4.4 shows the area managed by the Elgin Area Primary Water System. A similar boundary could be used for a water sustainability plan, since this area is already the boundary for a water-related activity (in this case, drinking water supply)

As mentioned earlier, previous studies and plans might contain background information for water management activities within the study area. As an added benefit, water management and planning professionals who worked together on these studies and plans may already have well-established working relationships. Applicable planning activities could include source water protection, water supply systems, and multi-region wastewater management systems.

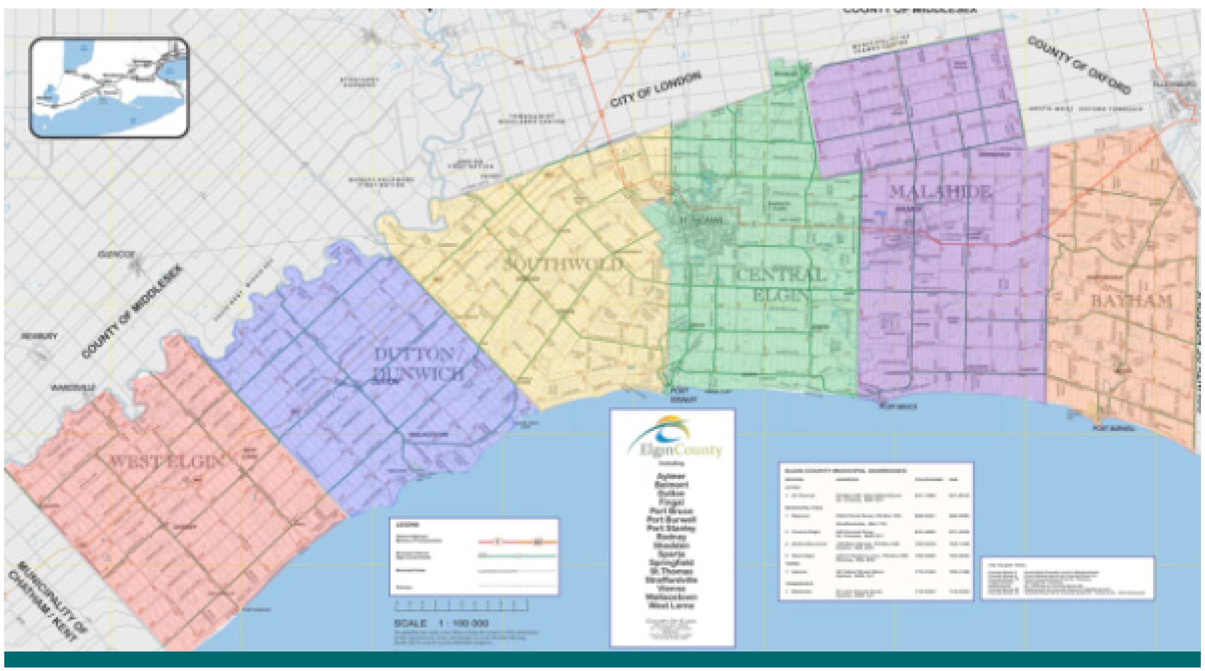



**Figure 2.4.4:** The lower-tier municipalities within Elgin County receive drinking water managed by the Elgin Area Primary Water System. The six lower-tier municipalities each border the northern Lake Erie shoreline, and have similar land uses and natural features. A joint plan could facilitate cost-sharing. (Source: Elgin County)

### Example: City of Mississauga Living Green Master Plan

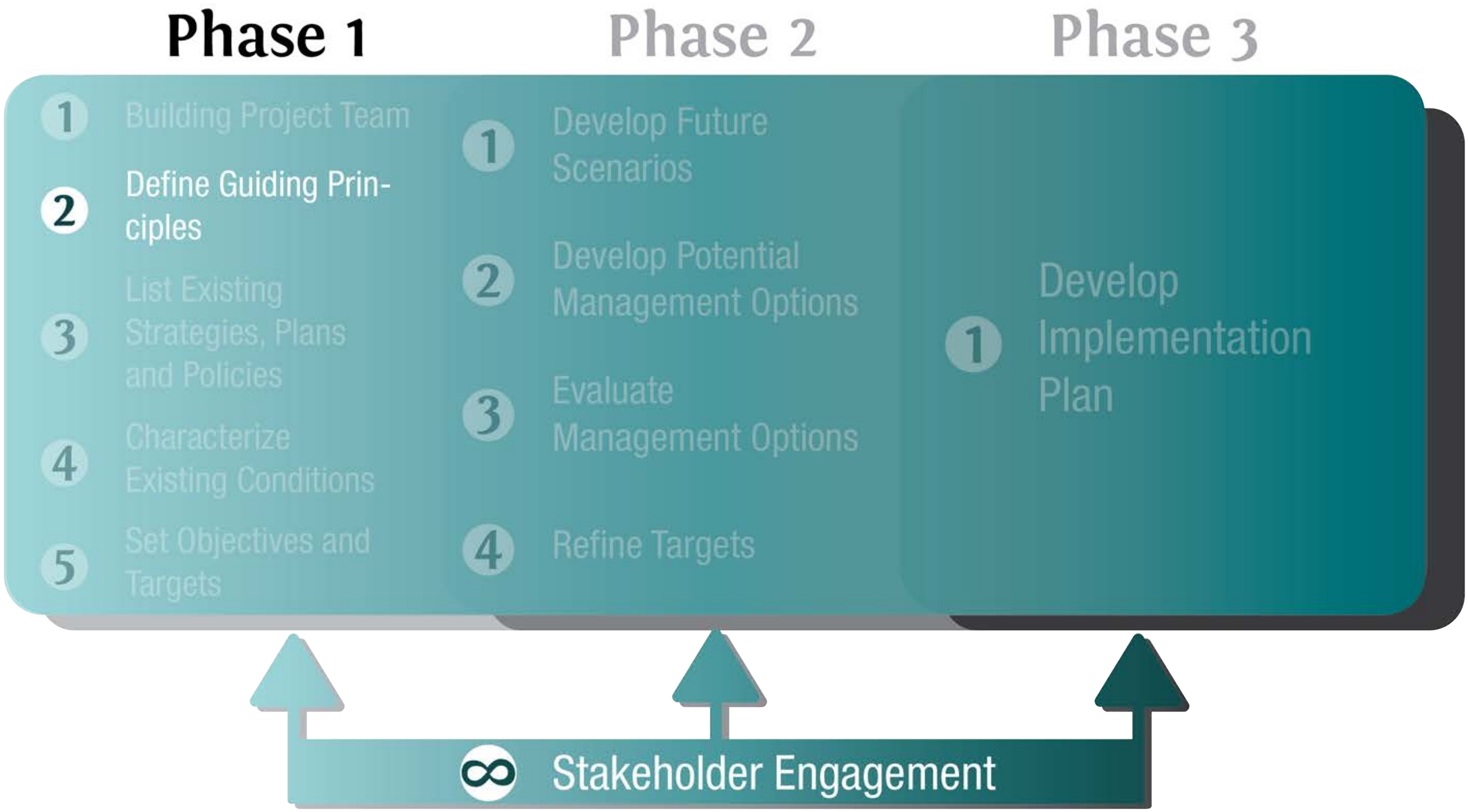
The City of Mississauga created an Environmental Master Plan titled the Living Green Master Plan, which provides a single plan for the City's current and future environmental programs and policies. The first section of the Living Green Master Plan outlines the vision for the plan, which consists of expansive, future-thinking statements, such as:

*"Mississauga's rivers and streams teem with fish. New wetlands and natural areas along with a regenerated off-shore waterfront provide habitat for indigenous aquatic species and wildlife.*
*Mississauga is a healthy place where people choose to live, work and play."*

The study also outlined goals, which included:

- Implement the Strategic Plan Vision
- Choose Priorities and Allocate Resources
- Support Better Integration among City Departments
- Develop Baseline Information, Targets and Indicators to Measure Success
- Provide Education, Public Awareness to Help Residents Live Green
- Foster Partnerships and Collaboration

# 3.0 Guiding Principles



The term "sustainability" has been used and applied broadly. Many municipalities in Ontario have already created sustainability strategies or sustainability plans that include various aspects of environmental sustainability across their programs and departments. A water sustainability plan is similar in that it focuses on the long-term sustainability of water infrastructure and services, and is likely to overlap with existing sustainability strategies and plans. The project team should define sustainability in the context of the water sustainability plan, and identify the vision, goals, and guiding principles of the plan.

## 3.1 Visions and goals

Once the project team has defined sustainability in the context of the plan, it should clearly outline the vision and high-level goals that the water sustainability plan will fulfill. The vision and goal(s) should clearly outline to readers what the plan will help accomplish, as well as articulate a long-term vision for water management within the study area.

Depending on the composition of the project team, there may be multiple goals that reflect the mandates of the different parties involved in the water sustainability plan. For example, goals may be reflected in the strategic plans set by each municipality involved in the study. It is recommended, when possible, to create goals that reflect the integration of water management across all parts of the study area.

The goals of a water sustainability plan could include, for example, these statements:

- *Sustain and enhance natural environment*
- *Protect stream health and aquatic environments*
- *Regulate and protect groundwater*
- *Promote green infrastructure*
- *Ensure safe and abundant drinking water*

## 3.2 List the guiding principles

In addition to listing the goals and vision of your study, it will be helpful for the project team to determine the guiding principles to be used to direct the water sustainability plan. Figure 3.2.1 shows some concepts that are important for a water sustainability plan.

These principles can be helpful as the study progresses, in terms of selecting objectives and targets for the study, and screening and evaluating the different water management actions to reach those objectives. Guiding principles that will frame the water sustainability plan may include changes in traditional approaches to water management. Table 3.2.1 demonstrates some guiding principles that can be adapted for water sustainability planning.

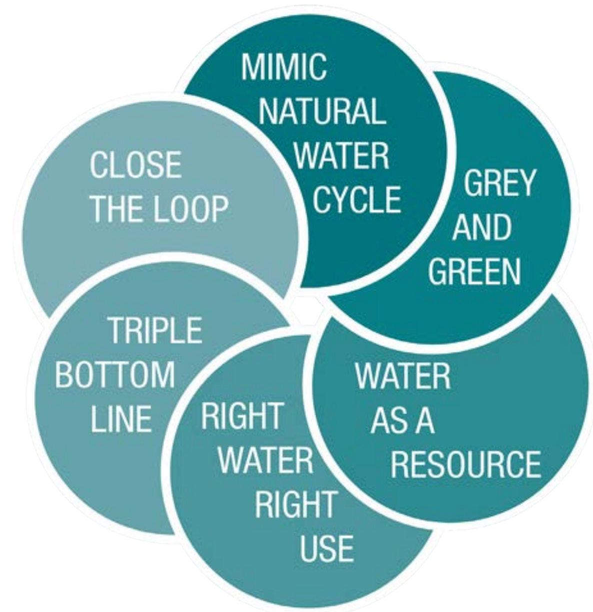
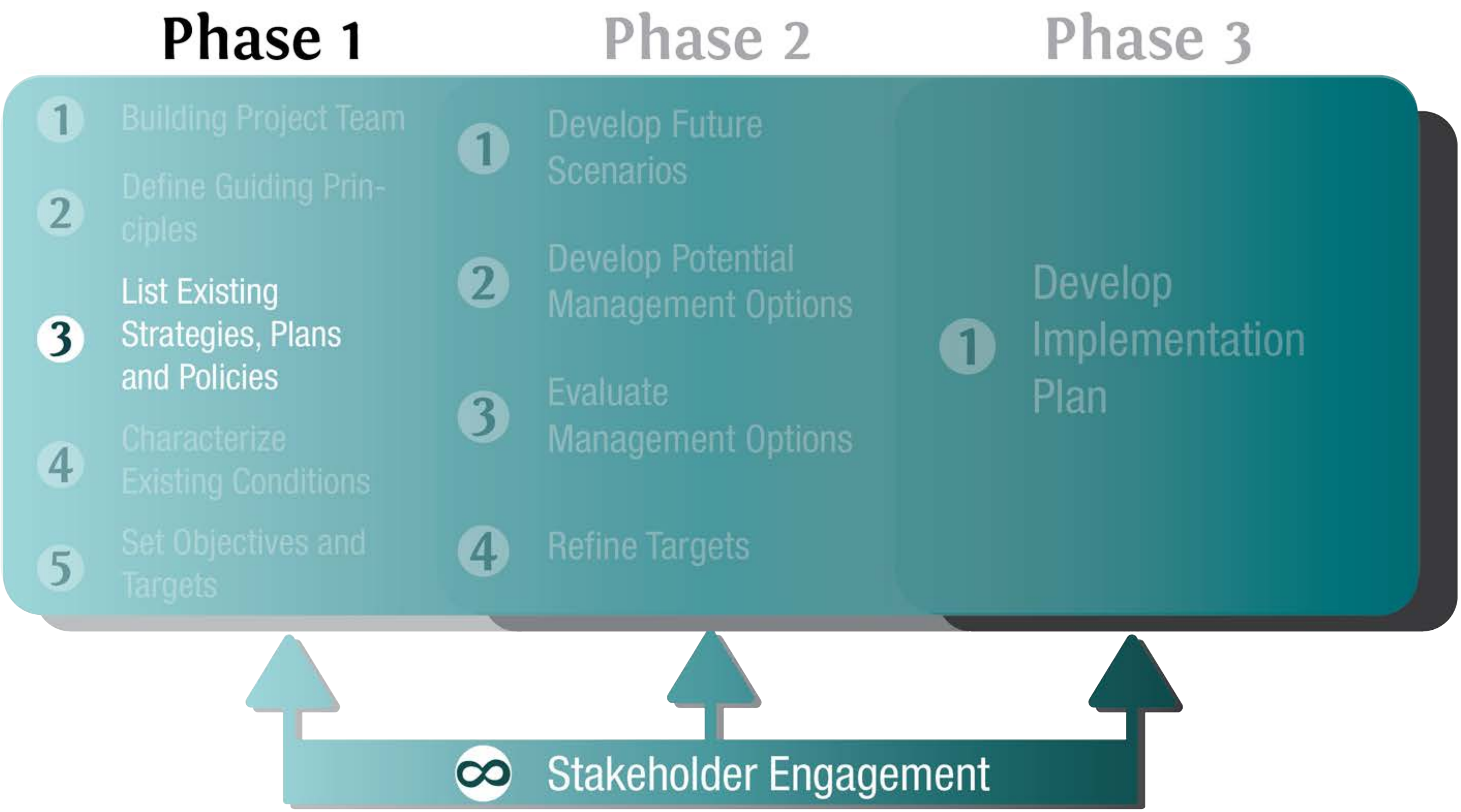



**Figure 3.2.1:** Some concepts related to water sustainability which that can be used to create guiding principles. (Source: CVC)

**Table 3.2.1:** Guiding principles based on the One Water approach to water management. (Source: Adapted from EPRI, 2010)

| Topic | Guiding Principle |
|---|---|
| Water use | Multiple use and water conservation – Use household greywater for irrigation. |
| Water quality (supplied) | Apply “right water for right use” – Treat water to a level of water quality suitable for its intended use, e.g. We don’t need to use potable water for irrigation purposes or to flush toilets. |
| Wastewater | “Close the loop” – Recover valuable resources (reclaimed water, nutrients, carbon, metals and biosolids) from “waste” water for beneficial uses such as potable water offsets, fertilizers, and generating power. |
| Stormwater | Harvest stormwater for water supply, irrigation, and/or infiltration benefits  Managing rain where it falls at the site (or close proximity) |
| Climate change | Ensure greenhouse gas reduction has been considered in all actions |
| Increase system capacity | Implement cost-effective, demand-side, green infrastructure before increasing grey infrastructure. |
| Type of water infrastructure | Integrate the natural capacities of soil and vegetation (green infrastructure) to capture, infiltrate and treat water with grey infrastructure. |
| Centralized infrastructure | Multiple decentralized small water treatment and distribution systems combining local needs and the triple bottom line. |
| Complex design | Require new infrastructure design technologies and strategies to address today’s complex water problems. |
| Infrastructure integration | “Water is water” – Integrate infrastructure and management of all types of water regionally to reduce risk and streamline management planning. |
| Public involvement | Engage public, businesses and stakeholders in the decision-making system from the beginning. |
| Monitoring and maintenance | Move smart systems out to end users to provide real-time feedback regarding energy use and water use rates to build understanding, modify behavior for higher efficiencies, and notify for maintenance. |
| Cost-benefit analyses / Return of return | Develop an understanding of the full cost and benefits of infrastructure, including externalities and the rate of return on investment from social, economic and environmental benefits. |
| Pollution prevention | Using practices and approaches to minimize contact of pollutants with water |
| Education | Empowering the public to draw connection between behavioral change and health of the environment. |
| Restoration of green infrastructure or natural assets | Repairing water cycle and enhancing natural features |

# 4.0 Existing Strategies, Plans, and Policies



Once the project team has established the goals, vision, and guiding principles of the study, the next step is to gather the relevant existing plans, strategies, and policies within the defined study area. In some cases, there may be an abundance of relevant documents regarding water management. In others, there may be very few.

## 4.1 The benefits of compiling existing information

Completing a thorough review of existing programs, policies, and plans relating to water from both internal and external partners (e.g., conservation authorities, upper and lower-tier municipalities) will help the project team identify any gaps or overlaps in existing programs. This review also promotes and encourages collaboration and coordination between different departments and agencies, and provides clarity on the mandate and roles of the various partners. The purpose of the water sustainability plan is to build upon previous work, not to reinvent or duplicate it.

*Compiling existing information is a great way to identify gaps and overlaps in existing programs, avoid duplication of work, improve efficiencies and reduce costs, and clearly define the roles and responsibilities of all municipalities and conservation authorities involved.*

## 4.2 Sources

There are several sources from which strategies, plans and policies can be collected. The level of complexity and number of plans will be dependent on the jurisdiction, the boundary of the study area, and the number of project partners. A good first step is to engage with the partner water departments to develop of a list of applicable documents for consideration. The list provided in Table 4.2.1 is a good starting point.

In some cases, it may be necessary to examine data and studies that fall outside the physical boundary of the water sustainability plan. The project team might also decide to review provincial legislation or policies that currently (or will, in the future) impact the study area. Consulting and collaboration with various partners and forming data-sharing agreements could support this work.

### Case Study: Headwaters Subwatershed Study

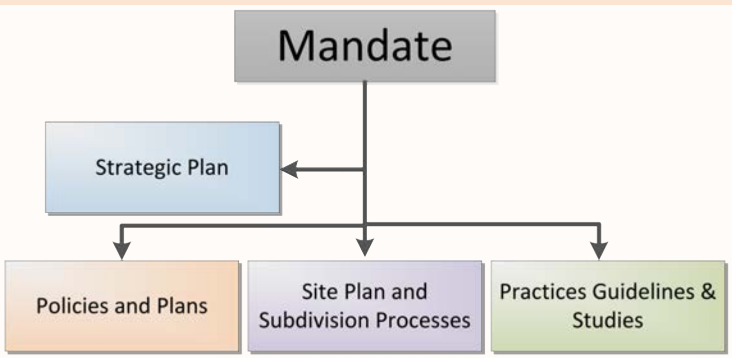
CVC's Headwaters subwatershed study integrated different water issues by sourcing material from previous studies and studies that were being completed concurrently. These studies included a Tier 3 water budget study of local water supplies, a Class EA for expansion of the Orangeville water pollution control plan, and an issues evaluation and threats assessment for wellhead protection areas in the study area.

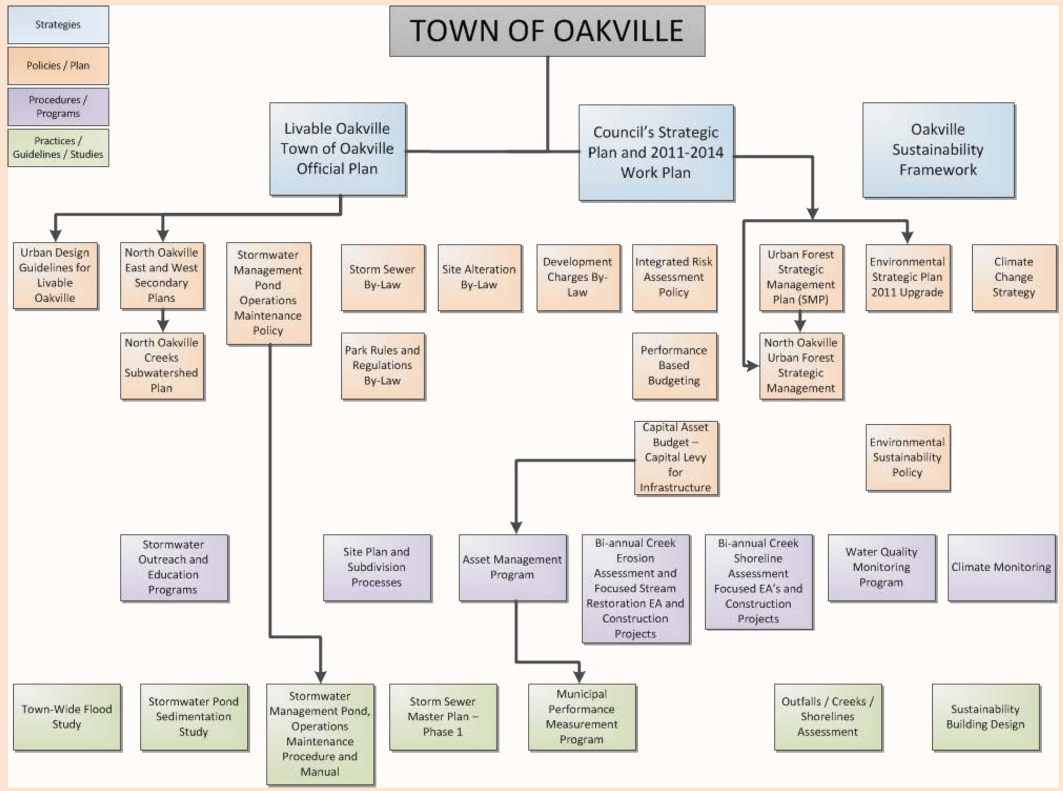
**Table 4.2.1:** A sample selection of existing documents and studies to be gathered as part of a water sustainability plan. (Source: CVC)

| Municipal | Others (Conservation Authority) | Provincial |
|---|---|---|
| Official Plan | Watershed studies | *Clean Water Act* |
| Strategic Plan | Nearshore studies | *Water Opportunities Act* |
| Master Plan (Water, Wastewater, Stormwater) | Flooding and erosion studies | *Municipal Act* |
| SWM Guideline | Water quality studies | *Lake Simcoe Protection Act* |
| Asset Management Plan | Monitoring programs (water quality, quantity, erosion, etc.) | *Great Lakes Protection Act* |
| Risk/Vulnerability Assessment | Stormwater Management Guideline | Asset Management Planning Guideline |
| Environmental Plan (including Sustainability Plan/Strategy, Climate Change Strategy) | Fluvial Geomorphic Guideline | Environmental Compliance Approval |
| Natural Heritage Plan | Watershed planning and regulation policies | Permit to Take Water |
| | | Places to Grow |
| Programs : Water Conservation, Education, Monitoring | | Stormwater Management Planning and Design Manual |
| Financial Plan | | Ontario's Climate Change Strategy |
| | Source Water Protection Plans | *Endangered Species Act* |
| | | Natural Heritage Reference Manual |
| | | Development, Inteference with Wetlands and Alternations to Shorelines and Watercourses Regulation |

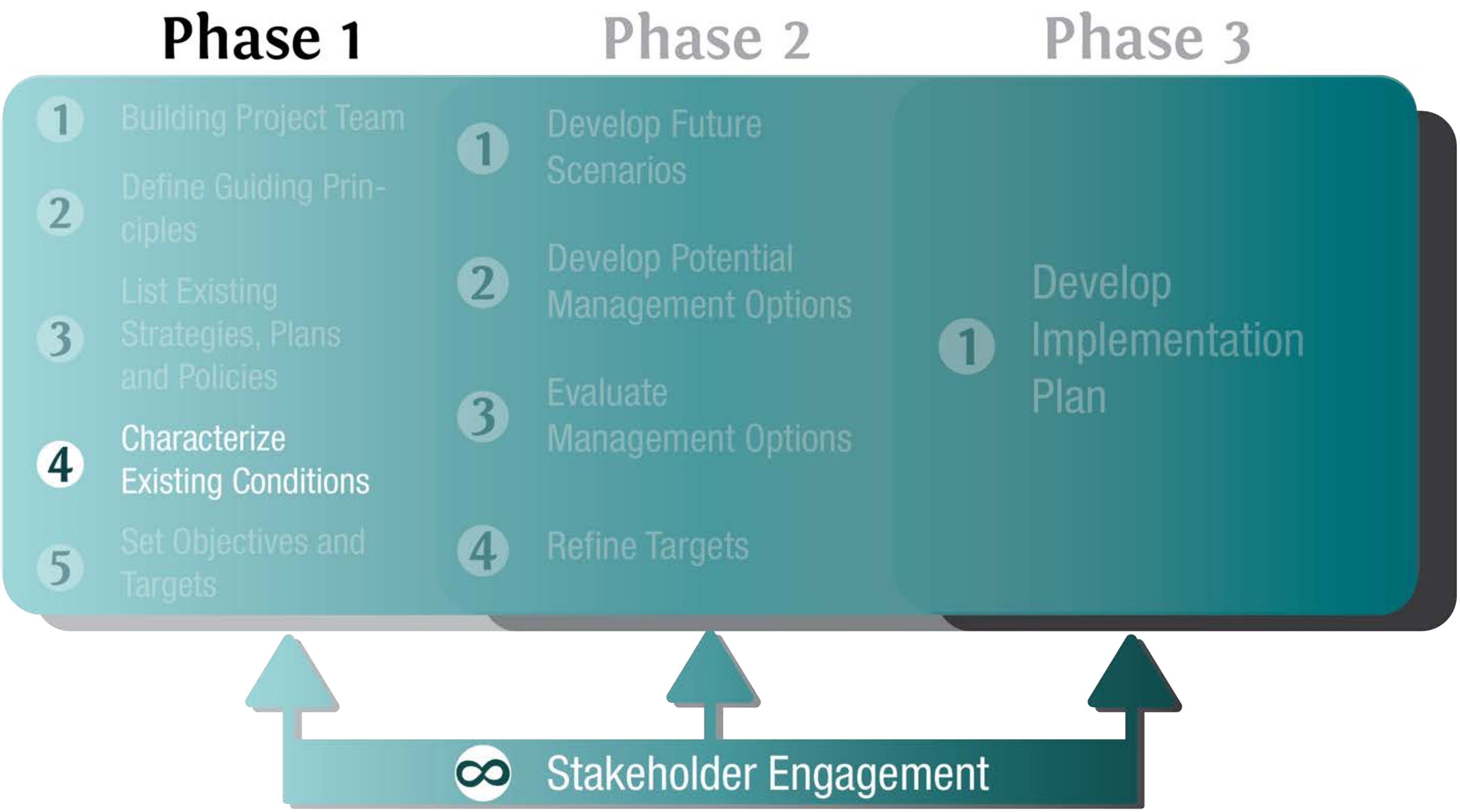
## Example: Town of Oakville Water Sustainability Plan

The Town of Oakville has completed a draft water sustainability plan, in which the project team, consisting of the Town, Halton Region, and Conservation Halton, collected all existing documents and programs relating to water management into a single document. An example for the Town of Oakville is shown below, along with a decision tree which outlines the types of documents and programs included. This framework clearly outlines the mandate for each partnering organization and helped identify opperunities to work together and streamline programs (i.e., monitoring) going forward and to identify data gaps.



# 5.0 Characterizing Existing Conditions



The next step in the water sustainability planning process is characterizing the existing conditions and infrastructure of the study area. In some cases, the project team can make use of background information from other studies, including watershed studies and master plans, to develop a comprehensive summary. For cases in which detailed plans are not available or are incomplete, this step may involve collecting new data through desktop and/or field efforts.

## 5.1 Existing land use

Determining existing land use is a critical part of characterizing existing conditions in the study area. This data should be readily available through official plan documents at upper and lower-tier municipal levels. Official plans also include information on the potential impact of land use on services, including water services.

Here is some of the land use information that can be used in a water sustainability plan:

- Parcel layer boundaries
- Zoning
- Property ownership
- Natural Heritage System
- Impervious and pervious areas

*Official plans provide information on the general policies of an upper, lower, or single-tier municipality regarding land use planning, including plans for future growth. Official plans are updated every five years to incorporate any changes that have been made to Ontario's Provincial Policy Statement and other provincial plans, such as the Niagara Escarpment Plan, and Oak Ridges Moraine Conservation Plan). As of this writing, the Provincial Policy Statement was last updated in 2014.*

## 5.2 Watershed characterization

The next step is to understand the watershed(s) in which the study area is located. Watershed characterization is a critical step in a water sustainability plan, as it provides a level of understanding of the constraints and opportunities within the unique watershed area. Project teams can gather this information through some of the existing documents discussed in the previous chapter, such as watershed and subwatershed plans and studies. This step will help the project team to identify the key issues within the study area from a watershed perspective.

*Watershed and subwatershed studies are excellent resources for information on watersheds.*

These key issues could include areas of historic urban and/or riverine flooding, high groundwater recharge or discharge, provincially significant wetlands, stressed water bodies due to water quality issues, aquatic habitat, aquatic species at risk and erosion or sedimentation within streams and lakes. If a watershed plan indicates that development largely occurred prior to the 1970s, and therefore prior to flood control, there is a good chance that there are some flooding issues. Likewise, if watershed plans or source water protection plans indicate wellhead protection areas, groundwater protection will likely be a major issue driving your water sustainability plan. If previous studies and plans do not indicate key issues, conservation authorities can provide guidance.

Depending on the study area, the level of detail supporting watershed characterization may vary. Watershed/subwatershed studies may be outdated, particularly for areas without recent development.

## Case Study: Cooksville Creek Vulnerability Mapping

As part of the Cooksville Creek vulnerability study, the project team used mapping to determine the areas within the watershed that may be more vulnerable to flooding events, such as:

- Critical infrastructure (i.e., fire, ambulance, and police stations, schools, medical centres, evacuation centres, and municipally owned facilities)
- High proportion of senior citizens
- High proportion of children
- Assisted living/social housing
- High proportion of basement apartments

The team used this information to determine priority areas that might require emergency response or changes in policy and water management.

## Existing beneficial water uses

Before starting watershed characterization, it is helpful to first define and quantify the various ways water is used in the study area. These uses will drive the water management decisions. Here are some examples of water uses:

- Municipal water taking (lake-based, river-based, groundwater-based)
- Agricultural water taking (existing and future)
- Private wells
- Industrial water taking, including aggregate extraction
- Assimilation of wastewater flows (municipal, industrial)
- Aquatic and wetland habitat
- Hydropower
- Recreational activities (e.g. golf courses, beaches)
- Navigation

Listing, characterizing, and quantifying the water uses in the study area will help the project team begin to understand the issues that it will need to consider in the water sustainability plan. As water uses are defined and quantified, your team should note the sources, be they lake, river, precipitation, or groundwater-based.

## Watershed mapping

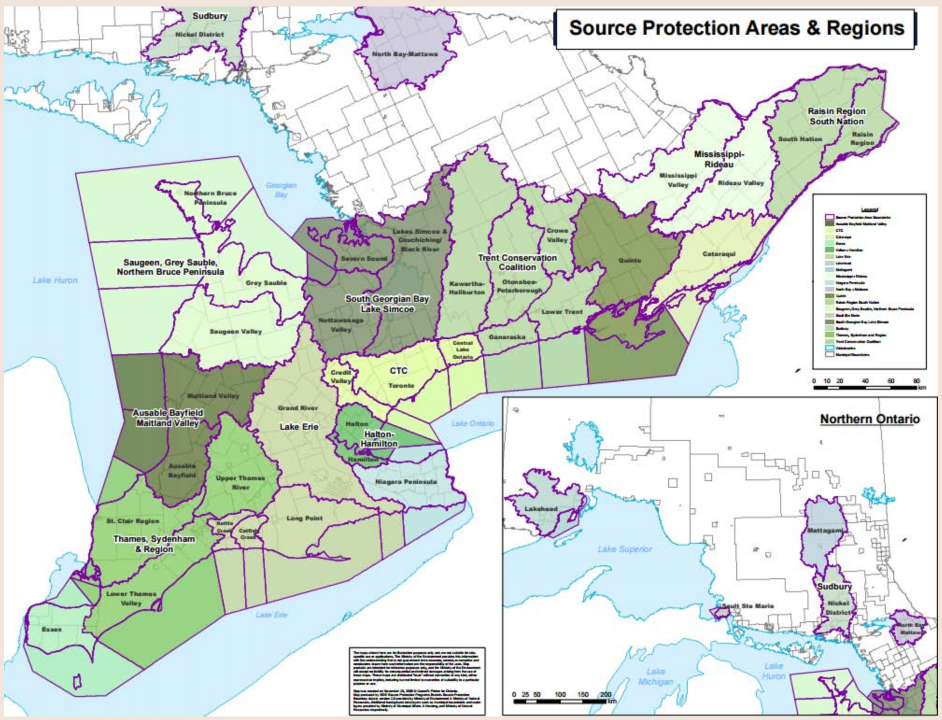
Gathering data on the watershed through GIS mapping allows the project team to integrate spatial data with infrastructure and land use information. Existing watershed and subwatershed plans are likely to include most, if not all, of this information. Here are some of the useful layers and features:

- Surface contours
- Permeable/impermeable areas
- Groundwater recharge/discharge areas
- Wellhead protection areas
- Water table elevation
- Intake protection zones
- Forest cover
- Soils
- Floodplains
- Water bodies (lakes, streams)
- Sensitive habitat (e.g., cold water streams), endangered species habitat

Watershed mapping can provide information on any spatial constraints within the study area. For example, stormwater management techniques to encourage infiltration may not be feasible in areas where water tables are high, or in areas with shallow bedrock. Mapping can also identify areas of opportunity, for example, areas with sandy soils where infiltration techniques would be most effective.

## Filling Data Gaps: Source Water Protection Plans

The *Clean Water Act* requires the completion of source protection plans to protect municipal drinking water sources. Source protection plans are a good source of watershed mapping and characterization data, including locations of wellhead protection areas and intake protection zones. This map shows Ontario's source protection areas and regions. (Source: Conservation Ontario)




## Watershed data

The water sustainability plan should also capture non-spatial watershed data for the study area. Depending on the location, this may include water quality and flow monitoring data, modelling data, and reports on the condition of natural features, such as streams, forests, and wetlands.

Water quality and flow data may be available through conservation authorities in the area. Ontario's Provincial Water Quality Monitoring Network provides stream water quality monitoring data at sites across Ontario for parameters such as chloride, nutrients, and metals, with datasets spanning from 2002 to the present day. The Water Survey of Canada collects and provides water level and streamflow monitoring data, both archived and real time, at stations across Canada. There are more than 1,600 real-time flow stations with data available through Environment Canada's website. Furthermore, the HYDAT database includes archived data for over 2,500 active and 5,500 discontinued monitoring stations across Canada, including daily and monthly mean flow, water level and sediment concentration data.

Modelling efforts relating to water and watershed management may have been carried out within the study area by municipalities or conservation authorities, and should have been gathered during the previous step of compiling existing material.

## Filling Data Gaps

If it is has not already been completed through another study, such as a master plan or asset management plan, characterizing the grey infrastructure within the study area may involve additional work. Field programs, including surveys of existing infrastructure and its sizes and condition, may be required.

## Filling Data Gaps: Flow and Water Quality Data

When flow and water quality data is not available for in the study area, field programs can fill the gap. Stream base flow can be determined by measuring flow during the low-flow season when there has been several days of antecedent dry conditions. Water quality samples during low-flow and wet weather flow periods can characterize pollutant loading from urban and rural stormwater in receiving streams.

## 5.3 Grey and green infrastructure characterization

The water sustainability plan should also characterize and map the water management infrastructure in the study area. This includes traditional grey infrastructure (such as pipes, watermains, and treatment facilities) and green infrastructure (such as ponds, wetlands, forests, floodplains, streams, LID features).

At this point in the process, the project team has already compiled the existing material relating to water management and infrastructure in the study area. This material may include water, wastewater, and stormwater management master plans, asset management plans, and/or asset inventories. Consult these resources to define the existing infrastructure within the study area.

### Grey infrastructure

For the purpose of this report, grey infrastructure refers to water infrastructure that does not use natural processes for water management. Here is a list of grey infrastructure components to characterize in a water sustainability plan.

- Stormwater grey infrastructure
  - Catch basins and inlets
  - Maintenance holes
  - Collection and transmission pipes
  - Outfalls
  - Culverts
  - Ditches and channels
  - Dams
  - Erosion control structures
  - Stormwater ponds (dry and wet)
- Wastewater grey infrastructure
  - Sanitary collection and transmission pipes
  - Maintenance holes
  - Sewage pumping stations
  - Septic systems
  - Wastewater treatment facilities
  - Wastewater discharge outlets
- Drinking water grey infrastructure
  - Water transmission and distribution mains
  - Pumping stations
  - Water storage facilities (reservoirs, towers, tanks, etc.)
  - Water intakes
  - Municipal wells
  - Water treatment facilities

When characterizing grey infrastructure, gathering information for these components gives details to describe the overall condition and level of service they provide. This information may already be collected in a municipal asset management plan. Here is some of the specific data:

- Type of infrastructure
- Location
- Age
- Condition
- Level of service provided (e.g., capacity, treatment level, designed and actual performance)
- Replacement period

Some of the issues in the study area may require additional characterization. For example, the City of Mississauga, Region of Peel, and CVC have collaborated to expand a dual drainage stormwater model, which includes both the major and minor stormwater systems, to also include the sanitary sewer system in a few pilot neighbourhoods. This work is intended to characterize the inflow/infiltration issues within the study area and the broader City and Region.

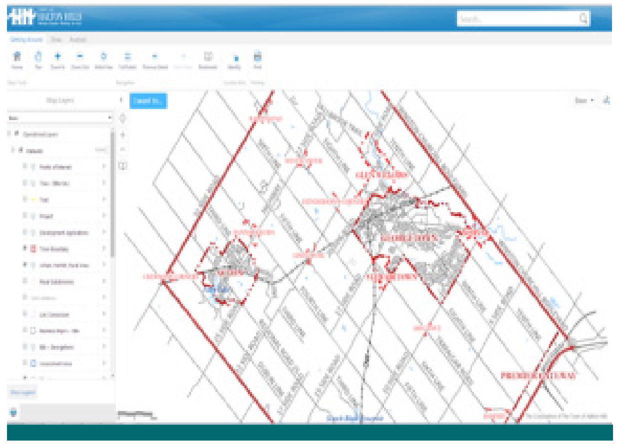


**Figure 5.3.1:** The Town of Halton Hills adopted a centralized data storage repository (MapLinks, interface shown above) for the storage, display, and management of all spatial and conditional data related to the Town's stormwater assets, including pipes, bridges, culverts, oil and grit separators, and ponds. The database also includes basic characteristic information like diameters and sizes of pipes and slopes. (Source: Town of Halton Hills)

## Filling Data Gaps

Municipal parks departments and natural heritage groups at conservation authorities likely already have information on the parks, forests, natural areas and LID that can help project teams characterize green infrastructure in the study area.

## Green infrastructure

According to the U.S. EPA, green infrastructure "uses natural hydrologic features to manage water and provide environmental and community benefits."[11] Green infrastructure generally provides benefits with respect to stormwater management, but there are also components that manage wastewater and minimize demand on drinking water systems. Here is a list of green infrastructure components that may exist within the study area:

- Wetlands (natural and constructed)
- Forests, parks, and greenspace
- Urban tree canopy
- Floodplains
- Streams
- LID (rain gardens, bioretention cells, green roofs, permeable pavement, etc.)
- Rainwater harvesting systems, cisterns

As previously described, information on the green infrastructure type, location, and level of service should be collected and may already be available within master plans or in studies completed by conservation authorities.

Since green infrastructure includes emerging technology (such as LID) which may not have been incorporated into asset management plans, as well as infrastructure which may not have been inventoried or even considered as providing a level of service (such as forests, wetlands and natural areas), there might be a lack of available data. Local conservation authorities may have supplemental information on the natural heritage systems that provide benefits with respect to stormwater management.

For both grey and green infrastructure, it is important to characterize the level of service. Depending on maintenance activities post-construction, the level of service delivered by green infrastructure, such as ponds, LID, or constructed wetlands, may not be what it was designed to provide. A study completed by Lake Simcoe Region Conservation Authority in 2010 examined the efficiency of 98 ponds within the watershed, and found that more than half of the ponds were not providing the level of phosphorus reduction for which they were designed.[12] This finding suggests that using design drawings or reports to determine the existing level of service is not always sufficient, and underscores the need for ongoing maintenance and monitoring to ensure infrastructure continues to provide the intended level of service.

Appendix B includes additional examples of green infrastructure considerations, as well as case studies for LID installations within the CVC watershed.

## Filling Data Gaps

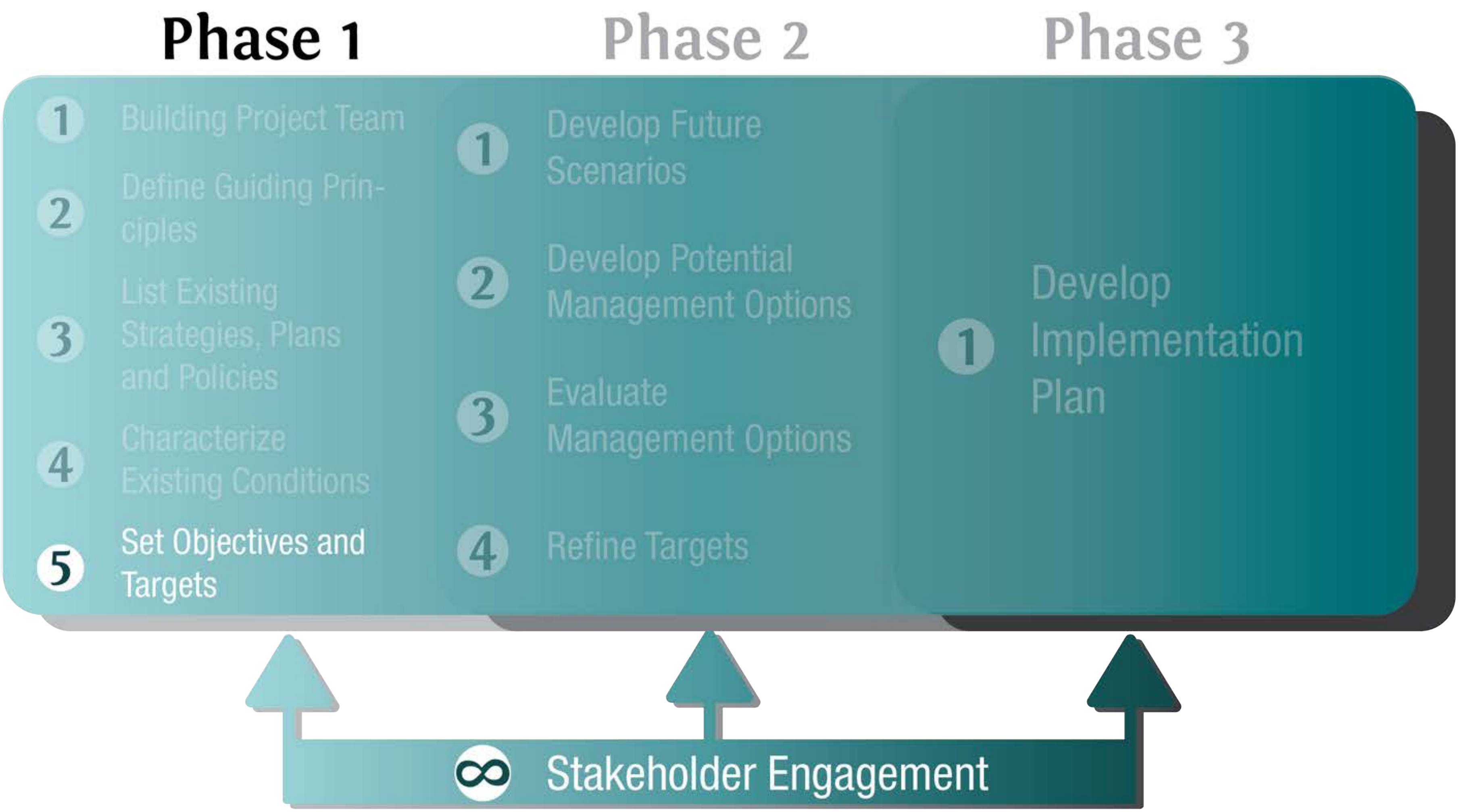
The green infrastructure within your study area may not be well characterized through existing studies. If so, the project team could use summer students or volunteers to conduct simple field programs to determine these details:

- Location
- Number
- Size
- Condition
- Design basis

Where time and resources are available, these details could be part of a more rigorous assessment:

- Surveying
- Water quality sampling
- Flow monitoring
- Water level monitoring
- Infiltration testing

# 6.0 Setting Objectives and Targets



In Ontario, given the range of beneficial uses of water outlined in Chapter 5, targets and objectives for water management should be based on specific issues. The project team can support its selection based on document and plan review (Phase 1, Step 3) and characterization of existing conditions (Phase 1, Step 4). By setting targets that are specific to the watershed (see Figure 6.2.1), rather than using general objectives applied across Ontario or Canada, the project team has the opportunity to close the gap between the needs of the watershed and the level of service that municipal water services can provide. Targets should reflect the level of risk that is acceptable for your study. Chapter 9 further explores the connection between risk and targets.

## 6.1 Setting objectives

Objectives help to define how a beneficial use of water will be protected and/or maintained. Objectives can vary in specificity; they can apply to the entire study area or to a particular part of the study area, depending on where specific uses of water exist.

While project teams should consider each beneficial water use in the study area when they are developing objectives, it is not necessary to have an objective specific to each use. Taking a holistic approach to water management means some objectives may impact multiple water services within the study area, and by achieving those objectives, multiple water uses may be protected or maintained.

The number of objectives is not prescribed; however, it may be helpful to use categories to group objectives relating to similar issues. Table 6.2.1 contains examples of categories and objectives, including a category for objectives regarding climate change mitigation, which refers to the potential benefit of reducing greenhouse gas emissions.

Chapter 7 also discusses climate change with regard to the development of future scenarios that reflect a changing climate, and the need for water infrastructure and services to adapt.


**Figure 6.1.1:** These photos show three very different streams. On the left is a natural stream with a receiving watershed that has not been developed, where the water in the stream is likely of good quality. The photo in the centre is a stream in an urbanized watershed, which receives runoff from mostly impervious surfaces via storm sewer systems, likely carrying high solid, nutrient and bacterial loadings. The photo on the right shows a stream receiving runoff from a rural watershed, where agriculture is a dominant land use, and stormwater runoff may be high in concentrations of nutrients and bacteria. Applying the same level of stormwater service criteria in all three scenarios does not take into consideration the unique characteristics and functions of each watershed, including local geology, hydrology, flood risk, environmental sensitivity, age of infrastructure, intensity of water intake, and effluent discharges. (Source: CVC)

## 6.2 Setting targets

Targets are the measurable parameters (one or more) that determine how successfully objectives have been met. Targets should be measurable with reasonable effort and can be based on indicator parameters (such as total suspended solids in stormwater as a measure for overall water quality), but they must provide enough information to demonstrate that objectives are being met.

*Setting targets and monitoring the ability of water management systems to meet those targets is a critical part of a water sustainability plan. This step creates accountability.*

### Infrastructure performance targets

The project team should set targets that explicitly identify the level of service that municipal water system end users for drinking water, wastewater, and stormwater services expect. These targets can also help municipal service providers assess the level of service being provided to public users.

For municipal drinking water and wastewater services, targets are already defined. Municipal drinking water in Ontario is regulated under the *Safe Drinking Water Act* (2002), which defines water quality standards through O.Reg. 169/03: Ontario Drinking Water Quality Standards.

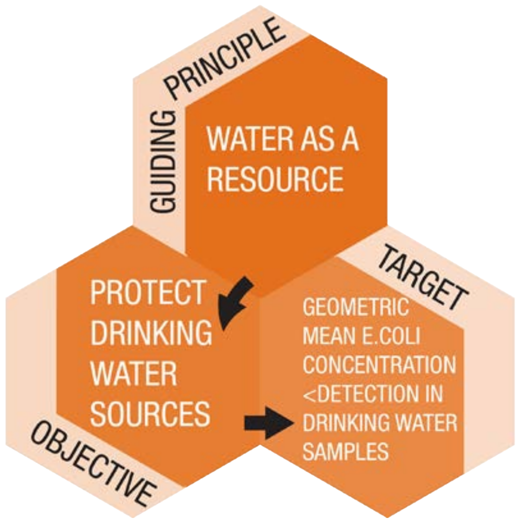



**Figure 6.2.1:** The goals and guiding principles set earlier in the water sustainability planning process should drive the objectives. Measurable targets, specific to the watershed and study area, should flow from the objectives. (Source: CVC)

**Table 6.2.1:** Categories of Objectives for a Water Sustainability Plan

| Category | Objective |
|---|---|
| Watershed – Water Quality | • Protect drinking water sources (groundwater, lake, stream)<br>• Improve water quality in lake for recreational purposes<br>• Reduce number of algal blooms leading to beach closures |
| Watershed – Water Quantity | • Maintain groundwater recharge<br>• Ensure base flows are sufficient to support aquatic life in streams<br>• Reduce or eliminate flooding threats to life and property |
| Infrastructure Performance | • Prevent wastewater bypasses to watercourse/lake<br>• Meet drinking water demand of current and future population<br>• Reduce or eliminate basement flooding resulting from inflow/infiltration |
| Climate Change Mitigation | • Reduce greenhouse gas emissions |

These standards include maximum concentrations for microbiological, chemical and radiological compounds in drinking water. The MOECC Design Guidelines for Drinking Water Systems (2008) includes considerations for water treatment plant and transmission capacity and storage of treated water. The guidelines specify that drinking water systems should be designed with a capacity equal to the greater of the peak hour demand, or the maximum day demand plus fire protection.[13] Targets for drinking water level of service should follow these standards and guidelines. Similarly, the Design Guidelines for Sewage Works[14] specify considerations for wastewater treatment and conveyance systems, including design criteria for sanitary and storm sewer systems and criteria for wastewater treatment. See Figure 6.2.2 for an example.

With respect to stormwater management, level of service refers to the ability of the stormwater system to adequately treat, infiltrate, convey, and store stormwater to avoid adverse impacts to residents. Level of service targets may include targets that measure the reduction and prevention of overland and basement flooding incidents, or the prevention of water quality impacts to recreational areas such as beach closures.

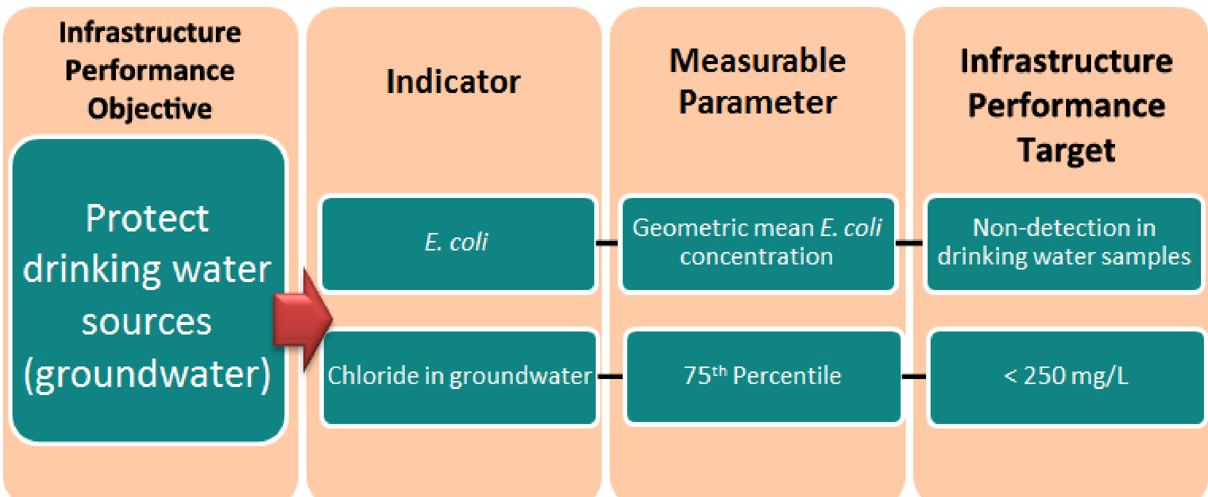



**Figure 6.2.2:** A water sustainability plan might identify the protection of drinking water sources as one of its objectives. The presence of E. coli and the concentration of chloride in groundwater are both indicators of groundwater health. Consult the Canadian Drinking Water Quality Guidelines and Ontario Drinking Water Quality Standards when identifying appropriate measurable parameters and setting targets. (Source: CVC)

## Watershed targets

Water quality targets refer to the quality of water discharged to natural environments through water management practices. Water quality targets for stormwater management systems are not as well defined as those for drinking water and wastewater systems. The Stormwater Management Planning and Design Manual (MOE 2003) provides design criteria regarding water quality, erosion control, flow, and water balance. These targets can provide a useful starting point where local monitoring data is lacking. The criteria provided in the stormwater manual apply across Ontario and are not based on the needs of a specific watershed. When possible, a water sustainability plan should incorporate targets reflecting water quality and water balance needs of the receiving watershed, including the beneficial uses of water within it. Figure 6.2.3 provides examples of watershed targets for a water quantity-based objective.

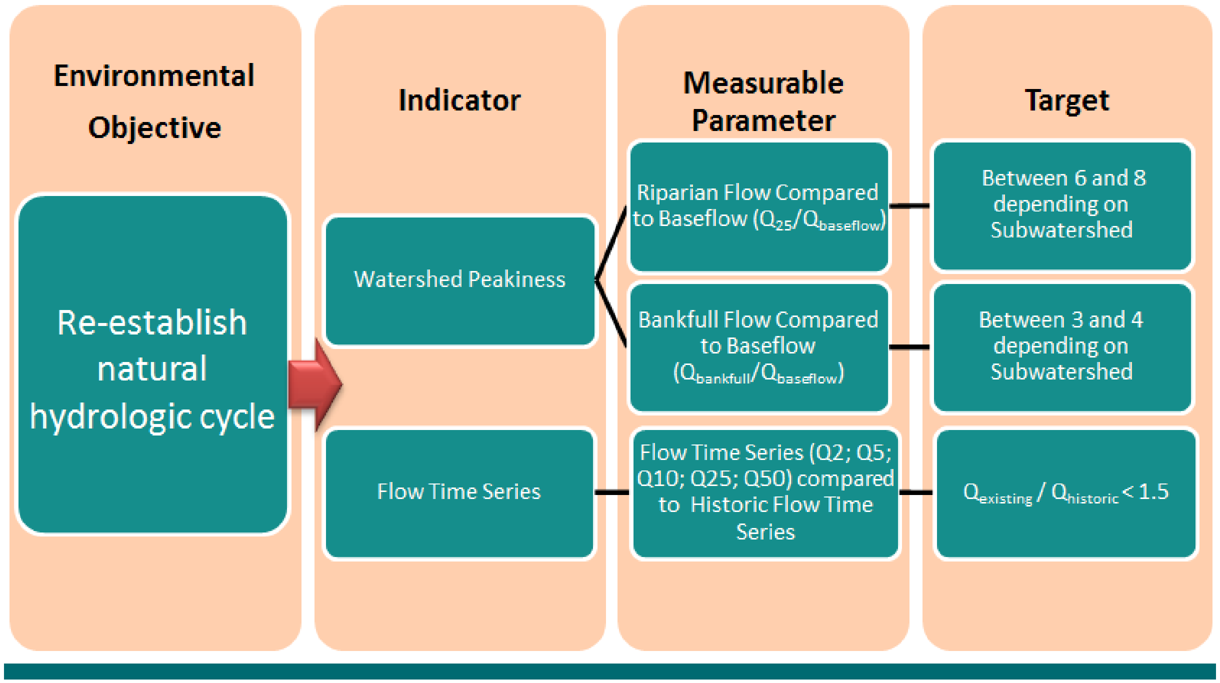



**Figure 6.2.3:** A water sustainability plan might identify preserving or establishing the natural hydrologic cycle as one of its objectives. Watershed peakiness is a good indicator of the degree of impact development has had on the hydrologic cycle of a watershed. Two measurable parameters are the ratio of 1:25-year flow to base flow and the ratio of bankfull flow to base flow. Watershed-specific targets should be set for each of these parameters. The ratio of existing flows to historic flows for various return period events is another indicator that can be used for gauging hydrologic response compared to natural conditions; again targets should be set on a watershed or subwatershed basis. (Source: CVC)

Project teams should review existing studies and plans, as well as existing conditions, when setting watershed-based targets related to stormwater and watershed management. If there are already targets for flow and water quality, consider incorporating them into the list of targets for the water sustainability plan. If not, start with the criteria listed in the stormwater manual. The project team can refine targets as it collects monitoring data over a longer term.

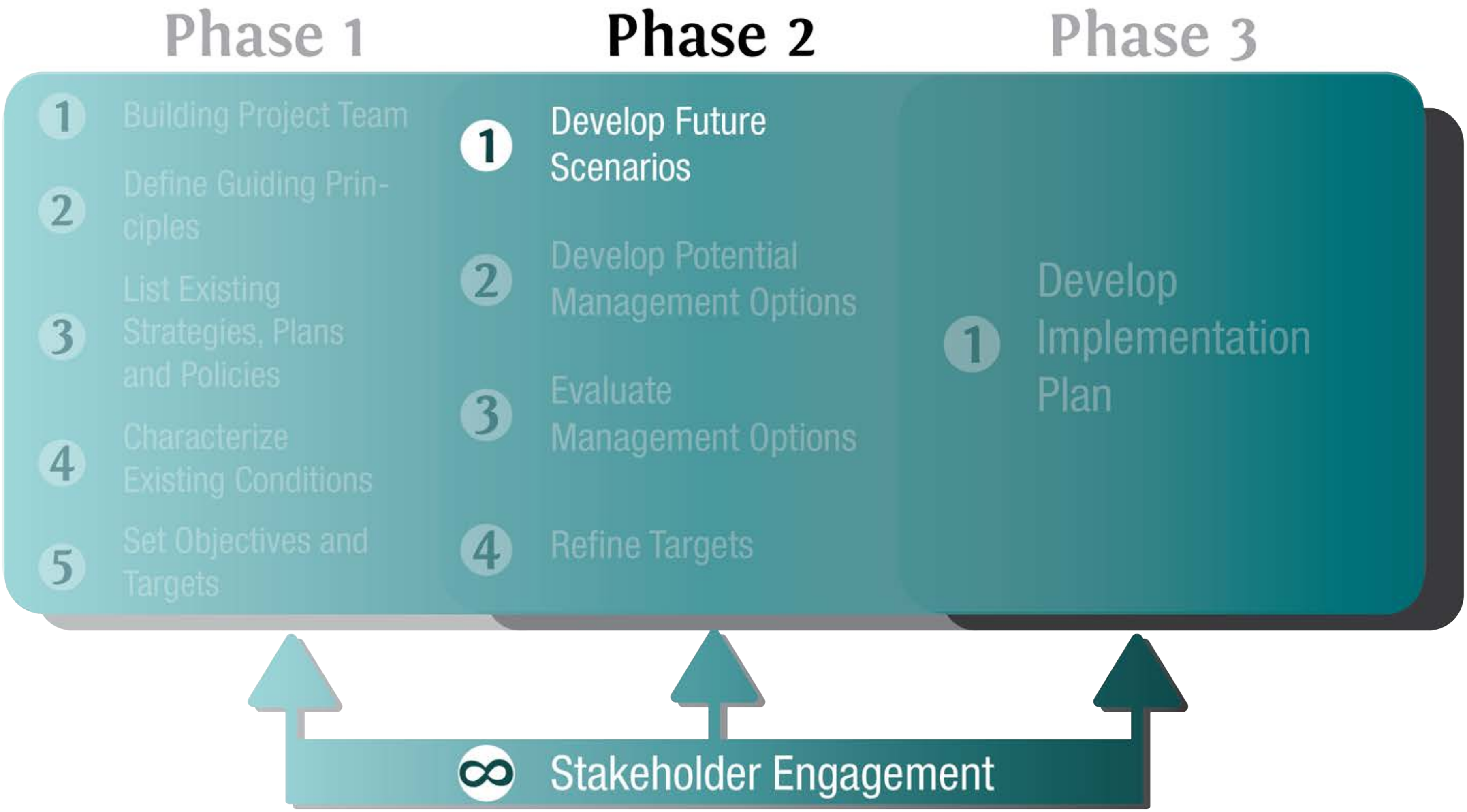
In October 2015, the Ontario government passed the *Great Lakes Protection Act*, which provides mechanisms to "protect and improve the capacity of the Great Lakes-St. Lawrence River Basin to respond to the impacts and causes of climate change[15]." The Act also includes provisions for targets to be set by the Minister of the Environment and Climate Change, at least one of which will be set within two years of the Act coming into force to reduce production of algae blooms in the Great Lakes-St. Lawrence River Basin. Targets may also be set by the Minister of Natural Resources and Forestry to prevent loss of wetlands within the Great Lakes-St. Lawrence River Basin. Targets set through a water sustainability plan should be reflective of any targets set through this Act.

Table 6.2.2 contains a list of targets that build on the Table 6.2.1 sample objective.

**Table 6.2.2:** Examples of objectives and targets that can be included in a water sustainability plan

| Category | Objective | Target |
|---|---|---|
| Watershed - Water Quality | • Protect drinking water sources (groundwater, lake, stream)<br>• Improve water quality in lake for recreational purposes | • Chloride in groundwater <120 mg/L<br>• E.coli in groundwater <100/mL<br>• Reduce phosphorus load to lake by 40% |
| Watershed - Water Quantity | • Maintain groundwater recharge<br>• Ensure baseflows are sufficient to support aquatic life in streams<br>• Reduce or eliminate flooding threats to life and property | • No reduction in groundwater recharge as a result of development<br>• Maintain existing ratio of baseflow to mean annual flow<br>• Reduce flood-vulnerable structures by 20% |
| Infrastructure Performance | • Prevent wastewater bypasses to watercourse/lake<br>• Meet drinking water demand of current and future population<br>• Reduce or eliminate basement flooding resulting from inflow/ infiltration | • Prevent 100% of overflows to watercourse/lake<br>• Meet drinking water demand of 300 Lpcd with peak hour factor of 3.0<br>• No basement flooding for <1:25 year design storm |
| Climate Change Mitigation | • Reduce greenhouse gas emissions | • Reduce energy used for water and wastewater services by 25% |
| Maintenance | • Develop maintenance program for all water infrastructure | • Complete maintenance checklist for all stormwater infrastructure once every three years |
| Funding | • Develop funding alternatives for stormwater management services<br>• Recover the full cost of providing water and wastewater services | |

# 7.0 Develop Future Scenarios



*In municipalities such as Toronto and Mississauga, major stressors in the watershed include urban flooding and sanitary sewer backup during wet weather events. These stressors are the result of urban development that does not have adequate flood control. Meanwhile, rural areas, such as Orangeville or Halton Hills, face stressors such as groundwater supply constraints and low base flow in local streams as a result of population growth and urban development.*

A number of drivers have the ability to impact Ontario's water resources, and thereby municipal water management decisions, due to changes and variability in both natural and human-influenced systems over time. A different set of drivers will impact future water management decisions in urbanized areas, as opposed to rural or newly developing areas.

Since certain drivers could worsen or lessen current water management issues, the project team should consider potential drivers of future change when developing future scenarios for a water sustainability plan. These drivers may include climate change, age and condition of infrastructure, population growth, and land use changes, such as urban development, agricultural intensification, and aggregate extraction. As an example, climate change may lead to increased periods of drought, which can exacerbate drinking water supply issues for groundwater-dependent municipalities.

Future scenarios should reflect the time horizon during which the water sustainability plan will apply. It may be helpful to choose the same time horizon as other planning activities in your study area, such as a watershed plan, master plan, or official plan. The time horizon will influence the considerations that are incorporated into future scenarios. Future scenarios can become part of the later stages of the study that include detailed modelling of management scenarios.

The following sections include further discussion on future drivers that project teams may want to consider for water sustainability plans.

## 7.1 Climate Change

Climate change is an important consideration for future conditions within the study area. The past three decades have shown indication that the Earth's surface is becoming progressively warmer, and the period from 1983 to 2012 has likely been the warmest of the last 1400 years in the Northern Hemisphere.[16] Impacts of climate change have included increased frequency of extreme events, including extremely cold and warm seasons, as well as increased frequency of heavy precipitation events.[17] The links between climate change impacts and water management make climate change a key consideration for a water sustainability plan.

### Case Study: Cooksville Creek Vulnerability Assessment

Future drivers and scenarios played a critical role in the Cooksville Creek vulnerability assessment. The project team chose two time horizons: 2050 and 2080. The year 2050 aligned with planning activities that had already been carried out in the study area, while 2080 aligned with the excepted lifespan of infrastructure within the scope of the study.

Many municipalities within Canada have communicated their concern with regard to flood risk and the need for access to regional and local climate projections. In Figure 7.1.1, results from 2014 National Consultation Workshop show that municipalities need guidance on updating floodplain maps and intensity-duration-frequency (IDF) curves, as well as toolboxes for evaluating adaptation strategies. General Circulation Models (GCMs) and related tools have been developed in the scientific community to provide essential data about future climatic conditions (e.g. annual and monthly averaged temperature, precipitation). The interpretation of climate model outputs and use of this data for municipal infrastructure planning and management typically requires professional expertise in meteorology, statistics, modelling, and analyses.

*Depending on the scale of the water sustainability plan, project teams may want to use climate data projections to determine the magnitude to which they can expect climate change to impact conditions within study areas. Climate modelling can help answer those questions. Data is available from a number of sources and organizations including Environment Canada, Ouranos, consulting firms, and academia. Appendix A highlights additional tools that can help you understand risks associated with climate change.*

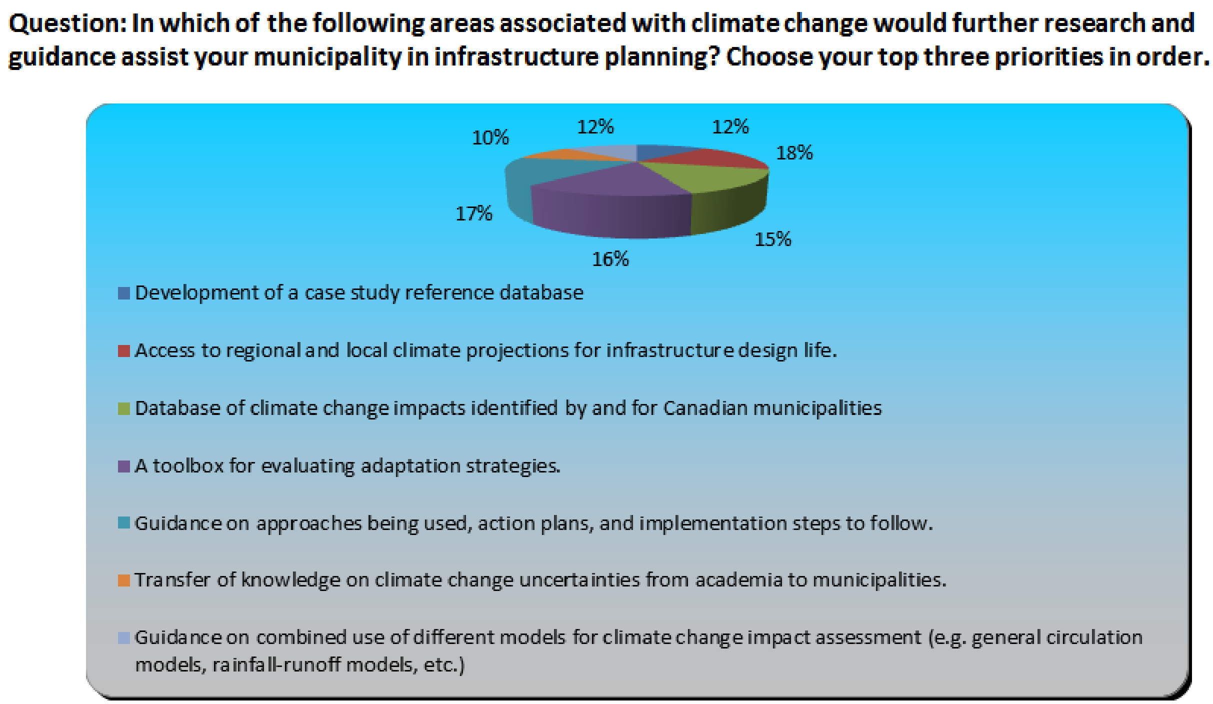



**Figure 7.1.1:** Feedback on areas of further research for climate change and infrastructure planning. (Source: CVC)

The following subsections provide some considerations and examples for climate change scenarios. Chapters 8 and 9 provide further information on assessing impacts due to climate change, Chapter 11 provides examples of development of action plans to address climate change impacts, and Appendix A provides a case study example of how the City of Mississauga, Region of Peel, and CVC assessed climate change scenarios in Cooksville Creek watershed.

## Case Study: Cooksville Creek Vulnerability Assessment

The Cooksville vulnerability assessment linked existing and future climate scenarios to water management issues. The project team used future climate scenarios in water quality modelling work to determine how instream water temperatures would change under future conditions. Increased probabilities of extreme weather events contributed to assessment of overall vulnerability during flooding events, including vulnerability of critical infrastructure and people. These future scenarios indicate changes may be needed in future water management, land use, and emergency response.

## Case Study: Town of Orangeville

EBNFLO Environmental and AquaResources Inc. completed a cast study for the Town of Orangeville to estimate the hydrologic effects of future climate change. Concerns associated with the study area include municipal groundwater supply, low base flow, and peak flow and flooding. Hydrogeologic and hydrologic modelling simulations showed warmer air temperatures resulted in earlier spring snowmelt, earlier decreases in flow from spring to summer, and increases in winter streamflow by up to 50 percent due to winter precipitation falling more as rainfall than snowfall. There was also some indication that summer flows would be below current levels due to higher summer evapotranspiration rates. (Source: Water Canada) Further guidance of developing climate change scenarios for assessing water supply vulnerability is included in Appendix A.

### Warming temperatures

An important impact of climate change is that temperatures are likely to become warmer than have been historically observed in Ontario. Over the past 50 years, average temperatures in Canada have risen approximately 1.4 degrees Celsius.[18] Recorded air temperatures in the GTHA since the 1970s demonstrate increasing trends, with 2013 being one of the warmest winters on record for the GTHA.

Project teams should consider how warming temperatures may impact water resources and infrastructure and include details in the water sustainability plan. Higher temperatures increase evaporation from land and water bodies, thereby resulting in more prevalent periods of drought, which can negatively impact ground and surface water resources by lowering groundwater tables and reducing stream base flows. If the study area relies on stream base flows for assimilation of a municipal wastewater treatment effluent stream, or on groundwater for municipal or agricultural water takings, the impact of warming temperatures should be part of a future scenario.

Another impact of warming temperatures, and in particular, of warming winters, is that more winter precipitation will likely fall as rain than snow under future climate conditions, reducing the winter snowpack. A small snowpack may cause the spring freshet (high flows) in streams to also be lower than at present. Under these conditions, the spring freshet may not flush sediments and nutrients from watercourses, where they have accumulated over the winter.

## Case Study: Cooksville Creek Vulnerability Assessment

The Cooksville Creek Vulnerability Assessment with respect to climate change identified that in the Cooksville Creek watershed (Mississauga), the frequency of extreme rainfall events is expected to increase as a result of climate change, with frequency of these events potentially doubling by the 2080s.

In 2012, this scenario was observed in Mississauga, when a small snowpack after a warm winter, combined with an early and warm spring, resulted in early spring blooms of cladophora algae in streams and lakes. The impacts included reduced aesthetics in the effected streams and nearshore areas, as well as clogged intakes at one of the water treatment facilities in the vicinity. The Cooksville case study provides further information on how climate change scenarios were developed and assessed to evaluate the vulnerability of drinking water supply.

## Extreme rainfall events

In Ontario, a number of extreme rainfall events and local flood events in recent years have made the headlines. Within the GTHA, several such high intensity-short duration rainfall events have occurred within the past decade, including the August 19, 2005 storm, which resulted in the washout of a major roadway (Finch Avenue) in Toronto, and the July 8, 2013 storm, which had widespread flooding impacts throughout the area. Figure 7.1.2 lists many of these storms, and compares them to total rainfall and rainfall intensity to the 100-year return period design storm, and to Hurricane Hazel, which is the regulatory flood currently used to develop floodplain mapping. Researchers from MIT and Princeton University have found that climate change could result in more frequent powerful storms making landfall. Their findings indicate today's "500-year floods" could occur once every 25 to 240 years.[19]

Figure 7.1.2 also shows that, while the events in recent years within the GTHA have had lower cumulative rainfall volume than the regulatory flood currently used in Ontario, the maximum one-hour intensities of these storms have been higher than Hurricane Hazel and the 100-year design storm for the GTHA.

Extreme events are often cascading in nature – where, instead of one dominant event, localities are dealing with multiple occurrences and types of extreme events, many of which are more severe than in recent preceding decades.[20]

Combinations of extreme rainfall events are very challenging from an operations perspective. During times of crisis, all systems are pushed to their maximum capacity, flexibility, and capability, often leading to startling discoveries of weaknesses and limitations that were not previously anticipated or understood.[21] Considering the vulnerabilities associated with climate change, sustainability planning must become more robust.

Increased frequency of high intensity-short duration rainfall events can also increase the impacts within the study area. If the study area has previously experienced issues with respect to urban and riverine flooding, a changing climate could exacerbate these issues.

As part of the water sustainability plan, the project team may also want to consider how future climate conditions will impact stormwater infrastructure and decide whether there is a need to design for more intense storms. The Cooksville Case study included assessment of near-miss events, looking

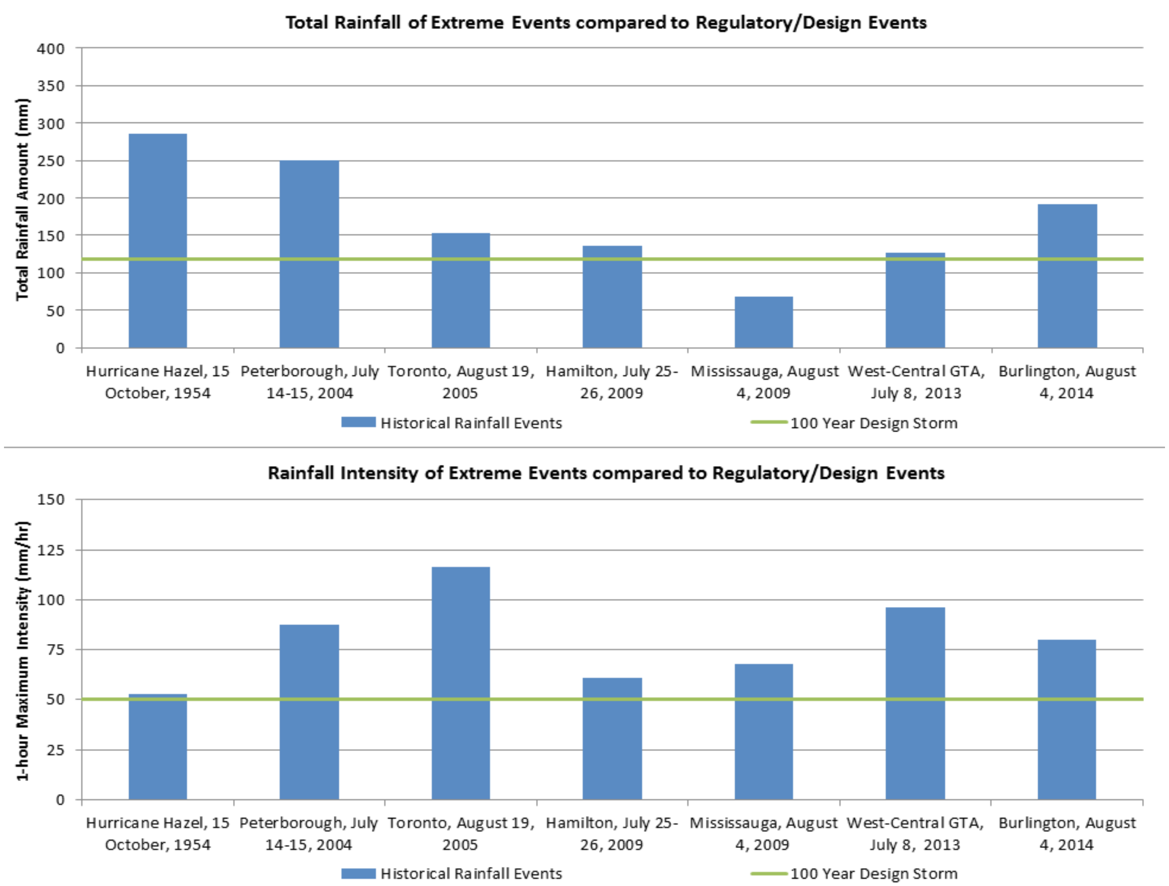



**Figure 7.1.2:** Recent extreme rainfall events in the GTHA have exceeded the total rainfall amount for the 100-year design storm. While these events have been smaller in total rainfall than Hurricane Hazel, the one-hour intensities of these storms have been greater than both the 100-year design storm and Hurricane Hazel. (Source: CVC)

at how timing and locations of events may influence service delivery, emergency response, and vulnerable populations. Refer to the Cooksville Case study in Appendix A for further information on extreme rainfall event scenarios.

## 7.2 Aging infrastructure and replacement

Project teams should also consider the condition of current water infrastructure – and how it might age, or be repaired or replaced, over time – in future scenarios. These changes will impact the vulnerabilities of water management systems.

*Up to 30% of piped water in Canada is lost due to leaks that have formed in aging pipes.*[22]

A large portion of Canada's water and wastewater infrastructure was installed during the post-World War II era: a time of rapid economic growth and development. Water supply, wastewater and stormwater systems are now approaching the end of their service life, especially in older communities. The estimated deficit is $31 billion.[23] Communities require massive investments to maintain current levels of service for clean drinking water and prevent aging wastewater, stormwater, and combined sewers from causing widespread environmental contamination.

## 7.3 Population growth and land use changes

Population growth and land use changes can also put pressure on water resources, particularly if land use changes will change the natural water balance, or increase the extent of water-intensive or impactful industry within the study area. In such cases, the project team should also consider the resulting increased demand on water resources in the future conditions of the water sustainability plan.

### Population growth and urban development

Population growth is a critical consideration for a water sustainability plan. Fortunately, it is already incorporated into planning activities such as official plans, strategic plans, and master plans.

Future population growth can influence water resources issues and management in two ways. Firstly, an increased population leads to increased demand on water resources and services. Secondly, when new development and expansion of urban boundaries is necessary for housing growing populations, the overall watershed character will change. This has and will continue to be the case in Ontario.

Urban development is typified by increased impervious area, thereby increasing runoff peak flows and volumes. Urbanized areas can also be the source of water quality impacts, and untreated urban runoff typically includes pollutants such as oil and gas, manufacturing discharges, and other contaminants. Urban development may also have impacts on groundwater resources. Recharge rates are often reduced due to increased impermeable areas. These two factors can put pressure on existing water infrastructure systems, which may already be under stress.

The project team should also consider the changing design and demographic characteristics of the study area. For example, an area developed prior to the 1970s will likely not have flood control measures, such as ponds, incorporated into its design. However, future development will likely include provisions for flood, erosion, and water quality control, as well as water balance requirements for stormwater management (such as infiltration of 25 mm of runoff onsite).

Another dynamic characteristic of urban development is the demographic. For example, demographic changes and intensification may result in higher proportions of children or seniors living in a particular area, which may already be vulnerable with respect to water, such as through repeated flooding. The future increase of vulnerable populations within those already stressed areas can increase the overall vulnerability of the study area. More information on vulnerable populations is provided in the Cooksville Creek case study in Appendix A.

The project team should consider any anticipated future growth and development and redevelopment within the study area. Projections for future growth can help the project team to estimate future demands on water and wastewater systems, as well as potential impacts to stormwater and natural water systems resulting from urbanization.

### Agricultural intensification

Agriculture plays a role in the overall character of the watershed. Intensification of agriculture can have a direct influence on hydrology and water quality in rural areas, but the downstream impacts are also important to consider. Agriculture intensification can put pressures on water systems. For instance, irrigation practices and livestock watering can increase the demand for water. Depending on the water supply sources (such as private wells, surface water), the impacts of water taking for agricultural lands will differ. Runoff from agricultural lands can result in negative impacts on water quality to receiving streams, such as high loadings of nutrients, solids, farm chemicals (e.g., pesticides), bacteria from animal waste, and other contaminants.

There is a growing movement in Ontario towards sustainable farming practices, including water and soil management, fish habitat management, and nutrient management. The Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA) has released a series of Best Management Practices which can help conserve and protect water resources. The project team may want to consider that future agricultural practices may result in fewer impacts to water resources as a result of implementation of best management practices. Figure 7.3.1 shows an example of an agricultural best management practice.

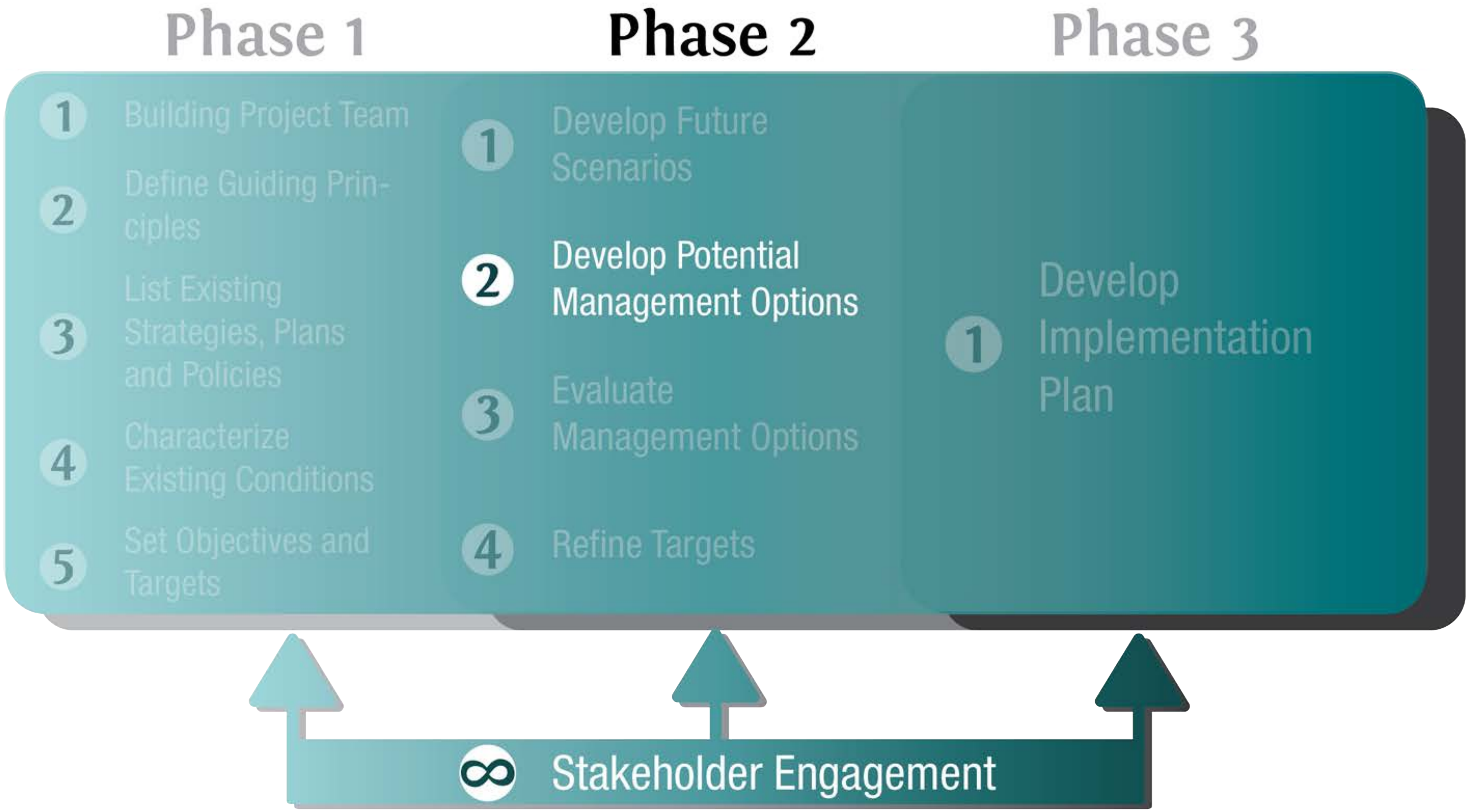
**Figure 7.3.1:** A buffer-strip is an example of an agricultural best management practice that can help reduce the amount of sediment, chemicals, and bacteria in runoff that goes from farm fields to receiving watercourses. (Source: CVC)

## Aggregate extraction

Aggregate extraction is another potential stressor on local water resources that may impact a water sustainability plan study area. Over the last three decades, production of aggregate in Ontario has fluctuated between approximately 100 million and 200 million tonnes annually.[24] Industry estimates that, over the next 25 years, the GTA will require approximately 1.5 billion tonnes of aggregate as urban infrastructure is renewed and built.[25]

Aggregate extraction can have direct influences on hydrology through lowering groundwater levels (directly through below water table extraction, or indirectly through reduced groundwater recharge), discharging water back to local receiving streams, and dewatering for the production purposes, such as for aggregate washing. The Ministry of Natural Resources and Forestry (MNRF) regulates, licenses, and enforces compliance for aggregate pits and quarries under the *Aggregate Resources Act.*[26] Aggregate licences typically include water management activities over the life of the site. The future development of aggregate extraction with the study area can become a part of the future scenarios.

# 8.0 Develop Potential Management Options



Now that the project team has established the existing conditions of the study area, set targets reflective of the watershed, and determined the future scenarios, it is time to develop a long list of potential management options that could be used to achieve the goals of the study. This list should include a wide variety of management options, including physical measures, grey and green infrastructure, and programs that would improve water management. Do not begin to eliminate management options based on feasibility or cost at this point; rather, create an inclusive list that the team can screen and evaluate based on a range of considerations.

Depending on the location, age, and size of the study area, the water systems under consideration in the water sustainability plan may look vastly different. As a result, the management options may need to be wide-ranging to cover the different issues within the study area. A watershed perspective can help the project team to understand the links between the different water systems (see Chapter 1) before building a list of potential management options. Figure 8.1.1 is a fictitious representation of different elements of a watershed system using the Credit River watershed as an example.

For study areas relying on groundwater for their municipal drinking water, potential management options may focus on wellhead protection through compatible land uses, appropriate stormwater management, and pollution protection programs, to meet water quality objectives. Where wastewater effluent is assimilated into streams, management options may be needed to ensure that dry-weather streamflows are maintained, through preservation of the natural water balance.

Some of these objectives can seem like they are competing with one another. For this reason, it is important to understand existing environmental conditions so the plan applies the appropriate land use, pollution prevention, and stormwater techniques in the appropriate area. For example, measures to promote infiltration of stormwater on a commercial site may not be compatible within a wellhead protection area, due to the high salting of commercial parking lots. This chapter will explore various management options, and Chapter 9 will provide step-by-step process for further evaluating these management options to inform the One Water approach.

## 8.1 Developing management options

The development of management options takes places at the watershed scale and there are different management approaches to consider, from grey solutions to integrated One Water solutions. As illustrated by Figure 8.1.1, the planning, management, protection and conservation of the urban and rural water cycles are best achieved within the context of watershed boundaries. The watershed perspective allows water managers and regulators to better coordinate the sustainable management of water, land, and related resources and make better and informed cost-effective decisions.

*Under the Planning Act, it states that planning authorities should use a* "watershed as the ecological meaningful scale for integrated and long-term planning, which can be a foundation for considering cumulative impacts of development." *It further states the importance of* "maintaining the linkages and related function among ground water features, hydrologic functions, natural heritage features and areas and surface water features including shoreline areas."

*PPS 2014*

The challenge for today's watershed manager is to select the appropriate approach to coordinate the sustainable management of water systems and make better and informed decisions that will achieve the best results and returns for public health, the economy, and the environment.

All identified management options should attempt to address the concerns highlighted in the characterization (Phase 1 Step 4) and future vulnerabilities (Phase 2 Step 1) stages. The approach should reflect the guiding principles, objectives, and targets defined earlier in the process.

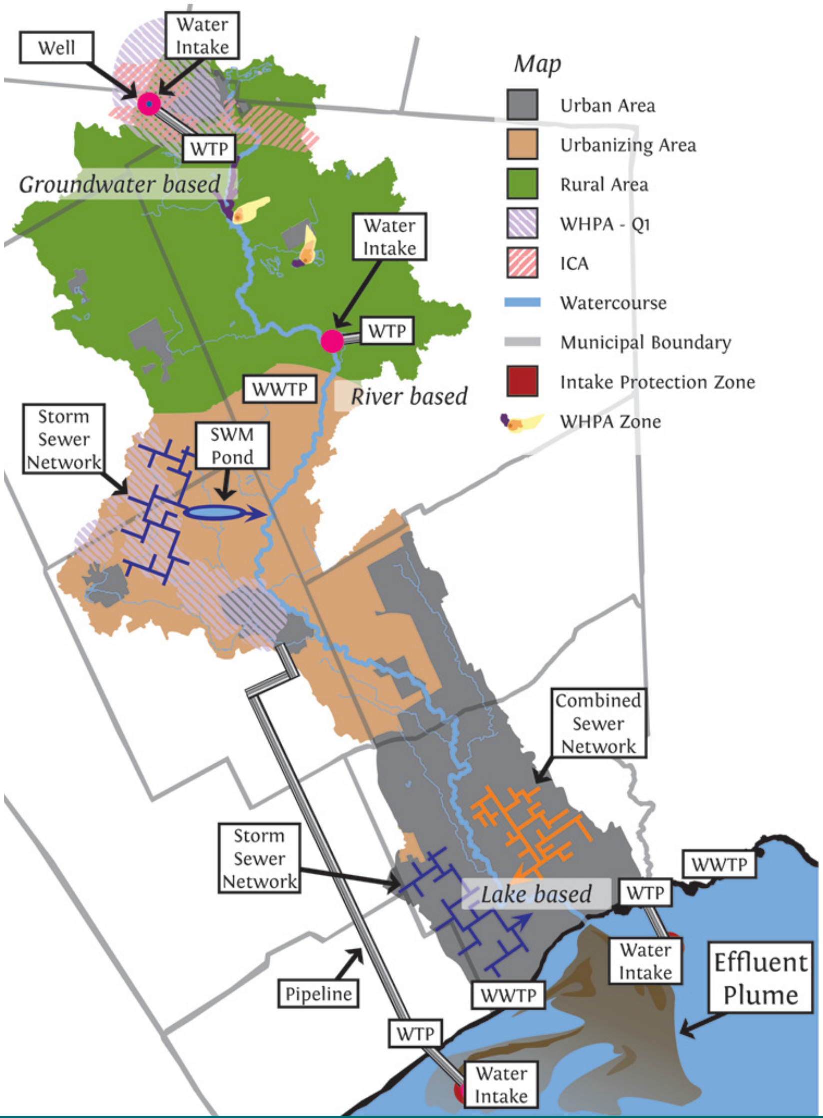



**Figure 8.1.1:** The above fictitious representation of the Credit River watershed demonstrates that a variety of water systems can exist within a single watershed. Drinking water sources, including groundwater, river and lake-based systems can be present, as centralized or decentralized facilities. Sanitary systems can be combined with stormwater or separate systems that convey wastewater to a centralized facility, or to individual or communal septic systems. Stormwater conveyance infrastructure can range from roadside ditches to curb-and-gutter conveyance, while treatment can range from no quality or quantity control, to end of pipe treatment, to a treatment train approach to water quality and volume. (Source: CVC).

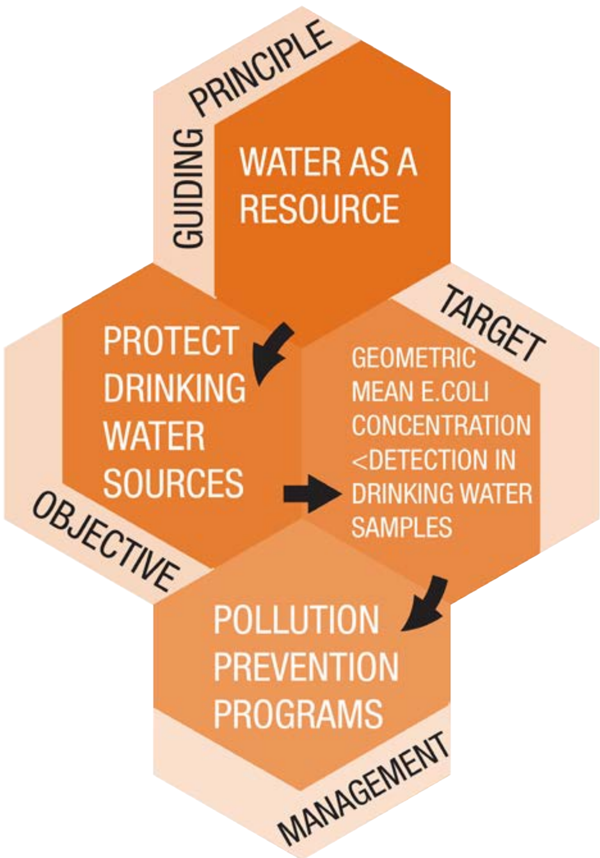



**Figure 8.1.2:** The guiding principles, objectives, and targets set earlier in the water sustainability planning process should inform the management scenarios developed at this stage. (Source: CVC)

## 8.2 Potential management options

CVC's Retrofit Guide to Enhanced Stormwater Management Master Planning provides a comprehensive list of management solutions that project teams can consider when they develop potential watershed management options. This list is focused primarily on stormwater management solutions; however, it also provides additional examples that highlight wastewater and water management solutions more typical of an "integrated" or One Water management approach.

The management options can be grouped into different categories such as structural vs. non- structural grouping options, where structural relates to physical or infrastructure-related management options and non-structural options are linked with policy, planning, educational management options. For example, land use planning is critical and needs to be integrated with infrastructure planning.

**Table 8.2.1:** Developing potential management options.

| Categories of Potential Management Options | Structural | Non Structural | Water | Wastewater | Stormwater |
|---|---|---|---|---|---|
| Residential Lands Source Controls (e.g. raingardens) | ✓ | | ✓ | ✓ | ✓ |
| Business and Multi-Residential Source Controls (e.g. green roofs, infiltration trenches) | ✓ | | ✓ | ✓ | ✓ |
| Public Lands Source Controls (e.g, permeable pavement, bioswales) | ✓ | | ✓ | ✓ | ✓ |
| Road Right of Way Conveyance Controls (e.g. bioretention, storm sewer upgrades) | ✓ | | | ✓ | ✓ |
| End of Pipe Controls (e.g. dry and wet ponds, wetlands, hybrid facilities) | ✓ | | | | ✓ |
| Restoration Measures (e.g. stream, aquatic habitat, day-lighting of storm sewers) | ✓ | | | | ✓ |
| Management and Operational Measures | | ✓ | ✓ | ✓ | ✓ |
| Water Conservation Programs (e.g. water metering, household greywater recovery) | | ✓ | ✓ | ✓ | |
| Nutrient Recovery (e.g. wastewater systems, household greywater recovery) | ✓ | | | ✓ | |
| Combined and Separate Sewage System Remediation Measures | ✓ | | ✓ | ✓ | ✓ |
| Wastewater and Water Treatment Plant upgrades (increase capacity, pumping station upgrades) | ✓ | | ✓ | ✓ | |
| Policy and Education | | ✓ | ✓ | ✓ | ✓ |
| Agricultural Best Management Practices | ✓ | ✓ | ✓ | | ✓ |
| Pollution Prevention | ✓ | ✓ | ✓ | ✓ | ✓ |

## 8.3 Screening potential management options

Once the project team has identified the potential management options, the next step is to evaluate the categories of options through criteria based on the suitability and need of the study area. This step is consistent with the Class EA process generally used for municipal master plans. Some of these criteria are listed here:

a) **Technical feasibility:** In many cases, upon review of technical constraints, such as soils, topography, or land use, some options will not be feasible. For example, land constraints may prevent the implementation of stormwater retention facilities in highly urbanized areas.

b) **Impact on environmental resources (goals, objectives, and targets):** Not all options will achieve the same level of goals, objectives, and targets relating to the environment.

c) **Cost-effectiveness:** The capital and life-cycle project costs should be approximated for each option; however, it is important to consider the effectiveness of municipal dollars. A method for calculating cost effectiveness using the matrices process is discussed at the end of Chapter 9.

d) **Public acceptance:** Public acceptance is important, especially for practices that will be implemented in public spaces (e.g. parks and community centres) and residential areas and will ensure that any actions taken by the owners and/or users of the lands will be in line with the intention of the options.

e) **Municipal and agency acceptance:** Consultation with municipal departments that will be involved in maintenance and operations is essential. Project teams may also consider soliciting the input of external agencies during the evaluation process. Conservation authorities, for example, will be able to provide input from a watershed perspective.

At the screening level it is not important to be precise with quantifiable characteristics, such as costs and impact on environmental resources, if the information is not readily available. Instead, consult reliable reference materials, such as technical papers and industry standards.

The purpose of the screening level evaluation is to present the initial findings to the committee, the public, and stakeholders for their preliminary response. Furthermore, the preliminary assessment will provide direction for the subsequent evaluation of options. After the findings from the screening level assessment have been evaluated, the next step is to undertake a detailed assessment based on a more rigorous set of factors.

## Example: Stakeholder Engagement

Once the project team has bundled, grouped, and further screened the potential management options, it is time to do some stakeholder engagement to vet the options.

Public and stakeholder consultation is critical and will help shape the water sustainability plan. The project team should encourage participation from all sectors to ensure that varied and competing interests within the study area support the strategy. Gaining support and cooperation from key stakeholders is critical, too, so the sustainability process can move forward without resistance.

Here are some of the possible stakeholders:

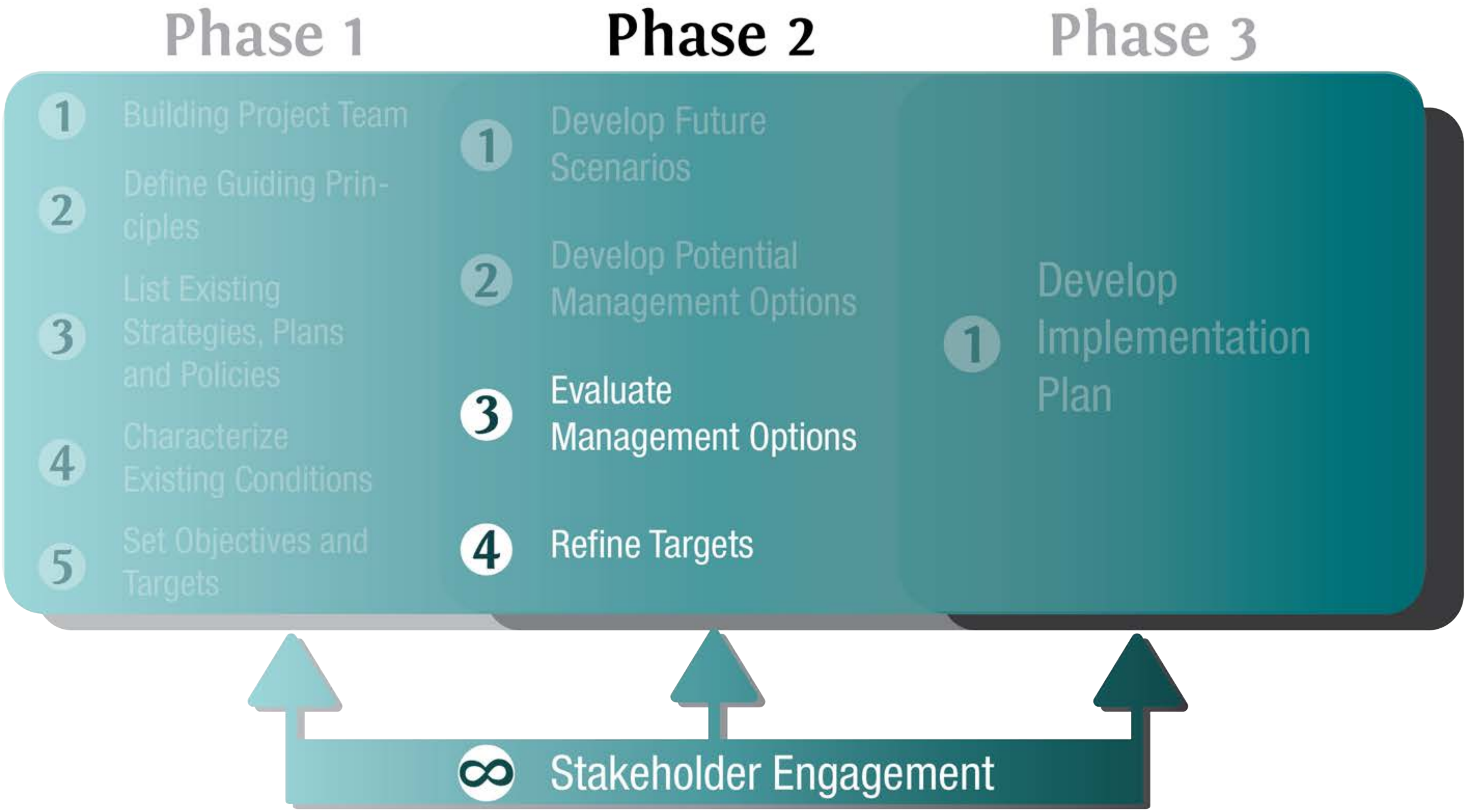
- Agricultural community
- Watershed residents
- Industry and business
- Municipal staff (operations, management, engineers, designers, etc.)
- Academic community
- Environmental NGOs

The Cooksville Creek case study highlights the process of stakeholder engagement with upper tier and lower-tier municipalities, including staff from emergency management services, social services, and public health services. The engagement process could occur while the plan is being developed and/or at crucial points of the plan. The engagement and input from stakeholders can be facilitated in various ways. Here are some examples:

- Webinars
- Public presentations
- Roundtable discussions
- Conferences

Example of a conference held to engage stakeholders from academic, business and municipal community. (Source: CVC)

# 9.0 Evaluate Management Options



At this point in the process, the project team has vetted and screened potential management options using input from key stakeholders within the study area. The next step is to further evaluate those options based on the objectives and targets set earlier in the process. This step is consistent with the Class EA process generally used for municipal master plans. Other impacts of the management options, including environmental, social and environmental costs and benefits, should also be assessed at this point. Water sustainability plans require an adaptable framework for ongoing action and coordination rather than a static, project-orientated plan approach. For this reason, it may be necessary to refine the targets at the end of the evaluation process before selecting a management plan.

## 9.1 Grouping management strategies

The first step is to group the screened management options into three to seven management strategies. The number of management strategies is not as important as the range of costs and benefits that is encompassed by the strategies; it is typical for the strategies to represent options which range from low to high cost, and options which provide low to high environmental benefit. For example, the Credit River Water Management Strategy Update evaluated three alternative management strategies: "Business as Usual", "Technology and Economically Driven," and "Ecotopia" which spanned a range of benefits and negative impacts to the environment.

Figure 9.1.1 illustrates the difference between management options and management strategies. Management strategies, consisting of a suite of screened management options, can reduce the number of alternatives for evaluation. This is particularly important if the project team needs to do a detailed evaluation process that includes modelling alternative strategies.

For the purpose of this guide, the following sections provide three management strategies as examples for a water sustainability plan. The three example strategies range from low to high benefit to the watershed. They are:

a) Grey management strategy
b) Grey and green management strategy
c) One Water management strategy

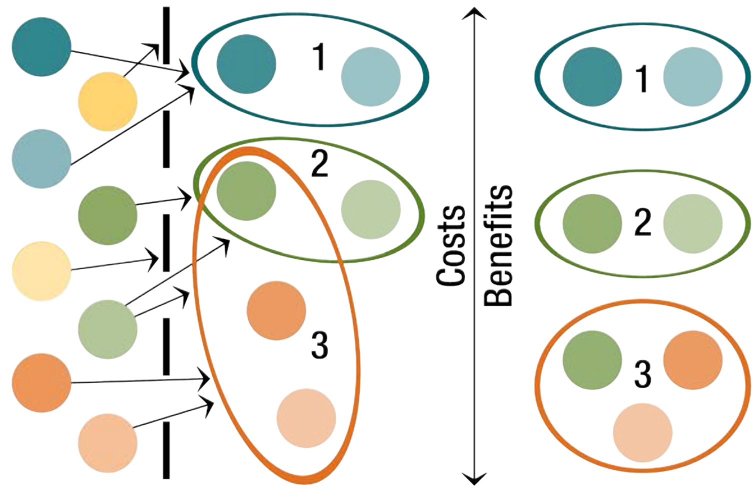



**Figure 9.1.1:** The process of evaluating management options includes grouping the screened management options into several different strategies, which encompass a range of costs and benefits. (Source: CVC)

The following sections include an overview of each strategy, a summary of the types of management options that could form each strategy, and the associated costs and benefits.

## Grey management strategy

As described in Chapter 5, grey infrastructure includes traditional engineered systems that do not mimic the natural water balance. Grey stormwater infrastructure includes systems that are designed to capture and convey runoff, such as gutters, storm sewers, and culverts.[27] Grey infrastructure also includes water and wastewater components, such as wastewater treatment plants and water treatment plants.

Traditionally, grey infrastructure systems tend to be centralized systems where water is conveyed to treatment facilities, including detention ponds, wastewater treatment plants, or water treatment plants. Centralized approaches tend to create challenges with meeting water balance objectives or lower cost for operation and maintenance due to their size and nature. In parts of Ontario, drinking water is pumped long distances crossing many watershed divides and then returned as wastewater to central wastewater treatment facilities for treatment before discharging back to the receiving system. This process is energy intensive – in some municipalities, the energy required to pump and treat water can account for half of the municipality's total energy use. Table 9.1.1 illustrates some examples of grey infrastructure management strategy, along with the ability of those options to meet a list of objectives which would likely be included in a water sustainability plan.

A grey management strategy represents a conventional and centralized approach to water management. This strategy recommends grey stormwater, water, and wastewater infrastructure upgrades to achieve the required minimum level of service without infrastructure optimization for achieving triple-bottom-line benefits.

**Table 9.1.1:** Management options for the grey management strategy and associated benefits

| Grey Management Options | P = Primary Benefit I S = Secondary Benefit I X = Benefit | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Water Quality | Water Balance | Erosion | Improved Wastewater Service (e.g., capacity, condition) | Flood Control | Water Use | Wellhead Protection or Groundwater Recharge | Amenity & Aesthetic Value |
| Sewer and Manhole Rehabilitation | S | X | X | P | P | X | X | X |
| End of Pipe Rehabilitation | S | X | S | X | P | X | X | S |
| End of Pipe Controls (Including Ponds) | S | X | X | P | X | X | X | X |
| Sewer Replacement | P | X | X | P | X | X | X | S |
| Wastewater Treatment Plant Upgrades | S | X | X | P | X | X | X | X |
| Pollution Prevention | P | X | X | S | X | X | P | X |
| Policy & Education | P | X | X | P | P | P | P | X |

This type of approach could include these elements:

- Treating all water to potable standards regardless of the intended use.
- Single use of water (no reuse or recovery of valuable resources).
- Centralized infrastructure solutions (e.g. stormwater management ponds, water treatment plants, wastewater treatment plants).
- Larger pipes to convey and keep up with increasing water demands.

This approach does not embrace all of the guiding principles listed as examples in Chapter 3. For example, the strategy does not seek to mimic the natural water balance through infiltration, or treat water at the source through infiltration. These are some of the negative outcomes of this strategy:

- No savings in life-cycle costs.
- Further downstream environmental degradation.
- No increase in resiliency to climate change vulnerability.
- No deferral on capital expenditure.
- No extension of lifespan of the existing infrastructure.

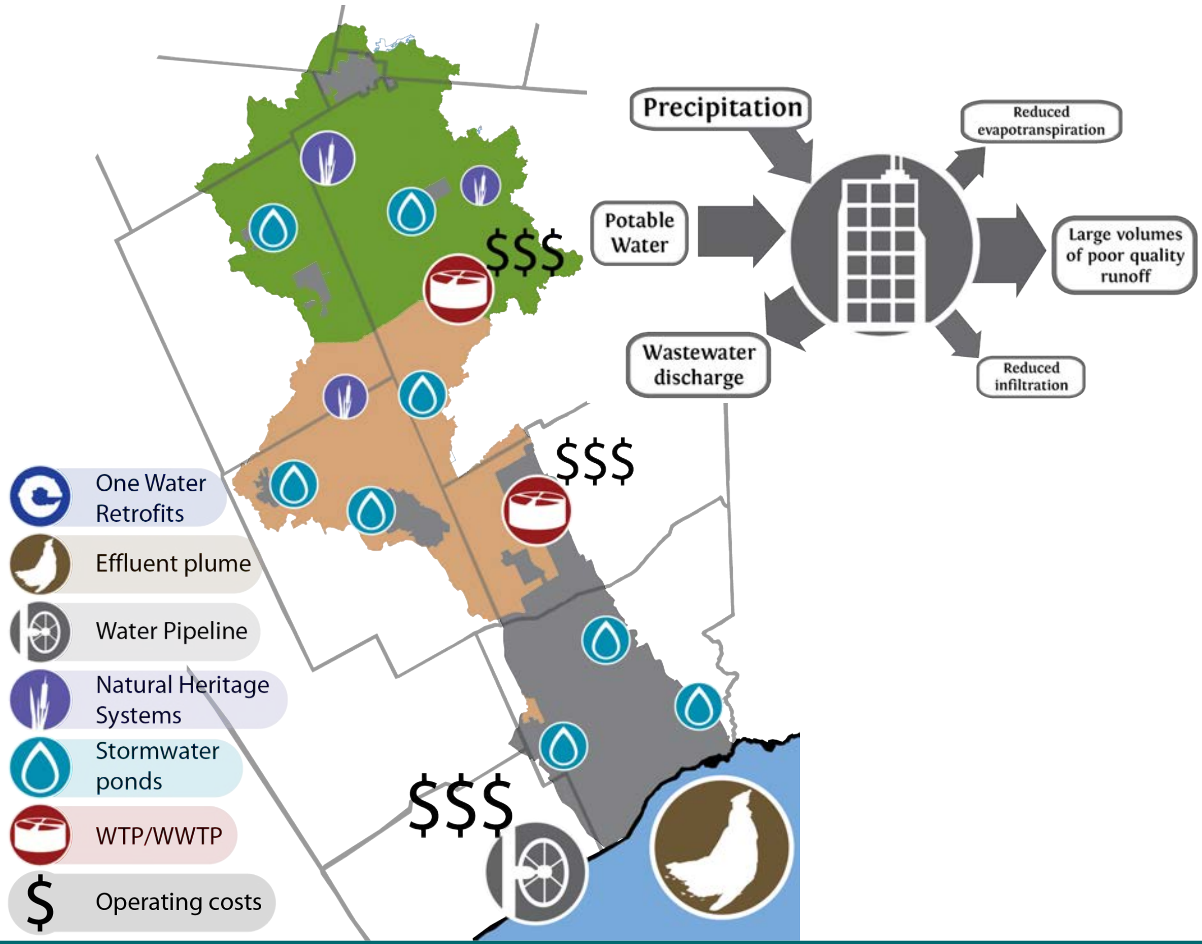



**Figure 9.1.2:** An example that illustrates a grey management strategy, which maintains the status quo of the urban water balance, where water, wastewater and stormwater runoff are pumped, conveyed, and treated at centralized facilities, resulting in high operating costs. (Source: CVC)

## Grey and green management strategy

A grey and green management strategy moves away from solely grey infrastructure, and begins to incorporate water management options that use natural or engineered systems to mimic natural processes to achieve water sustainability objectives and targets. As a general principle, green infrastructure uses soil and plants to replicate the hydrologic pathways lost through urbanization.

Grey and green infrastructure works in a complementary manner to enhance the environment, maintain and improve public health, quality of life, and resilience to climate change. Implementing grey and green management options will include incorporating the grey infrastructure options described previously, as well as green infrastructure management options, such as low impact development, stream restoration, tree planting, and pollution prevention. Table 9.1.2 highlights examples of grey and green infrastructure solutions that may work in a complementary fashion to meet integrated watershed management objectives and targets.

A grey and green management strategy represents a shift from the conventional approach of water management to the inclusion of green infrastructure solutions. This strategy recommends both grey and green stormwater, water, and wastewater infrastructure to achieve the required level of service, while also attempting to achieve other benefits.

**Table 9.1.2:** Management options for the grey and green management strategy and associated benefits

| Grey and Green Management Options | P = Primary Benefit I S = Secondary Benefit I X = Benefit | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Water Quality | Water Balance | Erosion | Improved Wastewater Service (e.g., capacity, condition) | Flood Control | Water Use | Wellhead Protection or Groundwater Recharge | Amenity & Aesthetic Value |
| Sewer and Manhole Rehabilitation | S | X | X | P | P | X | X | X |
| End of Pipe Controls (Including Ponds) | S | S | S | X | P | X | X | S |
| Sewer Replacement | S | X | X | P | X | X | X | X |
| Water Treatment Plant Upgrades | P | X | X | P | X | X | X | S |
| Pumping Station Upgrades | S | X | X | P | X | X | X | X |
| Pollution Prevention | P | X | X | S | X | X | P | X |
| Policy & Education | P | S | X | P | P | P | P | X |
| Water Conservation Programs | S | S | P | X | S | P | S | S |
| Source Control Measures | P | P | P | S | S | P/S | S | S |
| Restoration and Protection of Natural Systems | P | S | P | X | S | S | S | S |
| Agricultural Best Management Programs | P | S | S | X | S | S | P | X |

This type of approach could include these elements:

- Some grey infrastructure solutions and upgrades to water and wastewater treatment plants.
- Implementing cost-effective, demand-side, green infrastructure before increasing grey infrastructure.
- Retrofits to stromwater management in some existing urban areas.
- Land securement, floodplain management and implemention of compatible land uses within vulnerable areas.
- Partial or deferred upgrades to treatment facilities.
- Deferral of major infrastructure such as a water pipeline.
- Some extention of lifespan of existing infrastructure.
- Some outreach and education initiatives.
- Protection and restoration natural heritage features.
- Agricultural best management practices.

With this strategy, the watershed will benefit from increases in infiltration and improved water quality to the receiving streams. For implementation, this strategy may require funding mechanisms such as a stormwater rate system in order to implement green infrastructure projects. This approach will likely result in cost savings through management options that manage water at its source, reducing the need for added capacity for treatment and conveyance, deferral of major upgrades, etc. Figure 9.1.3 illustrates the state of the watershed under this strategy.

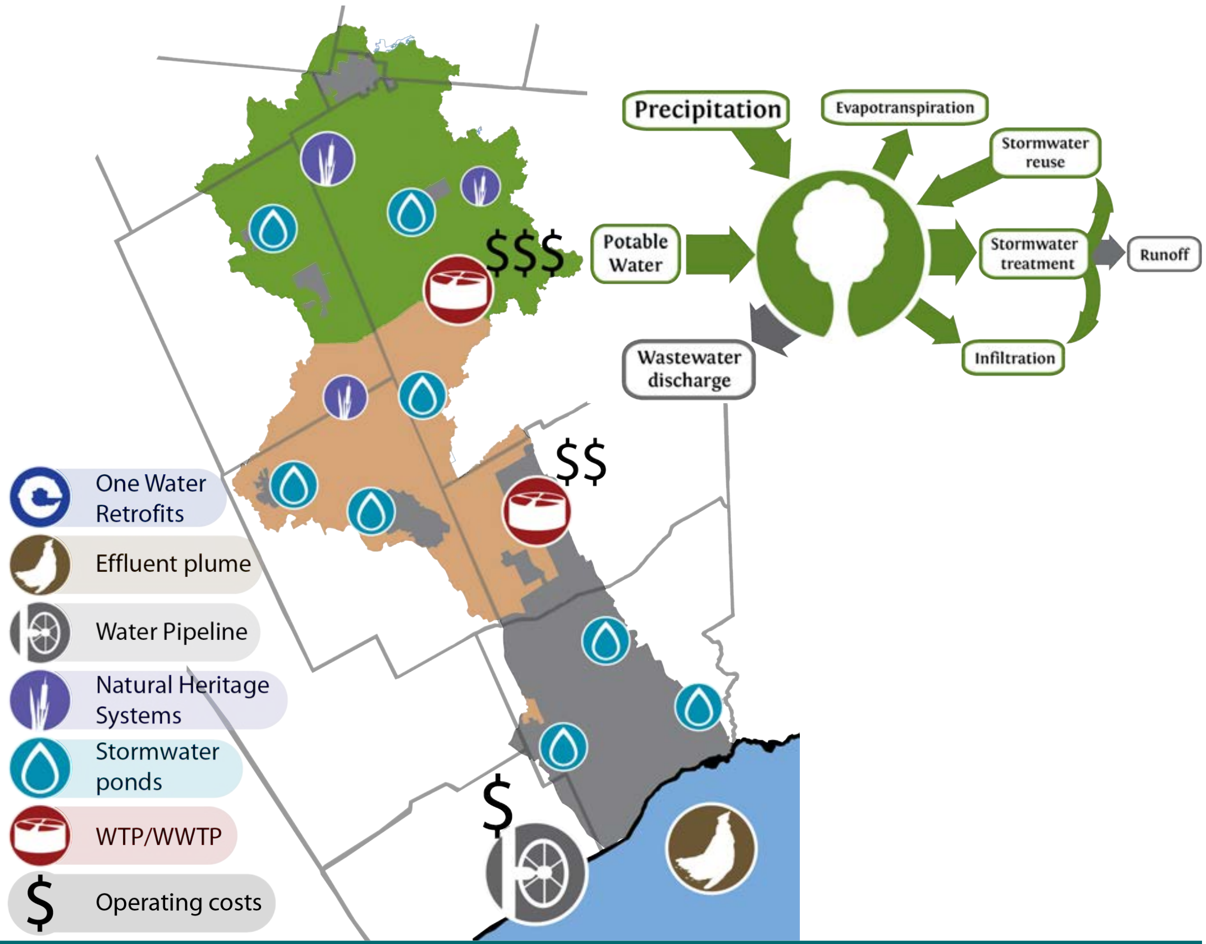



**Figure 9.1.3:** The example illustrates a grey and green management strategy, which expands from conventional water management to incorporate some management options that mimic the natural water cycle, including low impact development. (Source: CVC)

## One Water management strategy

A One Water management strategy uses green infrastructure solutions and incorporates technologies from a watershed scale that encourage reuse, nutrient recovery, decentralized systems, water conservation, and more. This approach seeks to apply all the guiding principles described in Chapter 3. Table 9.1.3 highlights examples of One Water options, and their ability to meet integrated watershed management objectives and targets.

A One Water management strategy represents a full shift towards water management practices and solutions that attempt to replicate the natural water cycle using innovative engineered and natural methods, in order to meet and even exceed the required level of service.

**Table 9.1.3:** Management options for the One Water management strategy and associated benefits

| One Water Management Options | P = Primary Benefit I S = Secondary Benefit I X = Benefit | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Water Quality | Water Balance | Erosion | Improved Wastewater Service (e.g., capacity, condition) | Flood Control | Water Use | Wellhead Protection or Groundwater Recharge | Amenity & Aesthetic Value |
| Sewer and Manhole Rehabilitation | S | X | X | P | P | X | X | X |
| End of Pipe Controls Including Ponds and Wetlands | S | S | S | X | P | X | X | S |
| Phosphorus Removal Media | S | X | X | P | X | X | X | X |
| Tree Clusters | P | X | X | P | X | X | X | S |
| Water Conservation Programs | S | X | X | P | X | X | X | X |
| Source Control Measures | P | X | X | S | X | X | P | X |
| Agricultural Best Management Practices | P | S | X | P | P | P | P | X |
| Nutrient Recovery (Greywater Nutrient Recover) | S | S | P | X | S | P | S | S |
| Land Use Planning (e.g., floodplain management, special policy areas, well head protection | P | P | P | S | S | P/S | S | S |
| Policy & Education | P | S | P | X | S | S | S | S |
| Wetland Restoration/Natural Heritage Protection | P | S | S | X | S | S | P | X |

This type of approach could include these elements:

- Using greywater for irrigation.
- Treating water to a level of quality suitable for the intended use (such as household water recovery systems that treats shower water to a level of quality suitable for flushing toilets).
- Implementing multiple decentralized small water treatment and distribution systems that serve local needs and the triple bottom line.
- Rural stewardship programs, education and outreach.
- Closing the loop on wastewater and recovering valuable resources for beneficial uses.
- Integrating management of all types of water infrastructure regionally.

An important implementation consideration for a One Water strategy is the integration of management options from a watershed perspective, as location-specific feasibility will determine where best to implement different management options. Chapter 10 will explore this further. This type of strategy embraces most of the guiding principles described in Chapter 3, and would have the best outcome for the watershed. This strategy would likely result in these benefits:

- Decentralized retrofit opportunities.
- Deferral of grey infrastructure capital investments.
- Savings in life-cycle costs (e.g.., operation, maintenance, renewal, and disposal).
- Extention of existing infrastructure lifespan.
- Deferral or potential elimination of the need for future water pipelines to accommodate growth.

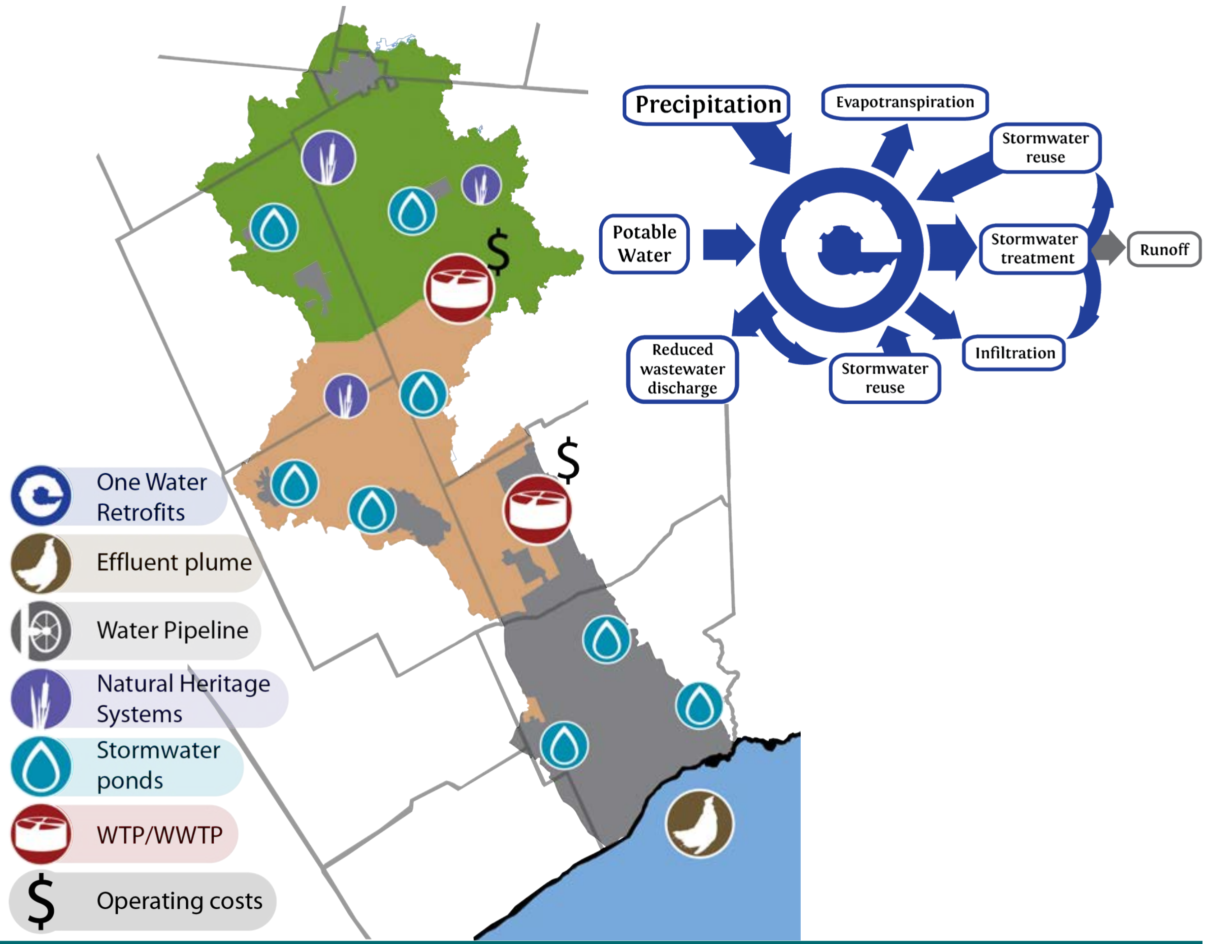



**Figure 9.1.4:** The example above illustrates a One Water management strategy, which expands from conventional water management to incorporate some management options that mimic the natural water cycle, including low impact development. (Source: CVC)

## 9.2 Evaluation methods

Once the project team has identified a range of management strategies, the next step is to evaluate them relative to one another to determine which strategy will be carried forward for implementation through the water sustainability plan. This section describes different methods of evaluation that can be used to make this decision. At this point, the project team should conduct some stakeholder consultation to ensure that decision-makers are invested into the evaluation of management strategies.

Depending on the study area's comprising municipalities and conservation authorities, as well as upon the existing material available, the method used to evaluate alternative strategies will differ. For study areas that already have robust plans, strategies and policies, the water sustainability plan will be an opportunity to integrate the various plans, including master plans and watershed plans. In this case, there may already be detailed evaluation of alternatives, and the results from those plans can simply be carried over into the water sustainability plan. For study areas that do not have detailed water management plans, the evaluation step is an opportunity to complete an analysis of the management strategies at differing levels of detail, depending on available information and resources.

### Case Study: Cooksville Creek Vulnerability Assessment

The Cooksville Creek vulnerability assessment is an example of a study that made use of an abundance of data, plans, and strategies that were already in motion. This information included a flood evaluation master plan that had evaluated different management options through modelling, and recommended a management strategy including stormwater management ponds and increased creek conveyance. These management options, as well as others including retrofitting parts of the watershed with LID, were evaluated using methods including water quality and quantity modelling, to make use of already completed and calibrated models.

### Defining the evaluation criteria

The first step in evaluating the alternative management strategies is to develop a set of criteria for assessment. This set of criteria should flow from the guiding principles, objectives, and targets set earlier in the water sustainability planning process. Since each study area will be vastly different, with varying issues and constraints, it is important to define clear and unique criteria that serve to represent and balance the overall goals of the plan.

The specificity of the criteria will depend on the level of detail with which the management strategies will be evaluated. For instance, if the project team is using technical methods of evaluation, including modelling and computational analysis, the team should include numerical targets set earlier in the process as criteria. For less detailed evaluation methods, objectives may be sufficient. Recall that objectives are general in nature (e.g. protect waterbodies for recreational purposes), while targets are specific and measureable (e.g. meet E. coli concentration of <100 counts/mL at all beaches).

The project team should incorporate all of the objectives and targets into the evaluation criteria. The project team may also choose to include additional criteria that are non-technical in nature, such as cost, feasibility, public acceptance, energy use, and integration into social fabric of the study area.

### Evaluating the management strategies

Once the evaluation criteria have been established, there are many possible methods the project team can use to evaluate the alternative management strategies. Table 9.2.1 highlights a number of evaluation methods, along with their advantages and disadvantages. The project team should select the method most suitable to the data and resources available for the water sustainability plan. The following sections provide additional information regarding two of the methods (matrices and economic methods) listed in Table 9.2.1.

**Table 9.2.1:** Methods to evaluate alternative management strategies. (Source: CVC)

| Method | Description | Advantages | Disadvantages |
|---|---|---|---|
| Matrices | • Used to display and evaluate alternative strategies vs. multiple criteria<br>• Preferences of interest groups (used for weighing criteria) can be considered | • Simple to use and easy to understand<br>• Considers trade-offs and comparisons<br>• Allows for weighing of criteria | • Difficult to ensure criteria are independent of others<br>• Scores are dimensionless (i.e. not on ratio scale) |
| Ad Hoc | • Impacts of alternative strategies described in narrative terms<br>• Professional judgment used to select among options | • Minimal data required<br>• Easy to implement | • Not traceable or accountable<br>• Does not asses trade-offs and comparisons |
| Checklists | • Alternative strategies must satisfy conditions before considered acceptable | • Helps eliminate unwanted alternative strategies, and develop a list of reasonable alternative strategies for detailed evaluation<br>• Useful first step combined with other evaluation methods | • Doesn't involve trade-offs and comparisons<br>• Rarely determines single preferred alternative |
| Constraint Mapping (GIS) | • Compare and evaluate alternative strategies using mapping | • Helps eliminate unwanted options, and develop a list of reasonable options for detailed evaluation<br>• Useful first step combined with other evaluation methods | • Doesn't involve trade-offs and comparisons<br>• Rarely determines single preferred alternative |
| Programming Methods | • Programming methods are designed to deal primarily with complex decisions for which an optimum solution is being sought (e.g. linear, dynamic or goal programming) | • Can handle large amounts of data systematically | • Complex and difficult to implement<br>• Available data and information are not always handled easily by programs<br>• Results can be difficult to understand and interpret |
| Economic Methods | • Attempts to represent all aspects of the project in monetary values (e.g. costs vs benefits, return on investment) | • Comparison in the form of an understandable unit ($) | • Difficult to assign a monetary value to all impacts (e.g. environmental impacts, feasibility) |
| Pair-Wise Comparison | • Compares each alternative vs. each criteria and develops a relative preference of alternative strategies based on these comparisons | • Allows the use of relative ranking of units rather than categorizing them into scores | • Complex to implement<br>• Traceability is a concern<br>• Results can be difficult to understand and interpret |

As an example, the following discussion provides further information on the matrices method and economic method. For more detailed information on other methodologies, refer to Appendix C.

## Matrices method

The matrices method is commonly used in the evaluation process for master plans and should therefore be familiar to most municipalities.

### Weighted criteria

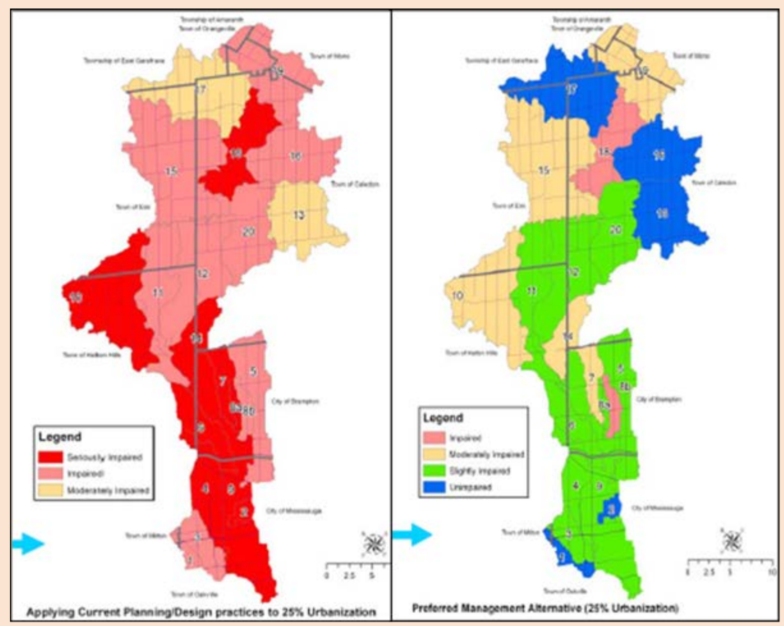
The matrices process uses weighted criteria as a method of judging the alternative management strategies against one another to arrive at a preferred management strategy. The criteria should be assigned weights that reflect the relative importance of one criterion over another. For instance, criteria reflecting the overall goals of the study will be weighted highly, as will public safety and cost, if they are included. Weighting for criteria should be set using stakeholder input.

### Impact values

The matrices method also assigns impact values to each of the management strategies for the different criteria. These impact values describe the ability of that strategy to meet the criteria. They can be quantitative, particularly for numerical targets, or qualitative, using a high-medium-low scale. For quantitative values, modelling may be required to determine the actual impact of the alterative management strategies on, for instance, water quality and quantity impacts, or the level of service provided by each strategy. This assessment should include the future scenarios that were developed earlier in the process (see Chapter 7).

## Example: Credit River Water Management Strategy Update (CRWMSU)

The CRWMSU used the matrices method to evaluate three alternative management strategies. Four criteria were selected and weighted for the evaluation, including cost, implementability, natural environment, and social benefits. Modelling was used to determine the impact on the watershed of the three management strategies on a subwatershed basis, using values of unimpaired, slightly impaired, moderately impaired, impaired, and seriously impaired, based on the ability of the management strategies to meet the targets set in the study, as shown below.



### Overall scoring

To determine the preferred management strategy, the weighted criteria are multiplied by the impact values to compute an overall score for each strategy. The preferred strategy is the one with the best overall score.

## Economic methods

Economic methods of comparing alternative management strategies attempt to represent all aspects of evaluation process through monetary value. The key to this approach is the ability to value and compare direct and indirect impacts of each management strategy, using comparable units, such as in dollars.

Calculating the return on investment or cost-benefit analysis of different integrated water management approaches to demonstrate how a solution can achieve multiple benefits is easy to describe but difficult to achieve. The differences between the return on investment and cost-benefit analysis approaches are summarized in these quotations:

When evaluating management strategies, particularly at the scale of the watershed, these economic methods could be used, likely in conjunction with other methods as described in Table. 9.2.1, to suit the particular needs of the study.

### Cost-benefit analysis

A cost-benefit analysis involves considering both the direct and indirect costs and benefits of a particular water management strategy. Indirect costs relating to water management may include adverse health impacts due to basement flooding, or economic loss when flooding is widespread in business areas. It can also include costs to implement the strategy, such as permitting fees, land acquisition, site sampling and investigation, and energy costs.

Indirectly, the benefits of green infrastructure have been well documented, and can include social and ecological benefits such as climate change mitigation, protection of the Great Lakes, increased property value, and open space for recreation.

### Life-cycle costs

When considering economic comparisons of water management strategies, the project team should consider full life-cycle activities. Life-cycle costs are the costs incurred during the life cycle of a physical asset, from the time of its acquisition to its disposal or rehabilitation. Figure 9.2.1 highlights the typical life-cycle phases.

Once the project team has assessed the indirect and direct costs and benefits, it can develop different point values and weighting criteria to score the options. The final score is determined by dividing the total project costs by the overall benefit score. A lower final score indicates that the option is more cost-effective and offers the best value.


**Figure 9.2.1:** There are six major phases of the service life of an infrastructure asset. (Source: Building Together, 2015)

### Return on investment

Another economic evaluation method is calculating and comparing the return on investment of each management strategy. This approach takes into consideration the full cost and benefits of infrastructure, the current and future delivery of municipal water services, climate change, and other externalities. The return on investment doesn't typically reflect the social, economic, and environmental returns on investment, which can be challenging; however, the project team can integrate these elements into the evaluation.

With the adoption of integrated water management approaches at the watershed scale, water managers can obtain returns on their investment through:

- Reduction in treatment costs through applying the principle of "right water for right use"
- Deferred or avoided capital expenditures
- Savings in operation and maintenance cost
- Increase in resiliency of infrastructure – extended lifespan
- Recovery of valuable resources from wastewater
- Implementation of decentralized system to take pressure off the centralized facilities
- Opportunities of green jobs/economy
- Restoration of the water cycle
- Reducing cost to integrated risk assessment and asset management planning
- Risk reduction through an integrated watershed planning approach

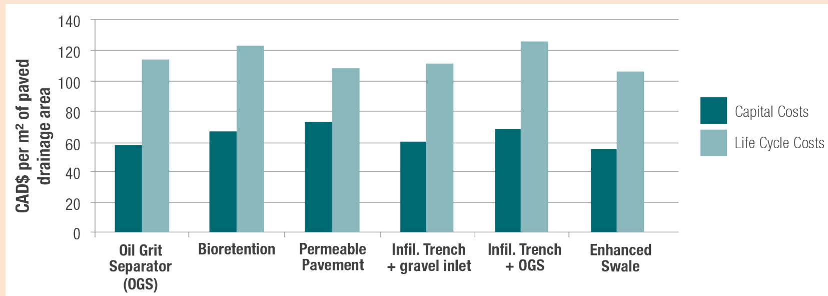
There are many tools available for calculating the return on investment for different water management strategies, some of which are listed in Table 9.2.1. There is more information provided in Appendix C.

## Example: High-level costing tool for LID option screening - using the STEP LID Practices Costing Tool

The LID Practices Costing Tool, developed by TRCA, is one tool for comparing the costs of green infrastructure solutions. The spreadsheet tool calculates capital costs and 50-year life-cycle cost estimates for different practices.

*Source: Evaluation of Life-cycle Costs for Low Impact Development Stormwater Management Practices, TRCA, 2013*

| LID retrofit option | Cost per impervious drainage area | Construction cost |
|---|---|---|
| Bioretention planters | 41 – 83 ($/m²) | 264 - 484 ($/m²) |
| Curb extensions | 9 ($/m²) | n/a |
| Boulevard bioretention | 40 - 65 ($/m²) | 108 ($/m²) |
| Bioswales | 7 - 23 ($/m²) | 594 - 2585 ($/m²) / 300 – 400 ($/m) |
| Perforated pipe | 55 ($/m²) | 150 - 250 ($/m) |
| Permeable pavement | 53 - 60 ($/m²) | 108 - 430 ($/m²) |



## Example City of Lancaster

This study conducted in Lancaster demonstrates the economic benefits of green infrastructure. The study evaluates how installing green infrastructure in combined sewers system area could reduce grey infrastructure capital investment and associated wastewater pumping and treatment costs, as well as other range of environmental benefits across the city.

*"The city of Lancaster opted for a strategy that involved both gray and green infrastructure. Their comprehensive Green Infrastructure Plan identified opportunities for adding green infrastructure throughout the City within the 5-year and 25-year timeframe.*

*With the green infrastructure plan, both the avoided capital costs associated with reduced storage needs and avoided operational cost associated with reduced wastewater treatment needs were valued. The reduction in volume and rate of runoff from green infrastructure reduces the need for both storage and treatment required. This in turn reduces the capital and operational cost of grey infrastructure system such as storage tanks and pumping stations.*

*The average annual reduction in CSO volume was translated into avoided capital costs for gray infrastructure storage systems and avoided wastewater pumping and treatment costs. Assuming the green infrastructure costs are directly proportional to the area of green infrastructure implemented, the total cost of green infrastructure in the area is $94.5 million and the marginal cost of green infrastructure is $51.5 million."*

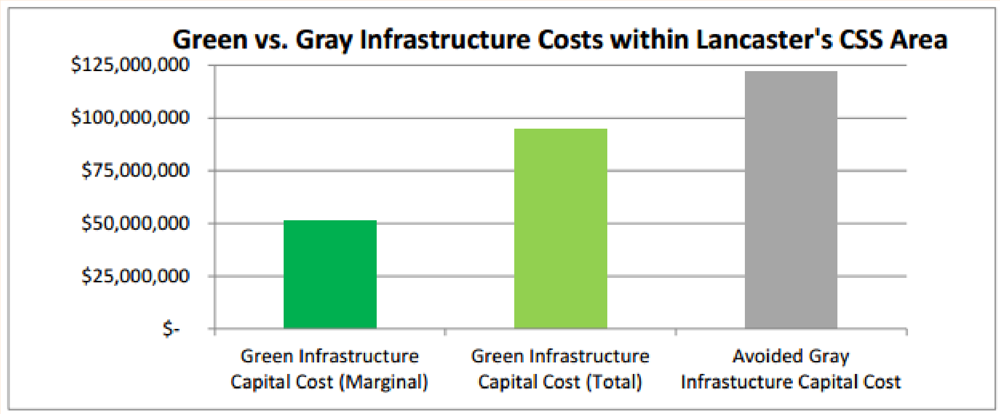



Figure 1: Comparison of avoided gray infrastructure costs to green infrastructure costs within Lancaster's CSS area.

| Estimated Value of Avoided Costs for Wastewater Treatment & Storage at 25-Year Implementation* | |
|---|---|
| Reduced Pumping and Treatment Costs (per year) | $661,000 |
| Reduced Gray Infrastructure Capital Costs | $120,000,000 |

*Benefits of green infrastructure stormwater reduction outside the CSS area were not included in this analysis

*Source: http://www.wri.org/blog/2012/06/green-vs-gray-infrastructure-when-nature-better-concrete*

**Table 9.2.1:** Tools available for calculating return on investment for water management strategies. (Source: Adapted from Envision Rating System.)

| Tools | Description |
|---|---|
| Business Case Evaluator | Developed to enhance the Envision Tool by adding the ability for it to provide value based and risk adjusted analyses of infrastructure projects. [28] |
| PRISM - A Triple Bottom Line Decision Tool | Comprehensive project/program evaluation tool used extensively on a full range of transportation projects for evaluation triple bottom line factors. The economic capabilities include cost benefit, and wider economic impacts resulting from improved regional accessibility.[29] |
| Sustainable Return on Investment (SROI) | A framework that has been used to measure the triple bottom line impacts of a project. It determines full value of a project through a robust economic-based approach to estimating all relevant cost and benefits and develops tangible indicators to community the full value of the investment.[30] |
| Zofnass Economic Process Tool | A platform that offers ways to achieve preliminary quantification of sustainability externalities in infrastructure projects based on the Envision® rating system.[31] |

## 9.3 Risk management

Once the project team has evaluated the various costs and benefits of the alternative management strategies, it is time to complete a risk assessment to ensure that the water management solutions can mitigate current and future risks. A watershed approach can be extremely helpful at this stage in helping the project team comprehensively identify risks within the study area that may not have been previously identified. The level of service targets (Chapter 6) and future scenarios (Chapter 7) developed earlier in the process, particularly with respect to future climate change, should form the basis of assessing future risk and the ability of management strategies to mitigate them.

A good first step is to conduct an assessment of the risks associated with not meeting the targets, or of meeting slightly lower interim targets, if this has not already been completed as part of the evaluation process. Assessing risk means comparing the probability of an event to the severity or impact of that event in order to gauge risk, which, with respect to water, can include risks of infrastructure failure, legal risk associated with flooding, and risk to the natural environment, human health, and life.

### Case Study: Cooksville Creek Vulnerability Assessment

The Cooksville vulnerability assessment used the PIEVC Protocol as a tool to identify risks and vulnerabilities to water, wastewater, stormwater and creek infrastructure in light of climate change. Five alternative management strategies were evaluated, ranging from stormwater ponds to extensive uptake of LID, and each were evaluated with future scenarios including climate change, using water quality modelling software. These results were compared to water quality targets that were set for the watershed. The study also expanded from this tool to incorporate consideration of the needs of the watershed, integration of water infrastructure, and linkages to other systems including health and emergency management. For more information on the Cooksville Vulnerability Assessment, refer to Appendix A, which contains the full case study describing the scope, methodology, and results of the risk assessment.

The economic tools described in this chapter can help the project team to better understand the direct and indirect costs of different management options which can meet a higher target, versus the costs associated with the level of risk of not meeting a particular target. Adding up the various costs can help the project team choose the best management strategy for the water sustainability plan. It is important to have strong stakeholder engagement at this step, in order ensure that the various risks and costs associated with meeting or not meeting targets have been understood and compared by decision makers.

Some of risks may be indirect results of water-related issues. An example could be the risk of health and safety impacts to residents following flooding events when living in homes where flood damage has caused mold growth. Another example is the risk of increased crime that often coincides with a flooding event, particularly when accompanied by power outages. Finally, the risk of potential lawsuits from homeowners who have experienced flooding impacts, of which there are many examples in Ontario and Canada, is a large monetary risk. The risk assessment stage allows the project team to quantify these risks, in order to make a clear case for investment in water infrastructure to mitigate those risks.

### Tools for assessing the vulnerability of water infrastructure

There are many tools that the project team can use to further assess the risks to and vulnerability of water infrastructure. Each tool is unique and addresses a range of risk-associated concerns. Appendix A includes a paper entitled Vulnerability and Adaptation of Water Infrastructure to Climate Change by Guy Félio, which lists and compares three risk assessment tools. These tools are:

1. Changing Climate, Changing Communities – ICLEI Canada
2. Municipal Risk Assessment Tool (MRAT) – Insurance Bureau of Canada
3. Public Infrastructure Engineering Vulnerability Committee (PIEVC) Protocol – Engineers Canada

These and other relevant tools that could be used for risk assessment within a water sustainability plan are highlighted in Figure 9.3.1, which identifies their capabilities and applications.

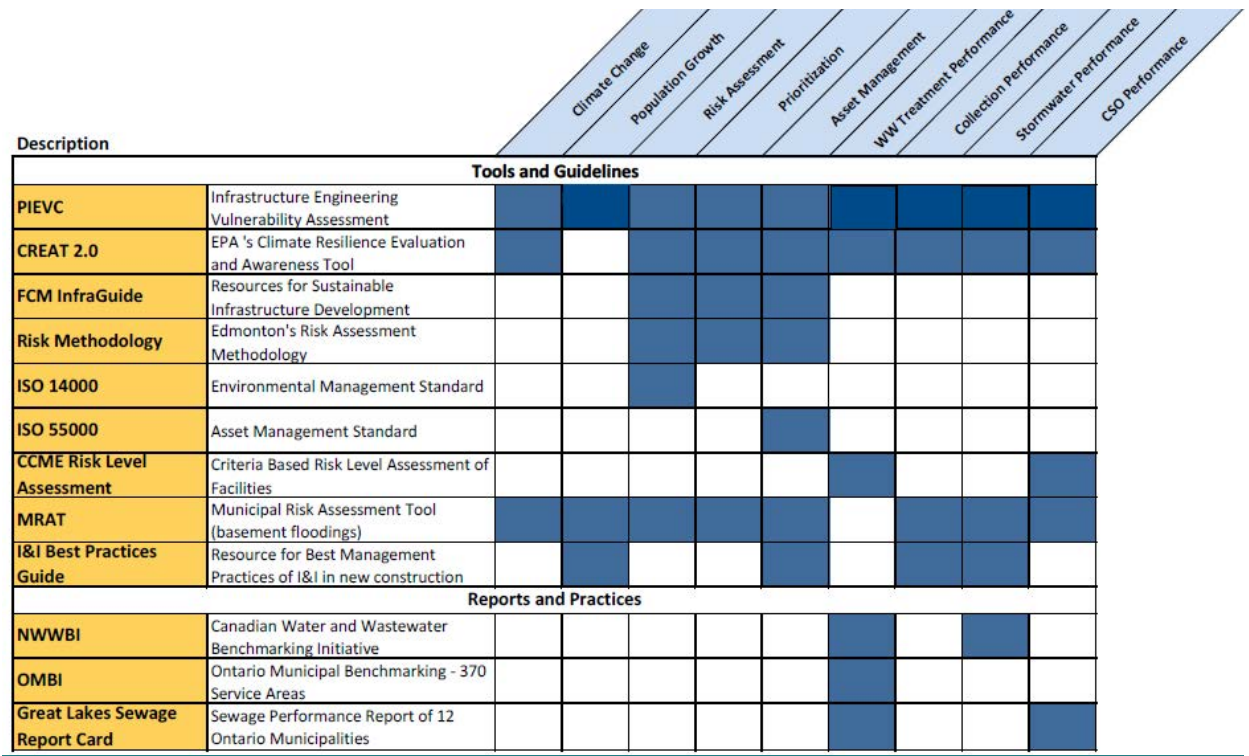



**Figure 9.3.1:** Capabilities and focus of relevant tools and reports for risk assessment. (Source: Ontario Coalition for Sustainable Infrastructure. WINA Report – When the Bough Breaks, November 2014)

## 9.4 Refining targets and management strategies

Once the management strategies have been evaluated and the risks assessed, it may be necessary to return to an earlier step in the water sustainability planning process and refine the targets that were set for level of service, water quality, and water quantity or create new management strategies. This may be warranted if the project team finds that one or more targets could not be met by any of the alternative management strategies, or if the targets could only be met with extremely high environmental, social, or economic costs and/or risks.

For example, a target to meet stream base flow requirements cannot be met with any of the management strategies the project team has evaluated. After assessing the risks, the project team might decide to establish an interim target that is more moderate than the original target, such as maintaining base flow targets for 80% of the time. This revised target would result in a level of risk that is acceptable to decision makers. Alternatively, if the risk of not meeting a target is considered too great, the project team may decide to create and evaluate an alternative management strategy that would meet the target.

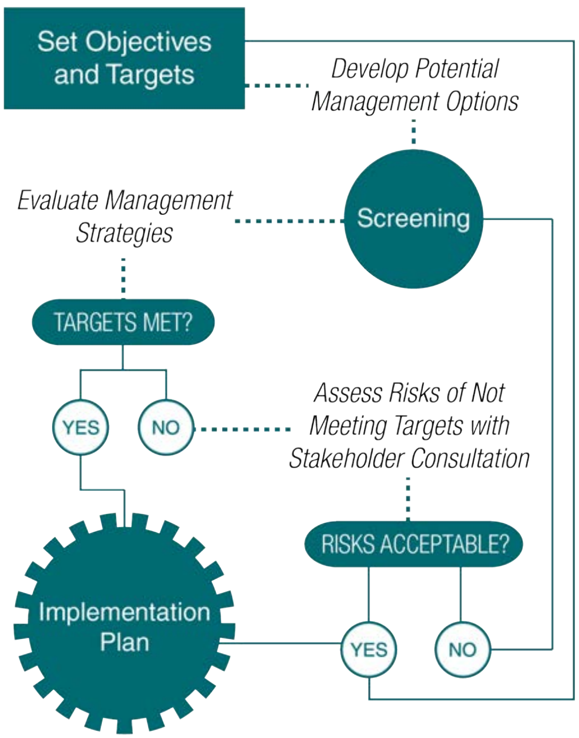
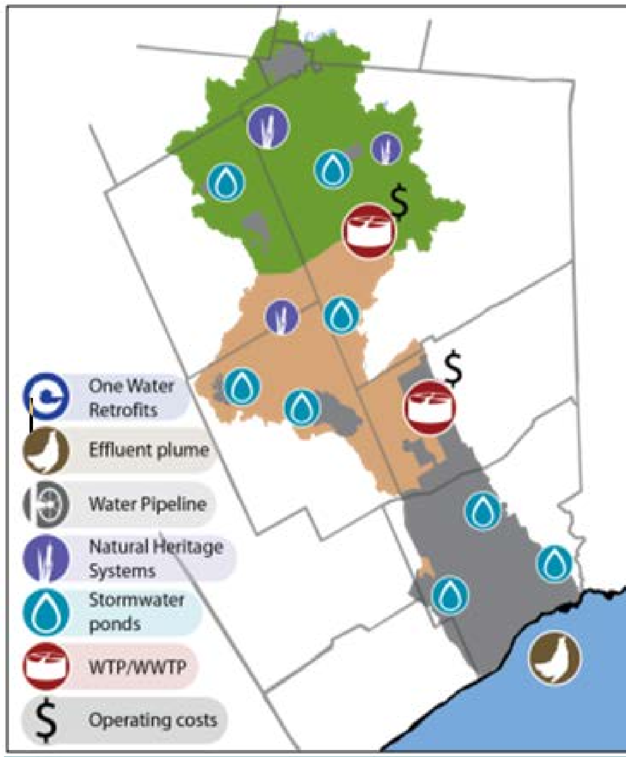



**Figure 9.4.1:** This diagram shows the feedback loop that can be followed in refining targets following screening, evaluation, and risk assessment activities. (Source: CVC)

## 9.5 Selection of preferred management scenarios

After a detailed evaluation, the project team selects the preferred management scenario to take forward to implementation through the water sustainability plan. The example shown in Figure 9.5.1 depicts a conceptual preferred management scenario, along with the details and benefits of selecting the options within the scenario.



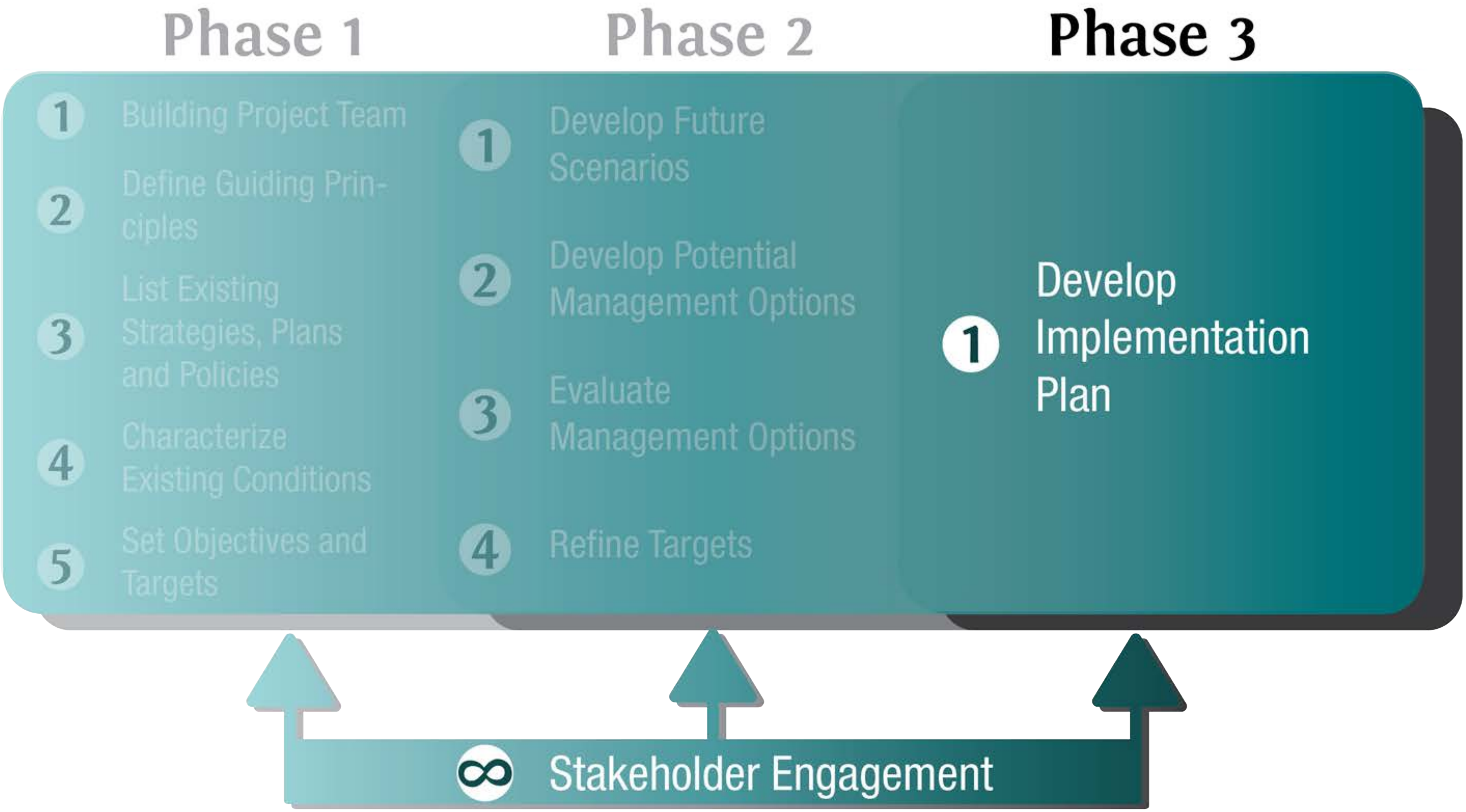

**Preferred Management Scenario:**

- Decentralized retrofit of 60 ha in the middle part of watershed.
- Defferal of grey infrastructures capital investments of $100,000
- Savings in life-cycle costs of $60,000 (i.e. operation, maintenance, renewal, disposal)
- Extention of existing infrastructure lifespan to 5 years
- Deferral or potential elimination of the need for future pipleines to accommodate growth
- Rural stewardship program or education outreach.

*Note: These options are part of a fictitious example. (Source: CVC)*

**Figure 9.5.1:** A conceptual depiction of a preferred management scenario, with details of the benefits provided. (Source: CVC)

# 10.0 Making an Implementation Plan



At this point in the process of creating a water sustainability plan, the potential management options have been evaluated against a set of criteria, including their ability to meet the objectives and targets. The next step is to select the management plan based on that evaluation, and outline the full set of actions that will make up that plan.

## 10.1 Roles and responsibilities

The actions can be listed in a tabular form, identifying for each the associated water service component, whether the action is structural or non-structural, and if it is a retrofit, expansion, or new project. The implementation plan should also specify how selected actions will be carried out, by whom, and in what locations and time frame.

*Recent legal cases in Ontario have demonstrated that having a plan is not enough – it must be implemented and enforced. For example, the City of Thunder Bay implemented a downspout disconnection program, but did not enforce it. As a result, the City was found liable for flooding damages because it had not followed through with its plan.*

The implementation plan may include a table similar to Table 10.1.1, which outlines the roles and responsibilities of partners. The timelines in the action plan should incorporate any internal and external timelines, such as dates when funding will be available (such as provincial infrastructure funding), or dates when compliance with a particular regulation must be achieved. For implementation of some measures, other parties including developers, residents, and businesses will have roles to play. For example, incorporating LID retrofits in a new subdivision will require inclusion of developers and residents, while implementation of actions such as a downspout disconnection program will require property owner engagement and action.

**Table 10.1.1:** Example of Water Sustainability Plan Actions

| Water Service Component | Action | Lead (Partners) | Timeline |
|---|---|---|---|
| Water | 1. Main Street Transmission Main Replacement<br>2. Increase capacity of water treatment plant | Region – Water Department | 1. 2016<br>2. 2018 |
| Wastewater | 1. Combined Sewer Overflow (CSO) Replacement<br>2. Sealing of manhole covers to reduce inflow/infiltration<br>3. Implement mandatory downspout disconnection program | Region – Wastewater Department (City – Stormwater Department) | 1. 2017<br>2. 2017<br>3. 2018 |
| Stormwater | Retrofit 30% of roads with LID in road right-of-way | City – Stormwater Department (Conservation Authority) | 2030 |
| Watershed | Acquisition and protection of significant wetlands each year | Conservation Authority | 20 years |

## Mapping priorities

In order to determine specific timelines and locations for water management actions, the project team can use mapping to ensure that the water sustainability plan is implemented in a thoughtful and efficient manner. Priority mapping can establish that a particular watershed, subwatershed, or neighbourhood, has higher priority over others in a study area, by identifying areas of high vulnerability, such as areas of historical flooding, where a high return on investment could be achieved to reducing those vulnerabilities.

Priority mapping may identify more detailed areas to prioritize investment. For example, timing and location of stream restoration works should be selected with consideration for phasing of upstream/upland actions which may alter the hydrologic and hydraulic properties of the watercourse, such as the timing of flows which may occur during fish spawning windows.[32]

Figure 10.1.1 shows mapping from the CVC's Headwaters Subwatershed Study Phase III – Implementation Plan. It shows areas where LID opportunities exists along with wellhead protection areas, municipal boundaries, and the watershed boundary. In conjunction with mapped areas of vulnerability, such as cold water fisheries and wastewater treatment plant discharges, this mapping could identify areas where LID could be used to promote infiltration to minimize base flow reduction.

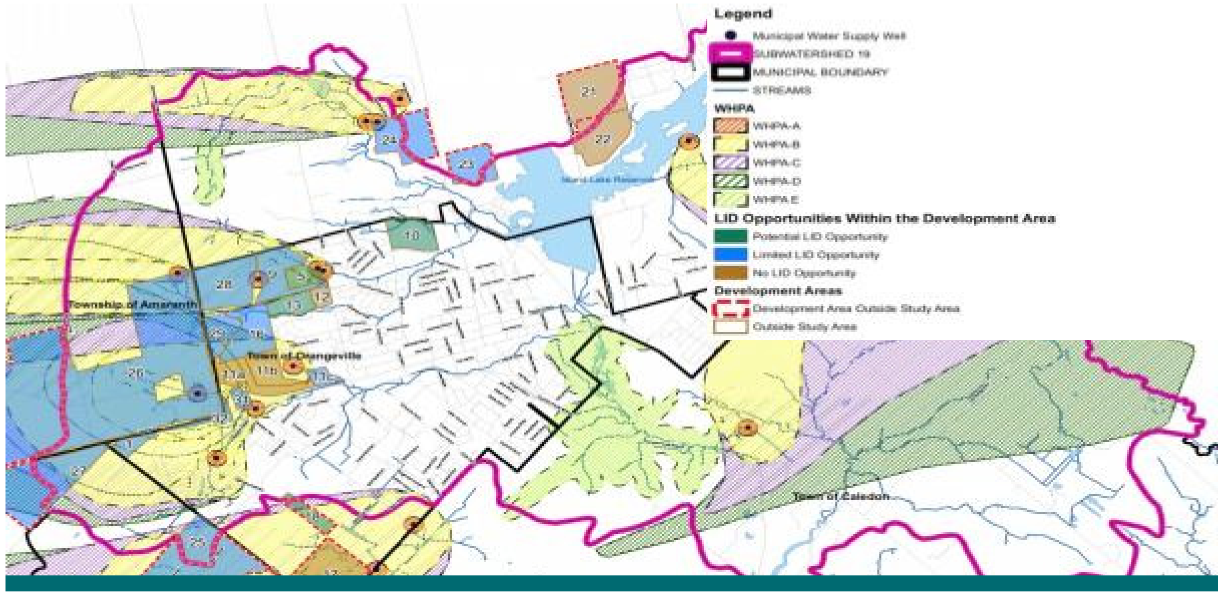



**Figure 10.1.1:** CVC's Headwaters Subwatershed Study Phase III – Implementation Plan shows areas where there are LID opportunities exists fpr LID along with wellhead protection areas, municipal boundaries, and the watershed boundary. (Source: CVC)

GIS-based mapping during the plan development will help identify implementation opportunities. This mapping can be overlaid with the spatial-based watershed mapping data described in Chapter 5 to identify where water management actions can be implemented, given environmental constraints and opportunities.

## Additional information

The implementation plan can also help the project team identify areas where it might require additional information before taking action. For example, the team may have identified a mandatory downspout disconnection program as an action to reduce inflow/infiltration issues, or to decrease stress on the stormwater collection system. Before the team implements this action, it must understand the requirements for enforcing it. The implementation plan is an opportunity to develop the additional information or data needs before implementing actions, and identify a timeline and plan to fill those gaps in knowledge.

## 10.2 Integrated water conservation plan

If a water sustainability plan includes municipal drinking water services in its scope, some of the actions within the implementation plan will pertain to water conservation. These are the actions that can alleviate pressures on water and wastewater systems to meet current and future demands of water users, by reducing demand for water, without necessarily needing to increase capacity through costly infrastructure upgrades or expansions. For example, the City of Guelph has set a goal to reduce municipal water consumption by 22.5 percent by 2025. The projected cost savings through the program implemented to meet this goal is estimated at $3 million per year. The program has already resulted in approximately $100 million of savings by deferring major infrastructure projects through efficiency activities.[33]

*Implementing your plan may require a marketing strategy to engage land owners, especially if your plan includes source controls on private land, including residential and business lands. CVC's Grey to Green guides provide more information on engaging residents and business owners to adopt low impact development practices on their properties.*

Water conservation and efficiency activities can also encourage energy savings. For example, the energy required to pump and treat water in the Region of Peel accounts for half of the region's total energy use. Water conservation means lower energy use, which contributes to lower greenhouse gas emissions and lower energy bills that help municipalities meet energy consumption targets.

Another way of looking at water conservation that is similar to the One Water approach is the "soft path" for water. This approach recognizes that water needs can be met either through the "hard path" (e.g. through centralized infrastructure to increase supply), or through the "soft path," which uses a series of methods including centralized and decentralized facilities, and innovative technology and economics to increase supply and reduce demand[34]. A handful of Ontario municipalities, including York Region and the Township of Centre Wellington, have used the soft path approach.

Water conservation can be particularly important in study areas where an increased water supply is a very costly, or completely infeasible, option. If a study area relies on groundwater for municipal water supply, municipal partners may be required to complete water conservation plans to conform to the local source water protection plan.

Several Ontario municipalities have already created water conservation plans and programs (also known as water efficiency plans). These municipalities include City of Guelph, City of Hamilton, City of Toronto, Region of Peel, City of Brantford, and Region of Waterloo. Here are some examples of the programs included in these plans:

- Watering restrictions and by-laws
- Educational programs on water-efficient plumbing and fixtures
- Rain barrel sales
- Rain garden workshops and education
- Leak detection systems
- Water audits
- Incentive programs for businesses

*York Region has created water conservation and protection programs that offer incentives for businesses to use less municipal water, and to prevent possible water quality impacts to drinking water sources, such as within wellhead protection areas. For more information about this water conservation program, visit york.ca.*

The Ontario Water Works Association (OWWA) has created a Water Efficiency Best Management Plan Manual,[35] which provides an overview of efficient water management and associated best practices. Here are some of the topics:

- Meters for all users
- Full-cost pricing
- Public information and education programs
- School programs
- Compile a water use database
- Water loss management
- Developing a water efficiency program/plan
- Implementing a utility/municipal water efficiency program
- Industrial/commercial/institutional water efficiency
- Indoor residential water conservation
- Landscape water efficiency program
- Reducing the flow in the wastewater system

OWWA has also published guidance on water efficiency through its Outdoor Water Use Reduction Manual (2008) and its Water Efficiency Guidebook for Small/Medium Sized Utilities (2006). In preparing a water conservation plan as part of a water sustainability plan, project teams can consult these resources for ideas and guidance.

## 10.3 Integrated asset management plan

Asset management plans are intended to provide the basis for making "the best decisions regarding the building, operating, maintaining, renewing, replacing and disposing of infrastructure assets."[36] If a study area already has an asset management plan, the project team could use it to characterize existing infrastructure conditions (Chapter 5). Once the project team has set new targets for the level of service for the assets (Chapter 6) and determined the preferred management strategy to meet that level of service (Chapter 9), the project team should revisit or create an asset management plan to ensure that the assets will continue to meet the required level of service through their service lives.

There are many guidance documents and tools that facilitate asset management practices for grey and green infrastructure. Here are three:

- MEDEI's Building Together
- MOECC SWM Planning and Design Manual
- STEP Assessment of Lifecycle Costs for Low Impact Development Stormwater Management Practices[37]

### Example: Region of Peel Water Efficiency Plan[38]

In 2004, the Region of Peel completed its Water Efficiency Plan, which provided a path forward for the Region to meet growing demands on its water supply and wastewater treatment system. Previously, the new infrastructure required to meet the growing population demand over the subsequent decade was estimated to cost about $112 million. However, implementing the Water Efficiency Plan was estimated to provide the same supply of water and wastewater services at a cost of approximately $33 million. The measures included in the plan were screened against four criteria:

- Technical feasibility
- Local applicability
- Social acceptability to residents
- Cost-effectiveness compared to infrastructure expansion

These five measures met all of the criteria:

- System leak detection
- Toilet replacement
- Clothes washer replacement
- Indoor water audits
- Outdoor water audits

*Additional information relating to asset management of green infrastructure is available in CVC's Grey to Green Retrofit Guides, which are available at bealeader.ca.*

In order to build integrated asset management into a water sustainability implementation plan, the project team will need data to fully characterize the risks to existing and future infrastructure and its performance. The integrated asset management plan will include information regarding advanced asset management for all relevant infrastructures at a watershed scale. This framework for implementing an asset management plan is based on five core issues:[39]

1. Current state of assets or condition assessment
2. Level of service
3. Minimum life-cycle cost
4. Risk assessment for critical assets
5. Long-term funding plan (financial plan)

Figure 10.3.1 illustrates the tools that project teams can use to integrate asset management practices.

The Province of Ontario requires that any municipality seeking provincial capital funding for an infrastructure project must provide a detailed asset management plan and indicate how the proposed project falls within that plan. The Building Together guide issued by MEDEI can help municipalities to develop asset management plans to support funding proposals.

## Condition assessment

One of the first steps of an asset management plan is assessing the condition of existing infrastructure. The condition assessment can be broken down into four stages, as shown in Figure 10.3.2. Some portions of the condition assessment may have already been completed earlier in the water sustainability plan. For instance, Phase 1, Step 4 includes reviewing available data regarding assets. Previously completed studies, such as risk assessments, or even out-of-date asset management plans, are good sources of information for the condition assessment.


**Figure 10.3.1:** There are several tools that can be used to integrate asset management practices. For more information on the stages of asset management planning and the tools to integrate, refer to Appendix D of this guide. (Source: Richard Harvey - "An introduction to asset management tools for municipal water, wastewater and stormwater systems).

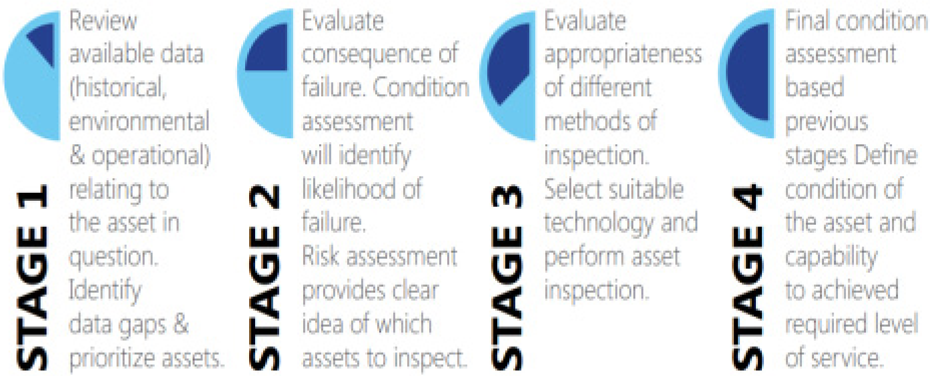



**Figure 10.3.2:** Four stages of a condition assessment. (Source: Sangster, 2010)

Since data for green infrastructure may not be collected widely within your study area, it may be more difficult to complete a condition assessment for these assets. As stated in Chapter 4, project teams will need to collaborate across departments and agencies to locate and/or determine this data. To ensure that future studies will have access to sufficient data for asset management planning, the implementation plan may include actions to coordinate monitoring and inspection activities. Figure 10.3.3 highlights an example of how this works in the City of Hamilton.


**Figure 10.3.3:** The City of Hamilton is a single-tier municipality that owns and operates all of its water, wastewater, and stormwater infrastructure. The City has demonstrated a commitment to inspection and condition assessment of its assets within a single management group. Its asset management plan outlines various practices, both formal and informal, that are used to assess conditions of all water infrastructures, including drinking water, wastewater, and stormwater assets. (Source: City of Hamilton)

*The Halton Hills case study in Appendix D provides an example of a lower-tier municipality that is taking steps to integrate stormwater within its asset management framework, while collaborating with the upper-tier regional municipality.*

## Example: Envision™ Tool

The Envision™ Sustainable Infrastructure Rating System is a tool that provides a framework for evaluating and rating the community, environmental, and economic benefits of all types and sizes of infrastructure projects.[40] This tool evaluates, grades, and gives recognition to infrastructure projects that use transformational, collaborative approaches to assess the sustainability indicators over the course of the project's life cycle. More information on the tool is provided in Appendix B.

## Level of service

The next step for the project team is to consider the level of service provided, or to be provided, by the water infrastructure assets and programs. As discussed in earlier chapters of this guide, level of service refers to a required performance expectation as defined by larger goals, be they municipal, regulatory, watershed, community-based, or a combination of factors.

It is important to note that infrastructure that is in "good condition," or designed to meet a high level of service, is not necessarily meeting it, particularly with respect to stormwater management. Figure 10.3.4 shows the results of a study of stormwater ponds by Lake Simcoe Region Conservation Authority, which found many ponds were not performing to their design level of solids removal.

The project team should consider the level of service for water, wastewater, and stormwater alongside the targets set earlier in the process. These level of service targets should be used to evaluate how well existing infrastructure assets perform relative to those targets, and should set the benchmark for future performance monitoring, which is discussed later in this chapter.

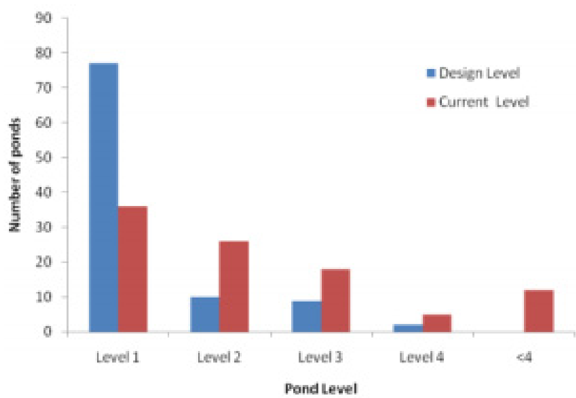



**Figure 10.3.4:** A study of stormwater ponds by the Lake Simcoe Region Conservation Authority indicated that many of the ponds were operating below their intended efficiency levels. The 98 ponds in the study ranged in age from 2 to 23 years old. (Source: LSRCA)

## Life-cycle cost

The next step in asset management planning is to consider life-cycle costs for existing and proposed water infrastructure assets. Life-cycle costing involves examining the various phases of an asset's service life, and the potential actions needed to achieve and maintain the desired level of service over the life of the asset, while at the same time managing risk. These are the different phases of an asset's service life:

- Concept
- Planning and design
- Purchase/construction
- Operation and maintenance
- Repair and renewal
- Decommissioning/disposal[41]

*When planning life-cycle costs and activities of your assets, it is a good strategy to coordinate multiple replacement or capital projects. For example, municipalities can replace underground water infrastructure (e.g., sewers and watermains) at the same time as it replaces a road. Coordination can result in significant cost savings and minimize impact on other services. (Towards Financially Sustainable Drinking-Water and Wastewater Systems, MOE, 2007)*

It is likely that the project team will have a strong understanding of the costs for early aspects of an asset's life cycle, such as design, purchase, and construction, as well as for replacement and decommission. It may be more difficult to obtain costs for operation, maintenance, and repair activities, particularly for stormwater infrastructure or green infrastructure.

Monitoring demonstration projects and collecting data on performance, operation, and maintenance costs will support these cost estimates. Other municipalities that have already implemented green infrastructure construction, and operation and maintenance programs for green infrastructure, can also be a good source for this information. For more information on developing a green infrastructure monitoring program, refer to CVC's LID Monitoring Guide at bealeader.com.

In the overall life span of a specific infrastructure asset, routine maintenance reduces the risk of catastrophic failure and financial burden. Figure 10.3.5 illustrates the benefits of regular maintenance versus full replacement. The life expectancy of water infrastructure requires regular maintenance and a schedule to manage replacements when assets reach the end of their useful life.

### Case Study: Town of Halton Hills

The Town of Halton Hills has developed a process where the full life-cycle cost of all infrastructures to be assumed by the Town through development – particularly stormwater infrastructure – needs to be calculated in advance. After this number has been calculated, the net present worth of the future replacement cost is computed assuming a useful service life of 50 years and a compound interest rate of 5%. More information is provided in the case study in Appendix D.

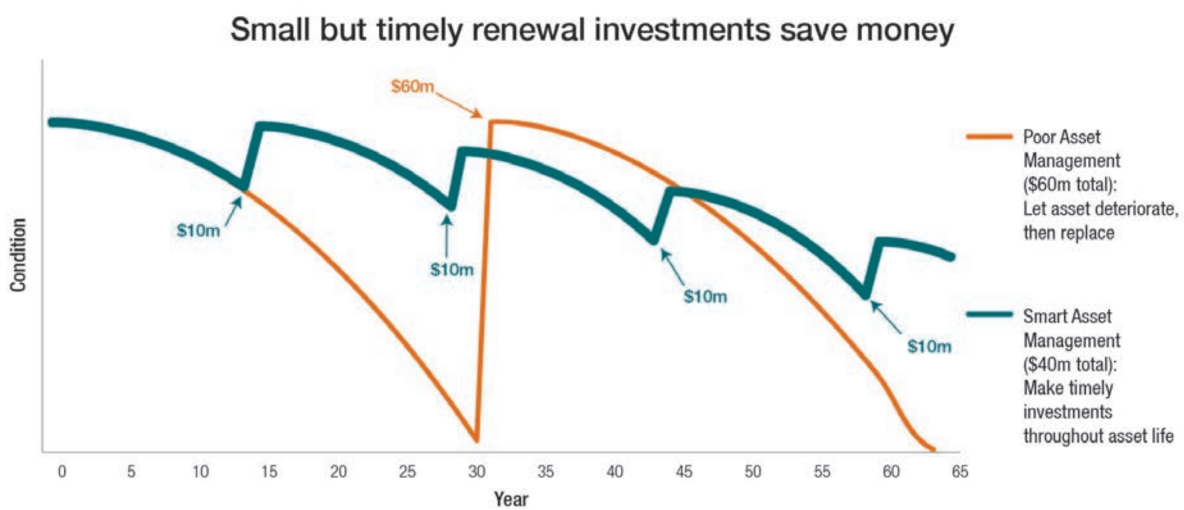



**Figure 10.3.5:** The benefits of regular maintenance, as opposed to the cost of full replacement of an asset. (Source: Building Together: Municipal Infrastructure Strategy, MEDEI, 2012)

## Infrastructure risk assessment

The next step of the asset management plan is to complete an integrated risk assessment for critical assets (if one has not already been completed). MEDEI's Building Together guide highlights that risk management is an important part of an asset management strategy. It involves evaluating the potential risks for an asset through comparative analysis, and scoring based on quantitative and qualitative measures. For a project team, a watershed approach is extremely helpful at this stage, since it helps to comprehensively identify risks to critical infrastructure.

## Financial plan

Building on the financial screening in Chapter 9, the project team must create an integrated financial plan and consider the long-term costs associated with future operation, maintenance, monitoring, and replacement of infrastructure assets.

This plan helps municipalities take steps toward developing a long-term capital budget to tackle future replacement needs, and an operating budget to deal with critical maintenance that will help ensure infrastructure achieves or exceeds the anticipated useful life and level of service. Such a plan can combine asset management data for all water infrastructure into one database to track and forecast when assets will reach the end of their service life and require replacement.

The life-cycle costing process described in this chapter can assist municipalities in building the costs for replacement or repair of infrastructure into their financial plan. The integrated financial plan should also include recommendations for the funding mechanisms needed to generate the funds to implement the water sustainability plan. Appendix C highlights financial tools that support a water sustainability plan.

### Elements of a financial plan

The financial plan will depend on the water services, project team, and solutions involved in the study. Figure 10.3.6 illustrates the typical elements of a financial plan for water infrastructure, with additional considerations that may not inform a typical financial plan, but should be included as part of the water sustainability plan, including risk assessment, and consideration of new technologies such as green infrastructure.

A number of the elements require knowledge of the life-cycle costs of infrastructure assets, such as capital and operating budgets. The time period used for the financial plan should be sufficient to incorporate these costs.

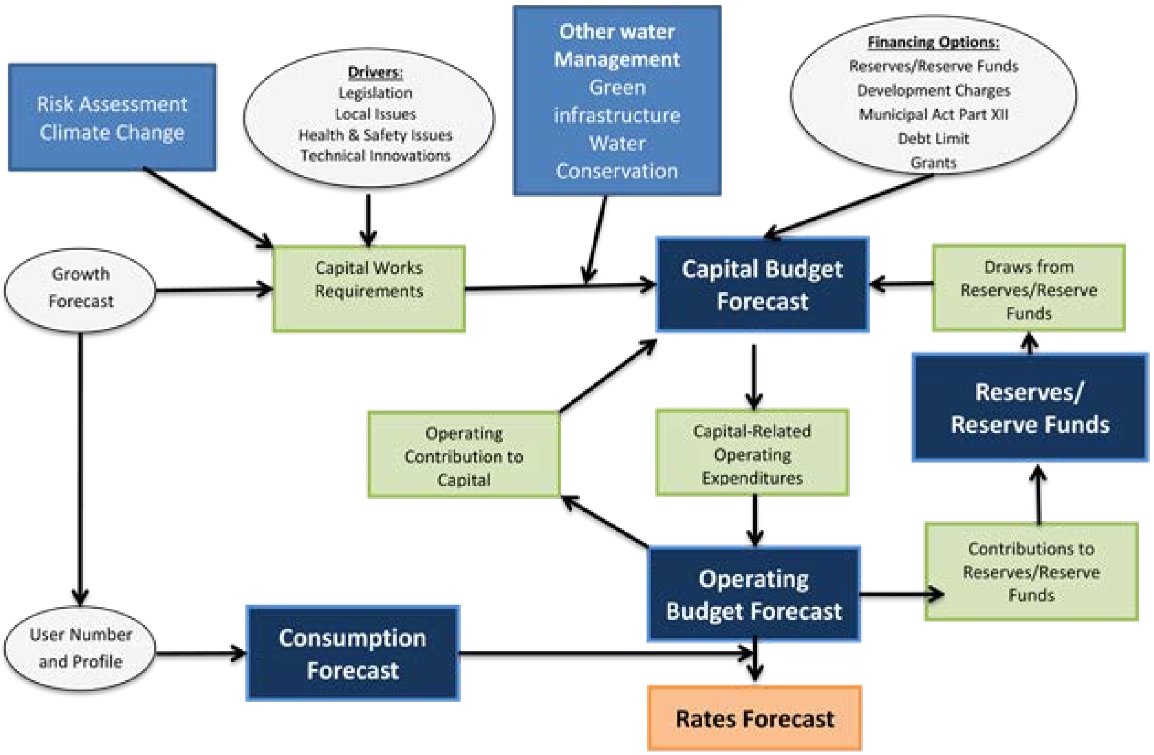



**Figure 10.3.6:** Typical components of a financial plan with additional considerations to enhance integration. (Source: Adapted from a chart provided by Gary Scanlan)

### Reserve funds

Reserve funds are an important element of a financial plan. The project team should explore the potential need for reserves based on the results of the risk assessment. Since risk is based on the likelihood of a negative event occurring and its severity, increasing reserve funds gives a municipality greater ability to respond when such events occur. For example, a changing climate may result in more varied and extreme seasons and weather events that are difficult to predict and can have drastically different impacts. These conditions would increase the risk to infrastructure, and therefore may result in larger reserve funds being held in order to respond accordingly.

### Financing options

Another element of a financial plan is the inclusion of alternative financing options to fund implementation. This can be particularly important for stormwater. Unlike water and wastewater, stormwater management is typically not funded through a dedicated rate. This is beginning to change, however, as a number of municipalities in Ontario, including Kitchener, Mississauga, and London, have embraced stormwater rates (also known as stormwater utilities) as a means of funding stormwater management programs.

## Example: LID Monitoring and Real Time Water Quality Monitoring at CVC

CVC has conducted performance monitoring of green infrastructure at a number of LID demonstration sites. Additionally, CVC carries out real-time monitoring for flow and water quality throughout the Credit River watershed, which could indicate performance of water management systems. Following the July 8, 2013 flooding event in Mississauga, performance monitoring results for LID sites during the storm led council to adopt resolution, and real-time monitoring data provided means of forensic analysis after the storm.

## Case Study: Halifax Water's Integrated Resource Plan

Halifax Water is a publicly owned utility owns and operates water, wastewater, and stormwater services to the residents of Halifax. Halifax Water developed an Integrated Resource Plan in order to define its overall program and resource needs for next thirty years. The Integrated Resource Plan (IRP) integrated the financial planning by focusing on these elements:

- Capital and additional O&M costs to meet the program and project requirements of the Recommended IRP for the 30-year planning period from 2013 to 2043.
- Development of an overall planning framework integrating the IRP into Halifax Water's business processes.
- Identification of institutional constraints required to implement the Recommended IRP.
- Recommendations for additions and refinements of Halifax Water's levels of service (LOS) to facilitate the measurement of program success.

The three main drivers for the IRP include growth, regulatory compliance, and asset renewal. The objectives under these drivers were based on the current Halifax Water LOS. This table provides some high-level statements of the benefits:

*Table ES-5 Overview Recommended IRP Implementation Benefits*

| Driver | Benefits |
|---|---|
| Regulatory Compliance | 1. Fully compliant wastewater system.<br>2. Continued fully compliant water system.<br>3. Enhanced environmental and public health through reduced overflows and WWTF loadings.<br>4. Continued high quality drinking water.<br>5. Fully meets LOS. |
| Asset Renewal | 1. Fully functional water, wastewater and stormwater systems meeting their LOS at an acceptable risk and reasonable cost.<br>2. Provides risk-based prioritized asset renewal expenditures for all infrastructure systems.<br>3. Balanced capital and O&M expenditures. |
| Growth | 1. Water, wastewater and stormwater systems meeting the servicing needs of planned growth.<br>2. Sustainable water, wastewater and stormwater systems.<br>3. Support for continued community vitality through growth and new opportunity.<br>4. Balanced system expansion needs with reduction in demand for services. |

Additional information on water conservation planning is provided in Appendix E.

Implementing a stormwater rate can be a challenge for municipalities, as residents often hold negative views of "another tax." One option to engage residents and develop support for a stormwater rate could be to use Participatory Budgeting for a portion of the collected stormwater rate, which allows residents to decide where those funds will be spent, and can potentially lead to greater understanding of needs and priorities with respect to stormwater.

Here are some other types of funding structures:

- Property taxes
- Utility rate
- Development charges
- Flat rate per property[42]

### Full Cost Recovery

Water and sewage services are typically funded in part through user rates, which have traditionally not accounted for the continued investment, maintenance, and operations costs associated with the services. Appropriate rates based on a full cost recovery model can cover the full costs of water services, including operating and maintenance costs, administration, capital investment, depreciation of assets, design, land acquisition, and source protection[43]. Rates incorporating the full costs of water and sewage services are important for the continued sustainability of those services, and should be considered as part of a water sustainability plan.

## 10.4 Performance monitoring

The implementation plan should specify monitoring measures to track the performance of the implemented actions over the long term. This data can also be used for asset management planning on new infrastructure components, as monitoring will indicate when maintenance activities are required, or when deterioration begins to occur. Monitoring data can also be used for forensic analysis after an event has occurred, and can demonstrate if infrastructure was performing as intended, should the question arise. Real-time water quality and quantity monitoring data can also be used to provide warning in the case of high water levels, or to shut down water intakes or close beaches if water quality becomes negatively impacted.

*Both taxpayers and the media are paying closer attention in recent years to municipal report cards produced by researchers and independent agencies, to determine how municipalities are using public funds. Performance monitoring can provide justification for how investments in water infrastructure are paying off through improved performance on measures such as watershed health, spending on capital projects, and response to emergencies relating to water.*

Performance monitoring determines whether the physical and non-physical actions taken as part of a water sustainability plan are achieving the desired result. It also provides an answer as to whether the targets are in fact being met to the extent that was assumed during the evaluation stage. Regular monitoring can also assist with contingency plans, which can be implemented when a particular indicator or target is exceeded.

The performance monitoring framework for a water sustainability plan should integrate monitoring of these key areas, some or all of which may already be monitored in the study area:

- Surface water (stream, lake) quality and quantity
- Groundwater quality and levels
- Fisheries and aquatic ecology
- Terrestrial ecology
- Stream morphology and erosion
- Low impact development/ green infrastructure

Earlier in the process, the project team collected information on the various programs underway in the study area, including monitoring programs. When developing a plan for performance monitoring, the project team should consult partners with existing monitoring programs to determine if these activities can be continued or expanded in scope and/or location.

Benchmarking allows stakeholders to analyze their own system performance against others and track the state of their system. One tool that municipalities can use to monitor their performance is the National Water and Wastewater Benchmarking Initiative, which was launched in 1997 and currently includes participation by 43 of Canada's municipalities. Collectively, these participating municipalities are home to 60% of the Canadian population.[44] The tool includes numerous performance measures for water, wastewater, and stormwater services, and a standardized utility management model established as a framework for performance measures (see Figure 10.4.1).

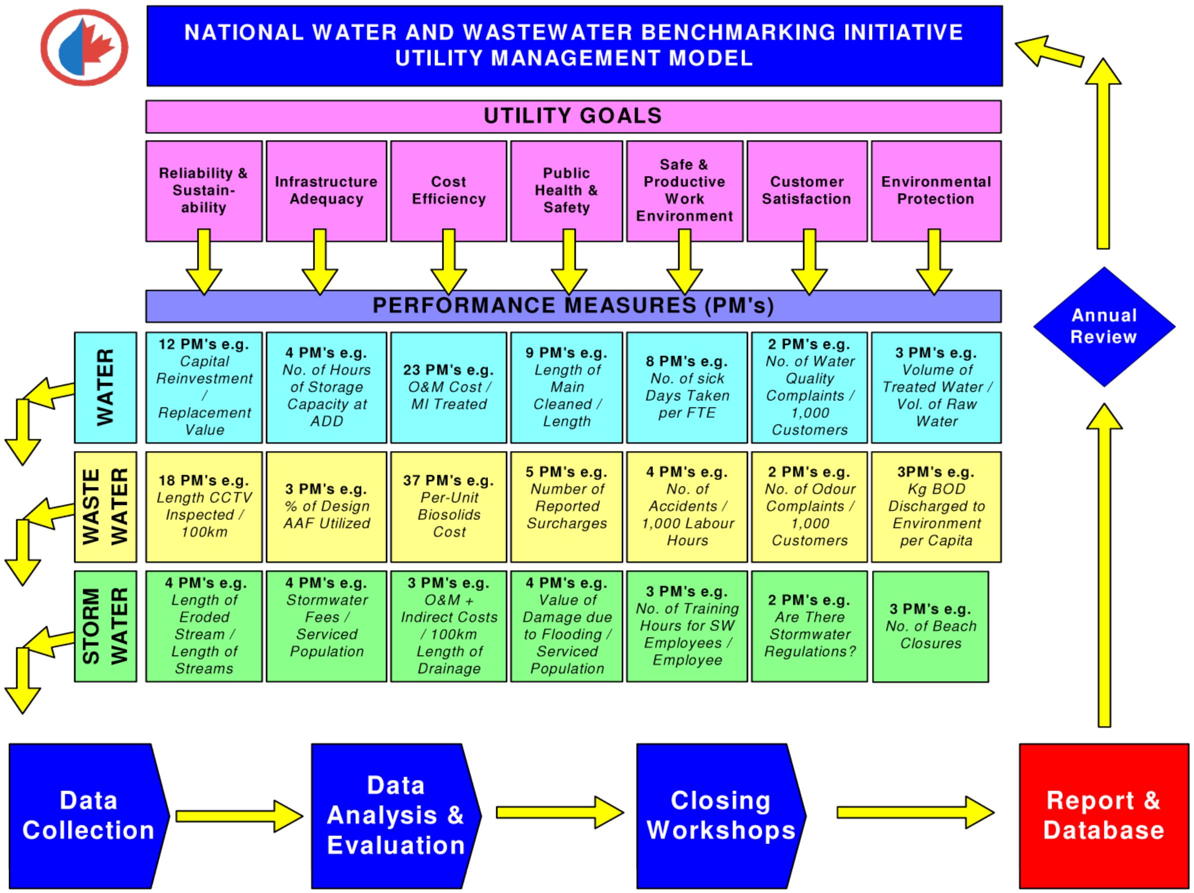



**Figure 10.4.1:** A standardized utility management model established as a framework for performance measures. (Source: Red Zone Robotics, Solo System, 2014)

Performance monitoring may also be conducted within the study area for some areas of water management. Environmental Compliance Approvals for stormwater and wastewater typically include provision for monitoring of water quality parameters and discharges to the environment, and annual reporting to the MOECC. In 2015, the MOECC required the City of Toronto to begin reporting sewage bypasses to the public. This could become a province-wide requirement in the future, further underscoring the importance of performance monitoring to meet reporting requirements.

Real-time monitoring can provide data on the watershed and water infrastructure systems. This data can be a very important tool in ensuring the optimum health of the watershed and performance of infrastructure. Real-time monitoring data can include water quality within streams (e.g., temperature, pH, dissolved oxygen, turbidity), as well as water level, flow data, and weather data. Stations send vital information in real time on current conditions which allows stakeholders to better understand, predict, and recognize risks and severities associated with water systems.

Real-time monitoring of infrastructure systems, including pumping stations and sewers, can provide crucial information to operators. For example, in areas prone to inflow and infiltration of stormwater into sanitary sewer systems, real-time rain data and real-time flow monitoring in sanitary sewers can provide operators at wastewater treatment plants of prior warning that additional capacity and/or treatment is needed for wet weather flows to avoid sewage bypass.

Alarm systems can be integrated into real-time monitoring systems and set to automatically trigger if readings fall outside of a permissible range. In watersheds that experience flashy flows, alarms could be used to alert the public of unsafe conditions as stream levels exceed a certain threshold. Collaboration with other organizations, including provincial and federal agencies, as well as conservation authorities, can make the programs more robust by not only sharing resources and information, but also potentially sharing the costs of maintaining the programs.

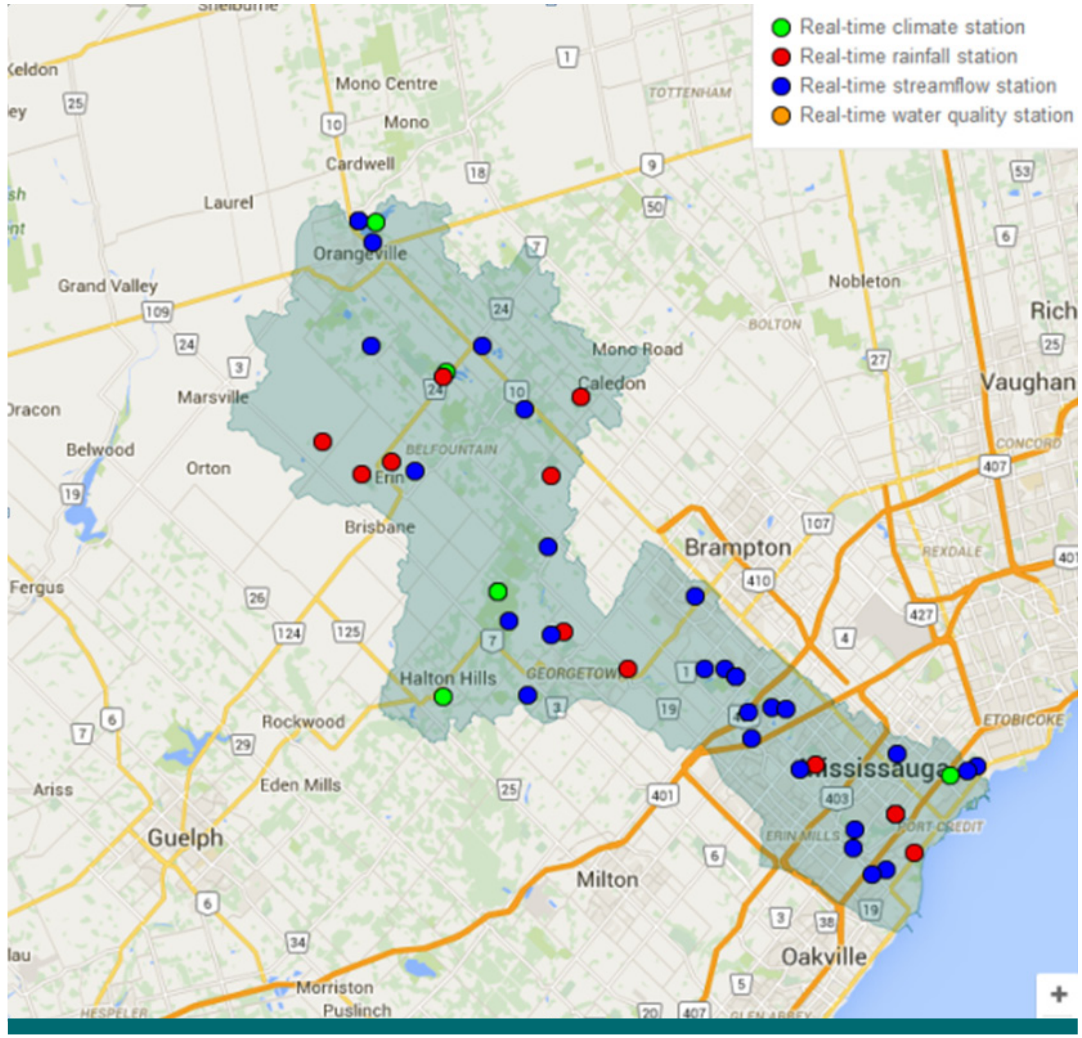



**Figure 10.4.2:** The real-time monitoring stations within the Credit River watershed include climate, rainfall, streamflow and water quality monitoring stations. (Source: CVC)

# 11.0 Next Steps

The preceding chapters have outlined the steps to integrate water, wastewater and stormwater services into a water sustainability planning process that takes into consideration the watersheds within which those services are located.

This document has identified the plans and programs that municipalities and conservation authorities are already implementing across Ontario, and discussed how project teams can integrate them into the water sustainability planning process, rather than duplicated or redoing the work. As described in the previous chapters, these plans and programs include master plans, watershed plans and studies, financial plans, asset management plans, and risk assessments.

The process of completing a water sustainability plan brings together water issues in a way that, generally, has not yet been achieved in Ontario. A water sustainability plan can identify current and future threats to water that municipalities may not have considered in the past, perhaps due to the fact that data and knowledge sharing at a watershed scale had not happened, or because the true impact of future changes on water, including climate change and urban development, were not fully understood.

A completed and fully integrated water sustainability plan would result in a streamlined planning and management plan for water services, as well as a comprehensive implementation plan including considerations for operations, maintenance, monitoring, and investment in water infrastructure.

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# Appendix A

## CLIMATE CHANGE VULNERABILITY ASSESSMENT

# Appendix A1

## VULNERABILITY AND ADAPTATION OF WATER INFRASTRUCTURE TO CLIMATE CHANGE


Photo of 2013 Calgary Flood Damage. Courtesy of City of Calgary

# Vulnerability and Adaptation of Water Infrastructure to Climate Change

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Paper prepared for the Canadian Water Network Project

## Water, A Risky Business

April 17, 2015
Revised January 15, 2016

# 1 CONTEXT

It is fundamentally clear that climate change represents a profound risk to the performance of engineered systems and to public safety in Canada and around the world. As such, engineers, asset managers and decision-makers must address climate change adaptation as part of their primary mandate – the protection of the public interest, which includes life, health, property, economic interest and the environment. Climate change results in significant modifications of statistical weather patterns and consequently can have impacts on design data. Physical infrastructure systems designed using this inadequate data (i.e., data that is less relevant because actual conditions have changed) are vulnerable to failure, compromising public and economic safety.

Engineering vulnerability and risk assessment form the bridge to ensure climate change is considered in engineering design, operations and maintenance of civil infrastructure. Identifying the components of the infrastructure within a system that are highly vulnerable to climate change impacts enables cost-effective engineering, operations and policy solutions to be developed.

This paper is not intended as an exhaustive literature review on the subject. The reader is directed to a recent report by Boyle et al. (2013) entitled *Climate Change Adaptation and Canadian Infrastructure - A review of the literature*. The authors found that “the adaptive capacity of various infrastructure is directly shaped by the extent to which policies, regulations and other market mechanisms support and incentivize actions that build climate resilience.” Furthermore, they state “though relatively nascent, these tools are beginning to shift from being reactionary in nature to having a stronger focus on ensuring the longer-term adaptive capacity of critical sectors.”

Boyle et al. (2013) identified four key levers of action:

1. Current Government Policy Responses and Related Tools. This includes a review of the status of enabling adaptation frameworks and funding at the federal level in Canada, as well as in the North, Atlantic Region, Quebec, Ontario, Prairies and B.C. Additional examples from outside of Canada are also provided given their potential relevance in the Canadian context.
2. Codes, Standards and Related Instruments (CSRIs). We consider the extent to which national building codes and other standards support climate resiliency. Also considered is the development of other important tools and resources, such as the Public Infrastructure Engineering Vulnerability Committee (PIEVC) Protocol and the Canadian Standards Council Northern Infrastructure Standardization Initiative, that support the integration of climate considerations into infrastructure planning.
3. Markets, Financial Incentives and Liability Rules. The private sector, and in particular the insurance (and reinsurance) industry, also has a key role to play. Here we identify the most recent thinking and potential tools available in this respect.
4. Industry Responses. Finally, we explore actions taken by key cement/concrete industry actors in shaping responses to sustainability challenges more broadly, and the linkages being made to adaptation and climate resilience specifically.

The PIEVC Protocol is one of the tools highlighted in this paper.

## 1.1 Objectives and Limitations

This paper intends to inform decision-makers and infrastructure practitioners about some of the tools that consider climate change impacts to infrastructure, from planning to operations and maintenance. It offers a brief review of selected methodologies that can be used to develop community adaptation plans, to assess the climate components in policy, and to evaluate the engineering vulnerability of infrastructure assets and systems. It focuses on processes and methods that have been used by public agencies and municipalities to identify and quantify risks, as well as to develop climate change adaptation solutions. It is not intended to provide an exhaustive list of all the methodologies that have been used or have been published on the subject.

The fact that a particular tool is presented in this article does not constitute an endorsement. If a tool has been omitted, it is because of space or scope limitations, and should not be construed as a rejection of the tool as beneficial.

The information and statements expressed in this article are those of the author and do not reflect the views, opinions or any official position of any organization.

## 1.2 Current and Future Climate

The changes in global climate have been, and continue to be well documented by a number of Canadian and international organizations such as the Intergovernmental Panel on Climate Change (IPCC) which produced its Fifth Assessment Report (AR5) in November 2014. In brief, the report tells policymakers what the scientific community knows about the scientific basis of climate change, its impacts and future risks, and options for adaptation and mitigation.

From an infrastructure's perspective, the story of climate change can be seen in the increasing number of occurrences of extreme weather events and their impacts. Table 1 presents the "billion dollar years" of payouts by Canadian insurers. Of note is the increased frequency of those devastating years, and the fact that 2013 was the first time ever insurance companies paid in excess of two billion dollars for losses.

Table 1. Billion-dollar payment years from Canadian insurance companies (Source: McGillivray, 2014)

| Year | Main event(s) causing losses |
|---|---|
| 1998 | Due solely to the Eastern Canada ice storm |
| 2005 | Greatly due to the August 19 Greater Toronto Area (GTA) rainstorm |
| 2009 | Mainly due to back-to-back windstorms in Alberta |
| 2010 | Due greatly to large hailstorm in Alberta |
| 2011 | Mainly because of the Slave Lake wildfire |
| 2012 | Caused mainly by one large and two smaller hailstorms in Alberta |
| 2013 | Due to the Southern Alberta flood and GTA flood. First time ever for two billion-dollar events |

It is therefore no coincidence that the Institute for Catastrophic Loss Reduction (ICLR) reported that:

> "Large insured losses from extreme weather appear to be 'the new normal' for the Canadian insurance industry, expecting that large-loss years will no longer be rarities." (Canadian Underwriter, November 2012).

### 1.3 Canada's Infrastructure Context

Public infrastructure systems are complex, often underground and therefore difficult to access and inspect. It is standard practice to differentiate between linear assets (pipes, roads, cables, etc.) and non-linear or discrete assets (pumps, plants, bridges, culverts, etc.) since each category presents different type of management challenges. However, providing services to the public requires all the components within a system to perform adequately since the robustness – and therefore the safety and quality of the service is dependent on its weakest link.

Infrastructure assets also have very long service lives – water or sewer pipes for example are commonly in use for 80 years, 100 years or longer – four generations or more. It is therefore critical that these assets be properly planned and managed.

Figures 1 to 3 show the condition distribution of core public infrastructure systems reported by the 2012 Canadian Infrastructure Report Card (CIRC). In general, the report card shows that underground systems (water, wastewater and storm water) are in good or better condition.

It is important to note that the data reported is about the physical condition of the infrastructure. Although the 2012 CIRC attempted to collect information on other performance indicators, particularly capacity, the data received was not sufficient to provide statistically relevant results.

In regards to the physical condition of stormwater systems, it should be noted that these are "young" relative to other core infrastructure such as roads or wastewater systems. Regulations regarding managing stormwater, particularly in new residential developments, are recent and therefore it is expected these infrastructures are in a better condition as shown by the data.

The data in Figures 1 to 3 are but snapshots of the condition of various infrastructure systems. The 2012 CIRC also found that asset management is, and will continue to be a critical activity to maintain and improve levels of service under the financial constraints municipal governments' experience. For example, the CIRC 2012 found that the majority of municipalities reported using some type of asset management system, whether computerized or/and paper based as follows:

| | |
|---|---|
| Drinking water | 90% of respondents |
| Wastewater systems | 68.8% of respondents |
| Storm water management | 50.5% of respondents |
| Roads | 85.6% of respondents |

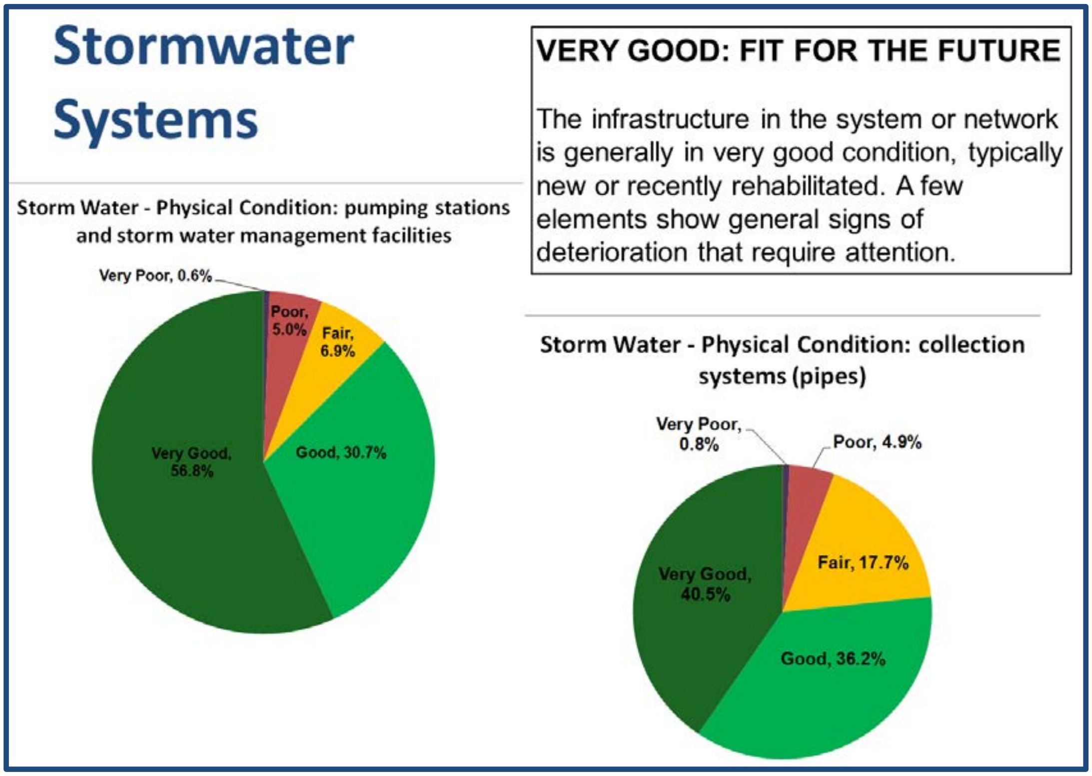



Figure 1. Canadian Infrastructure Report Card (2012) Results for Stormwater systems

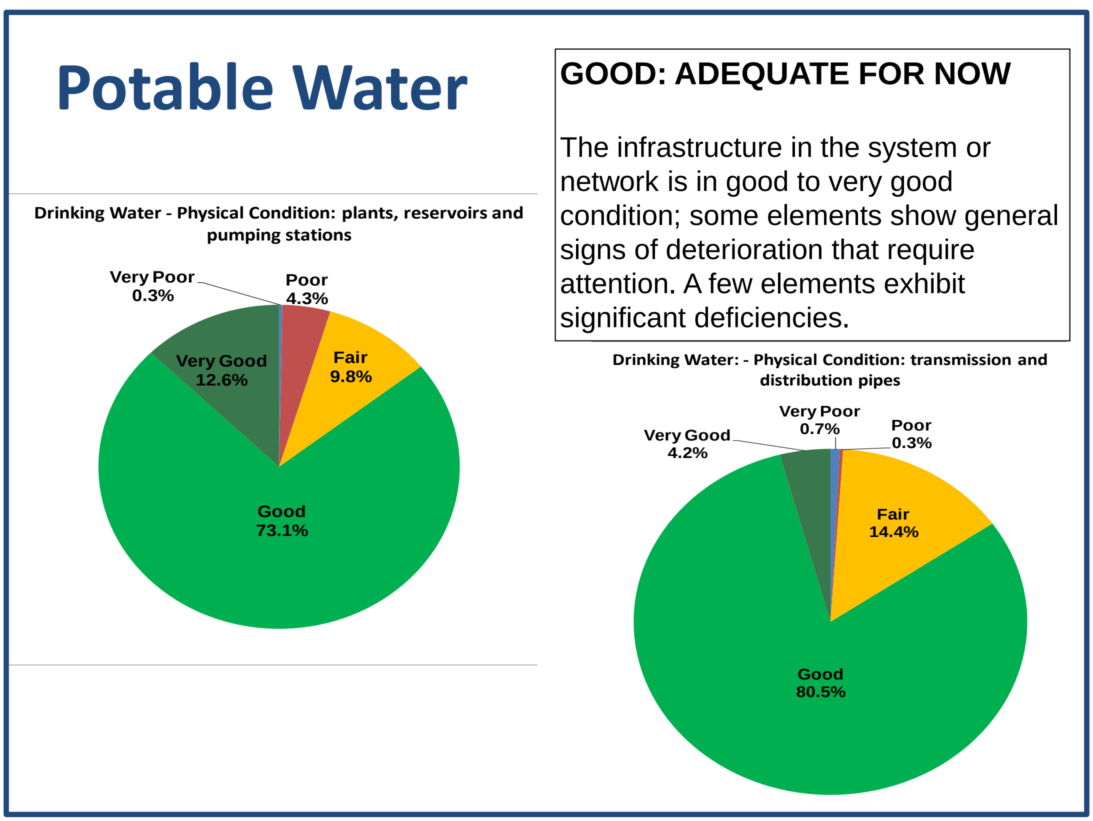



Figure 2. Canadian Infrastructure Report Card (2012) Results for Potable Water Systems

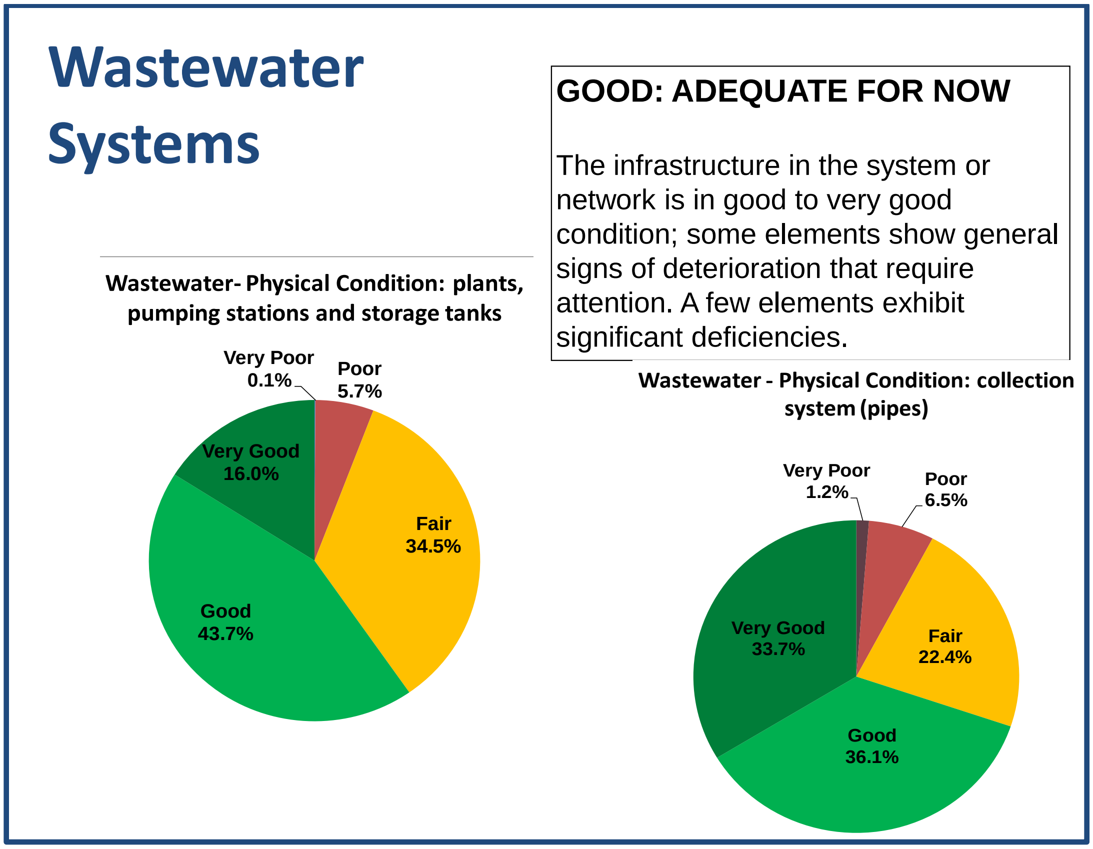



Figure 3. Canadian Infrastructure Report Card (2012) Results for Wastewater Systems

It is therefore interesting to note that one of the municipal infrastructure systems that can be significantly impacted by increased extreme precipitation events – stormwater management, had the lowest use of asset management in 2012. In addition, although the condition of SWM systems as reported by the CIRC 2012 municipalities was in the good/very good category, the results do not consider their capacity or lack of capacity. It is also important to note that Canadian jurisdictions have different approaches to storm water management, for example, some do not have floodplain management, others urbanized in the 1980's do not have flood control.

As a result, the report card partners issued an Asset Management Primer in September 2014. In the context of risk management, the Primer indicates:

> "Understanding and managing the risks associated with the failure of an asset is a key element in many AMPs (Asset Management Plans). The risks in municipal infrastructure are impacted by the physical condition of the asset and the social, economic and environmental consequences that would occur if the asset fails to provide the service for which it was designed."

### 1.4 Managing Infrastructure and Risks

Establishing the exposure and sensitivity of infrastructure to threats, whether from natural sources such as extreme climate events or earthquakes, or from man-made sources is an integral part of sound asset management. Figure 4 illustrates an asset management framework developed by the author and inspired by the InfraGuide best practice DMIP 7 – Managing

Infrastructure Assets (2007) and that is compatible with the intent of ISO 55000 – Asset Management. Providing the details of this framework is beyond the scope of this paper. There are however a number of steps in this framework that relate to and are influenced by current and future climatic conditions. For example, future loads on the infrastructure, whether from increased utilisation or changes in climate, may affect the physical condition, functionality or capacity of the infrastructure. This, combined with the infrastructure's current condition, can produce vulnerabilities and risks that require short term attention or that will need to be addressed in future capital or maintenance plans.

# 2 INFRASTRUCTURE SUSTAINABILITY, VULNERABILITY AND RESILIENCE: TOOLS AND PROCESSES

## 2.1 Definitions

In 1987, the Bruntland report from the World Commission on Environment and Development defined sustainability as "meeting the needs of the present generation without compromising the ability of future generations to meet their needs."

Sustainable Infrastructure

The US-EPA interprets this definition in the context of infrastructure as:

> "Sustainable (infrastructure) means having an active and effective program for renewal and replacement of components at a rate that allows for that infrastructure to continually serve our communities into the future. Achieving sustainability requires the establishment of a long-term plan to gradually and continually replace all infrastructure assets—a plan that ensures wise spending practices and a stable revenue stream for continuous support of needed future investments."

Infrastructure Vulnerability

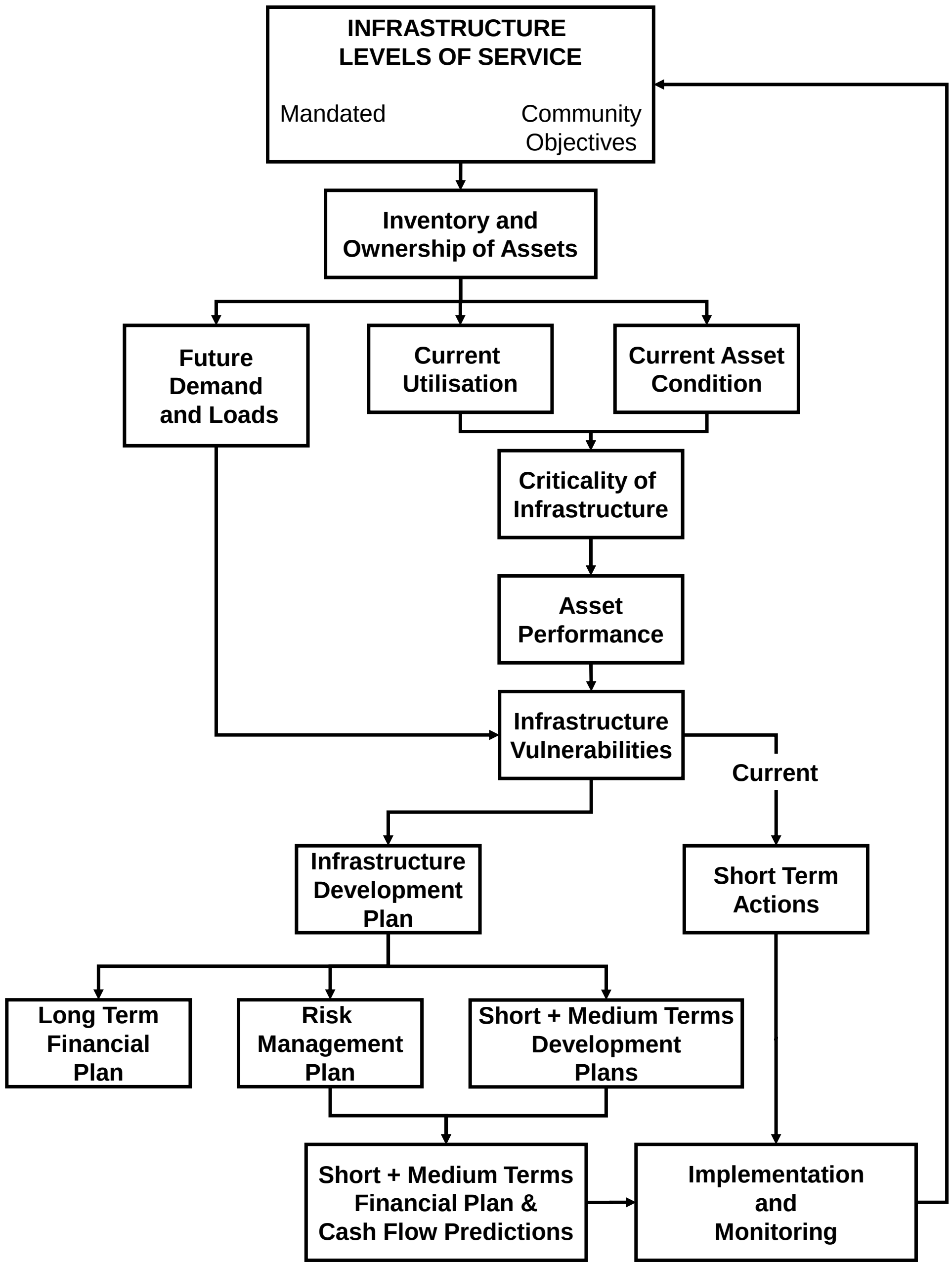
Engineers Canada's PIEVC Protocol defines the vulnerability of infrastructure as:

> "The degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity."

Vulnerability is a function of:

- Character, magnitude and rate of change in the climatic conditions to which infrastructure is predicted to be exposed;
- Sensitivities of infrastructure to the changes, in terms of positive or negative consequences of changes in applicable climatic conditions; and
- Built-in capacity of infrastructure to absorb any net negative consequences from the predicted changes in climatic conditions.

A vulnerability assessment will therefore require assessing all three elements above. Although this definition is given in the context of climate change, it is applicable to any hazard or threat the infrastructure may be exposed to.




**Notes:**
- Future Demand is based on community growth and vision.
- Asset performance measures structural performance, capacity and functionality, and relates to the mandated levels of service, community objectives and regulatory requirements including codes/standards.
- Risk is assessed with respect to health, safety, economic and environmental (e.g. climate change) impacts.
- Short term actions are to remedy any deficiencies for which short term risk is not acceptable.
- Long-term plans include: demand management, alternative service delivery, partnerships, etc.

Figure 4. Example of asset management framework incorporating risk management planning (Source: author)

Infrastructure Resilience

Resilience, on the other hand, is the capacity of the infrastructure to withstand and operate under hazards or threats. The UN International Strategy for Disaster Reduction defines resilience as:

> "The ability of a system, community or society exposed to hazards to resist, absorb, accommodate to and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions."

## 2.2 Sustainability Rating Tools

The International Federation of Consulting Engineers (FIDIC) produced a report in 2012 (summary available online at http://fidic.org/node/5943) on *Sustainable Infrastructure: Rating and Certification Tools* which summarizes an extensive international survey of these types of tools. The summary table is reproduced in Appendix A for convenience.

In general, sustainability rating tools include climate change risks to infrastructure and buildings as part the assessment. Some provide basic methodologies on how to assess risks associated with natural hazards, including those from extreme weather. In the Canadian infrastructure context, two rating tools seem to offer the greatest potential: Envision (from the USA but based on the UK CEEQUAL approach) and ISCA (from Australia) due, amongst others, to the support offered to the users, the extensive base of ratings conducted, and how comprehensive they are in terms of indicators.

Envision™ Sustainable Infrastructure Rating System

Envision™ is the product of a joint collaboration between the Zofnass Program for Sustainable Infrastructure at the Harvard University Graduate School of Design and the Institute for Sustainable Infrastructure. It provides a holistic framework for evaluating and rating the community, environmental, and economic benefits of all types and sizes of infrastructure projects. It evaluates, grades, and gives recognition to infrastructure projects that use transformational, collaborative approaches to assess the sustainability indicators over the course of the project's life cycle. Envision™ has assessment tools that can be used for infrastructure projects of all types, sizes, complexities, and locations.

1. Checklist:
    - An educational tool that helps users become familiar with the sustainability aspects of infrastructure project design. It can be used as a stand-alone assessment to quickly compare project alternatives or to prepare for a more detailed assessment.
    - Structured as a series of Yes/No questions based on the Envision™ rating system. It organized into five categories and fourteen subcategories.
2. Rating system:
    - Used by the project team to self-assess the project, or for an third-party, objective review.
    - Includes a guidance manual and scoring system.

At the time of writing this article, an economic optimization tool, construction and O+M phase credits, and other stages of the Envision™ rating system were under development.

Infrastructure Sustainability Council of Australia (ISCA)

The ISCA rating scheme was developed and is administered by the Infrastructure Sustainability Council of Australia (ISCA). It is a comprehensive rating scheme for evaluating sustainability across design, construction and operation of infrastructure.

The IS rating scheme can be used to inform and assess most types of infrastructure including:

| *Transport* | *Water* | *Energy* |
|---|---|---|
| Airports | Sewerage and Drainage | Electricity Trans. & Dist. |
| Bike paths and sidewalks | Storage and Supply | Gas Pipelines |
| Ports and Harbours | | |
| Railways | *Communication* | |
| Roads | Communication Networks | |

## 2.3 Community Assessment/Climate Change Adaptation Planning

In Canada, municipalities receiving federal Gas Tax funds are required to produce Integrated Community Sustainability Plans (ICSPs) or variations thereof. The level of details about infrastructure condition, needs and long-term plans varies across the country since the requirements were defined under each Federal – Province/Territory agreement. How climate change impacts have been considered in these plans is unknown but should be assessed.

### 2.3.1 ICLEI: Changing Climate, Changing Communities Framework

The International Council of Local Environment Initiatives (ICLEI) has developed a milestone framework, Changing Climate – Changing Communities, to guide local government practitioners through a process of initiation, research, planning, implementation and monitoring for climate adaptation planning. This five step process (Figure 5) is supported by an online interactive tool, the Building Adaptive and Resilient Communities (BARC) designed to assist communities in adapting to the impacts of climate change through the development of a Municipal Climate Change Adaptation Plan and is available through a subscription with ICLEI.

The process can be applied at various levels within a community or municipality:

- At the single sector or department level
- For a municipal operations plan covering all departments
- For a community wide plan with multi-stakeholder, community involvement
- Community driven for a vulnerable sector within a municipality (e.g., residents from a flooded area)

### 2.3.2 7 Steps to Assess Climate Change Vulnerability in Your Community Guide and Worksheets

The Atlantic Climate Adaptation Solutions Association has produced a guidance document and workbook called *7 Steps to Assess Climate Change Vulnerability in Your Community.*

1. Identify the types of climate and weather-related issues that have affected your community;
2. Locate where these issues have occurred or could occur in your community;
3. Assess what infrastructure has been or will be impacted;
4. Identify the residents who have been or will be most affected as well as those who can provide assistance in the community;
5. Assess which economic sectors have been or will be most impacted by the issues;

6. Identify how the natural environment has been or will be affected; and
7. Determine the best ways to address the issues identified.

The workbook produced for Newfoundland for example, includes climate (current, future predictions) information as well as expected trends and impacts from, for example, precipitation (intensity, frequency), temperature (average, extremes) and sea-level rise.

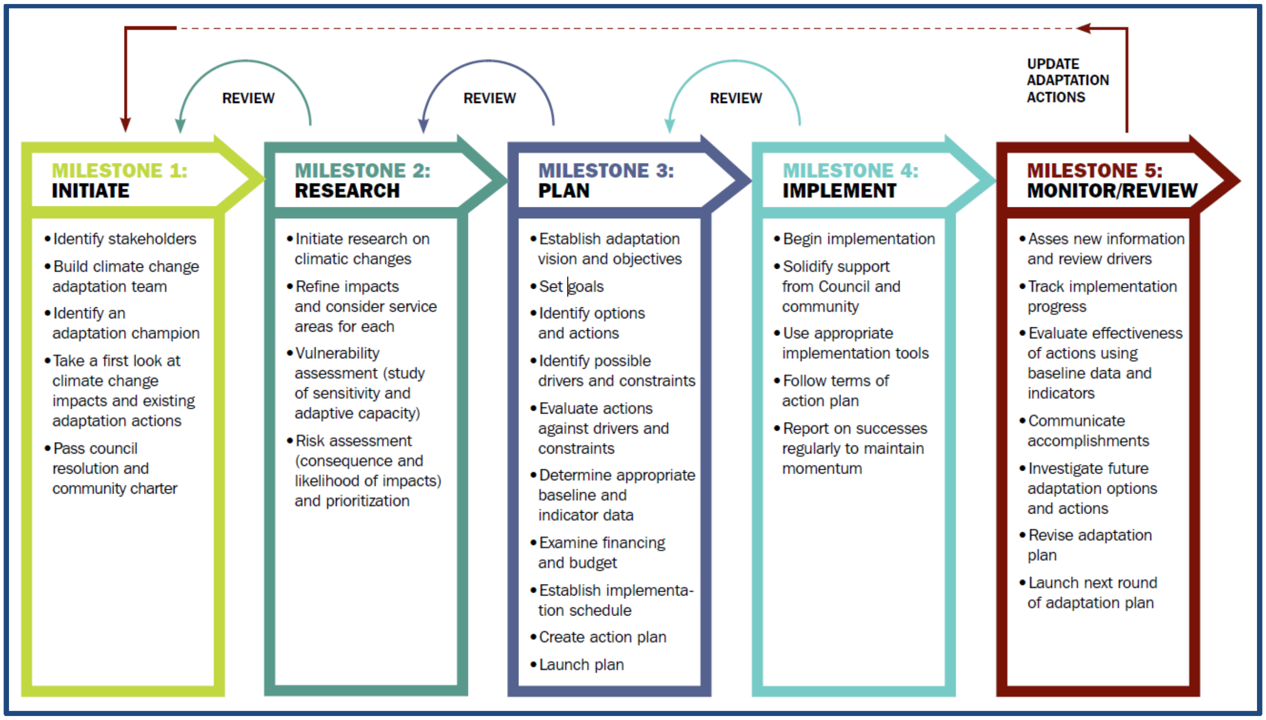



Figure 5. ICLEI's five-step milestone framework (Source: ICLEI).

## 2.4 Review of Tools for Assessing the Vulnerability of Watersheds

In a report to the Canadian Council of Ministers of the Environment (CCME) Nelitz et al. (2013) provide examples of when vulnerability assessments have been used, which include:

- Providing insight into the actions needed to prevent loss of life, damages, or disasters.
- Understanding vulnerability as a prerequisite for developing adaptation policies that promote equitable and sustainable development.
- Anticipating where impacts may be greatest at a Canada-wide scale, setting priorities for regional assessment of climate change impacts and adaptation strategies, and monitoring climate change effects.
- Understanding the economic costs to communities and infrastructure due to extreme weather events (for example the costs from extreme weather events in Canada from 1996-2006 were greater than for all previous years on record combined).
- Developing policies and adaptation plans for vulnerable areas, sectors, groups, etc. as well as reducing climate change risk.

The authors use the standard definition of risk in describing the vulnerability of watersheds, which comprises, as illustrated in Figure 6

- Potential impact: exposure (to the hazard) and sensitity (of the element to the hazard)
- Adaptive capacity

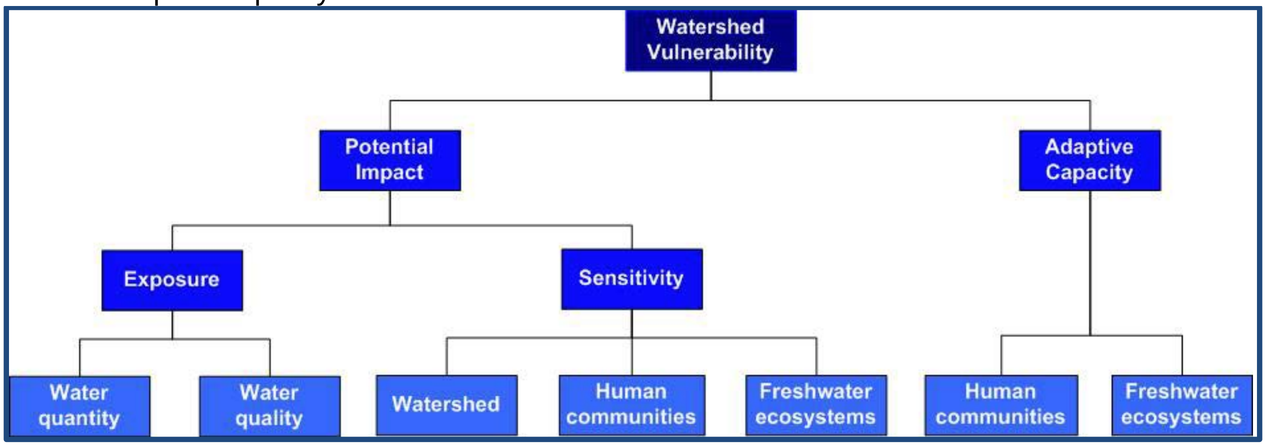



Figure 6. Elements of Watershed Vulnerability Assessments (After Nelitz et al., 2013)

The authors indicate the location and timing of a vulnerability assessment will be affected by the availability of sufficient expertise, time, and financial resources. Furthermore, they found that indicators are used in some form in most vulnerability assessments.

Throughout the literature, indices and indicators are often synonymously called themes, components, or sub-indices (index) and proxies (indicators). In their review, Nelitz et al. (2013) define an indicator is defined as single measure of a characteristic (e.g., water temperature), the units of which can be described by a particular metric (e.g., annual maximum temperature). An index is defined as a composite, or aggregate, measure of several indicators or indices. These terms are used even though they may not be consistent with the language of the original studies. They provide key considerations when identifying and selecting indicators, which include:

- Appropriateness and relevance to dimension of interest;
- Transparency (not too complicated, should be repeatable);
- Feasibility (considering cost of data collection and time availability); and
- Size and composition of each indicator (absolute vs. relative values, areal measure, etc.).

The tools in the report were selected to be representative of a broad range of water resource issues, data needs, and technical capabilities. They are varied and diverse and range from indicator-based approaches to sophisticated hydrological models that calculate exposure to flood events under future projections of climate change. They also range from qualitative to quantitative approaches that address a broad range of characteristics of social-ecological systems.

Table 2. Overview of tools for assessing vulnerability of watersheds (After Nelitz et. al, 2013)

| Dimensions | Components | Tool groupings | Tool sub-groupings / examples |
|---|---|---|---|
| Exposure | Water Quantity / Water Quality | Lumped models | • Canadian Water Evaluation Tool<br>• ForHyM & ForWaDy Hydrologic Evaluation of Landfill Performance<br>• Thornthwaite Monthly Water Balance Model<br>• Water Resources Evaluation of Non-Point<br>• Silvicultural Sources (WinWrnsHyd & ECAAlberta) |
| | | Semi-distributed models | • Hydrological Simulation Program-<br>• FORTRAN Model<br>• Water Evaluation and Planning System |
| | | Fully-distributed models | • MIKE SHE<br>• Variable Infiltration Capacity Model |
| | | Indicators, indices, and statistical models | • Precipitation minus potential evapotranspiration (P-PET)<br>• Isaak et al. 2010<br>• Swansburg et al. 2004<br>• |
| Sensitivity | Watersheds | Indicators of watershed condition or function | • Upslope<br>• Riparian-floodplain<br>• Inchannel |
| | | Biological indicators | • Macro-<br>• invertebrates<br>• Fish |
| | | Coupled or integrated watershed models | • Many possible examples |
| | Human Communities | Social vulnerability analysis | • Many possible examples |
| | | Engineering vulnerability assessment | • Engineers Canada's Public Infrastructure Engineering Vulnerability Committee (PIEVC) Protocol |
| | | Risk assessment | • Many possible examples |

Table 2. Overview of tools for assessing vulnerability of watersheds (After Nelitz et. al, 2013) Continued

| Dimensions | Components | Tool groupings | Tool sub-groupings / examples |
|---|---|---|---|
| Sensitivity | Freshwater Ecosystems | Bioclimate envelope models | • Many possible examples |
| | | Species or life history susceptibility | • NatureServe Climate Change Vulnerability Index<br>• System for Assessing Vulnerability of Species |
| | | Habitat or species models | • Conceptual models<br>• Indicator-threshold approaches<br>− Water temperature guidelines<br>− Flow standards<br>• Dynamic systems models |
| Adaptive Capacity | Human Communities | Determinants of adaptive capacity | • Economic resources<br>• Technology<br>• Information, skills, and management<br>• Infrastructure<br>• Equity<br>• Institutions and networks |
| | | Assets of adaptive capacity | • Human<br>• Social<br>• Natural<br>• Physical<br>• Financial |
| | Freshwater Ecosystems | Indicators of ecosystem resilience | • Genetic diversity<br>• Integrity of landscape mosaics<br>• Biological diversity |

## 2.5 Residential Basement Flood Vulnerability Assessment Tool - MRAT

In 2013, the Insurance Bureau of Canada (IBC) launched its Municipal Risk Assessment Tool (MRAT) through pilot applications in three cities: Fredericton (NB), Hamilton (ON) and Coquitlam (BC).

MRAT focuses on basement flooding risks, and more particularly on mapping vulnerable areas to flooding within a city. The tool uses data from municipal infrastructure (inventory and condition), land use, current and predicted future climate, and insurance claims. The risk formula considers the probability of climate events occurring (in this case precipitation and resulting floods), the exposure (infrastructure interacting with the particular climate event) and the vulnerability which establishes the susceptibility of the infrastructure to the climate event. Figure 6 illustrates the results expected from the application of MRAT to a municipality.

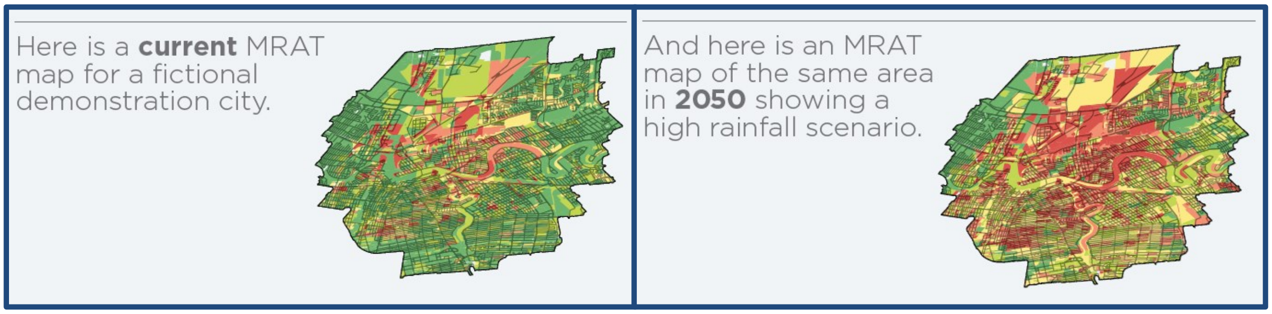



Figure 7. Illustration of MRAT basement flooding risk maps (Source: IBC)

### 2.6 Engineers Canada – PIEVC Infrastructure Engineering Vulnerability Assessment

Engineers Canada, with support from Natural Resources Canada (NRCan) created the Public Infrastructure Engineering Vulnerability Committee (PIEVC) in 2005 to address engineering concerns with infrastructure risks to climate change impacts. By 2008, the PIEVC had created a tool, the Protocol, to guide engineers working with other professionals in assessing the vulnerability of infrastructure and develop adaptation solutions. An engineering tool, the Protocol helps assess vulnerabilities in several related areas such as planning, operations and maintenance of the infrastructure.

Initially targeted to water resources infrastructure (potable water, wastewater and storm water), roads, bridges, and buildings, the PIEVC Protocol has since its inception been used for a wider spectrum of infrastructure, including dams, coastal structures, airports and electricity transmission grids. In fact, as of November 2014, the Protocol has been or is being used for more than 40 risk evaluations in Canada as shown in Figure 8, and two have been completed abroad. There are no known limitations to the type of infrastructure the Protocol can be applied to. It has been used both by small (e.g., District of Shelburne, NS – population about 3,000) and large (Toronto, ON) municipalities across Canada.

The Protocol is a five-step process that systematically reviews historical climate information and projects the nature, severity and probability of future climate changes and events. It also establishes the adaptive capacity of an individual infrastructure as determined by its design, operation and maintenance. It includes an estimate of the severity of climate impacts on the components of the infrastructure (i.e. deterioration, damage or destruction) to enable the identification of higher risk components and the nature of the threat from the climate change impact. This information can be used to make informed engineering judgments on what components require adaptation as well as how to adapt them e.g. design adjustments, changes to operational or maintenance procedures.

The Protocol provides a screening level profile of high, medium and low risks of climate to infrastructure. It does not require comprehensive and complete data to complete an assessment. Gaps are addressed by professional judgment and experience of the inter-disciplinary team of professionals needed to define the nature and consequence of climate impacts that damage or destroy infrastructure or impede its service to the community it serves. Experience has shown that screening level risk assessment of infrastructure climate risks produces cost-effective and timely evidence at an affordable cost to large and small communities. Recommendations to address the highest risks to improve climate resilience range from collecting more data or more targeted and quantitative engineering analysis to adjustments in operations and maintenance policies and procedures to design improvements that require additional cost information.


Figure 8. Locations and Type of Protocol Vulnerability Assessments Completed or in Progress as of February 2013

Appendix B lists a number of completed and ongoing PIEVC Protocol application projects in the areas of transportation and stormwater/wastewater systems of interest to the transportation industry.

Engineers Canada has also completed the initial development and testing of a Triple Bottom Line Decision Support Module. This tool evaluates adaptation recommendations from the Protocol using a multi-factor analysis that includes social, environment and economic factors. Engineers Canada offers this additional tool as a complement to the Protocol.

The Appendices provide summaries of five applications of vulnerability assessments to various types of water infrastructure using the PIEVC Protocol (full reports at www.PIEVC.ca ), namely:

- Appendix C: Metro Vancouver (BC) Vancouver sewerage area infrastructure (2008)
- Appendix D: City of Calgary (AB) potable water supply (2011)
- Appendix E: District of Shelburne (NS) vulnerability of Sandy Point STP upgrade (2011)
- Appendix F: City of Welland (ON) stormwater and wastewater infrastructure (2012)
- Appendix G: City of Nelson (BC) stormwater infrastructure (2014)

Appendix B presents a table of the 25 Water and Related Infrastructure Climate Vulnerability Assessments Completed and In Progress as of January 2015 (source: www.PIEVC.ca)

## 3 CONCLUSIONS

While all the tools reviewed here provide valuable information for engineers, asset managers and decision-makers, the PIEVC Protocol has the engineering depth and breadth of application to help communities large and small adapt to a changing climate. The methodologies developed for risk assessments and climate change adaptation planning in the United States, Europe and Australia are all valuable, but may not be as affordable and timely as the PIEVC Protocol in engaging engineers who must work closely with other professionals to support the planning, operation, maintenance, management and use the infrastructure to benefit society. The results inform decision-makers to a level that is adequate to develop cost-effective recommendations that adapt the highest risk components to improve their resilience to climate impacts in ways other assessment tools may not.

The table below provides a summary of the tools reviewed for this paper and, in the opinion of the author, the best fit to address climate change considerations for water infrastructure.

| **Description – Climate Change impacts on Infrastructure Considerations** | **Product Type** | **Community Sustainability Planning** | **Infrastructure Vulnerability Assessment** | **Risk Management** | **Asset Management** | **Type of Infrastructure Considered** | **Infrastructure Sustainability Rating** |
|---|---|---|---|---|---|---|---|
| Atlantic Climate Adaptation | Guide | ☑ | Limited | Limited | | All | |
| ICLEI | Guide + Tool | ☑ | Limited | Limited | | All | |
| MRAT | Tool | | ☑ | ☑ | | Storm Water | |
| PIEVC | Tool | Limited | ☑ | ☑ | ☑ | All | |
| | | | | | | | |
| Envision (US) | Tool | | Limited | Limited | | All | ☑ |
| ISCA (AU) | Tool | | Limited | Limited | | All | ☑ |
| | | | | | | | |
| ISO 31000 | Standard | | ☑ | ☑ | | All | |
| ISO 55000 | Standard | | | | ☑ | All | |
| | | | | | | | |
| US EPA VSAT | Tool | | ☑ | ☑ | | Water + Wastewater | |

There are other tools and methodologies that have been developed in other countries or for other types of infrastructure. For example, several US Federal agencies including the Federal Highway Administration or the Environmental Protection Agency have created methodologies for detailed quantitative risk assessments and comprehensive climate change adaptation planning for very large capital-intensive projects. There also exist similar tools developed in Europe and Australia that require quantitative data.

It is also important to note that most, if not all methodologies, including those presented here, fit the general ISO 31000 Risk Management principles and framework. In the medium to long-term, compliance of all these methodologies with ISO 31000 would be a desirable outcome.

## 4 ACKNOWLEDGEMENTS

In addition to the support provided by Engineers Canada and its staff in preparing this paper, the author wishes to acknowledge the Canadian Water Network project *Water: A Risky Business* and the Credit Valley Conservation Authority for their help in the research and background material used in preparing this paper.

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## Appendix A - FIDIC Summary of Sustainable Infrastructure Rating Tools (2012)

From the International Federation of Consulting Engineers (FIDIC) 2012 report (summary available online at http://fidic.org/node/5943) on *Sustainable Infrastructure: Rating and Certification Tools*

## RATING & CERTIFICATION TOOLS

**Key for Rating & Certification tool summaries**

- Y Applicable sector
- Y Existing award type
- P Provisional or interim award
- D Award under development

| Tool | Countries | Applicable sectors | | | | | Award types | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | General civil infrastructure | Transport or hydro only | Buildings | Public Realm | Community / precinct | Design | As built | Operation* | Planning | Other |
| BCA Green Mark | Singapore | Y | | Y | Y | Y | | Y | Y | | |
| BEAM | Hong Kong | | | Y | | | P | Y | Y | | |
| BERDE | Philippines | | | Y | | | P | Y | Y | | |
| BREEAM** | UK developed. Used throughout Europe + other international applications. | | | Y | | Y | Y | Y | Y | Y | |
| CalGreen | California state only, USA | | | Y | | | Y | | | | |
| CASBEE | Japan | | | Y | | Y | Y | Y | Y | D | Y |
| CEEQUAL | UK & Ireland version, Hong Kong version, internationally applicable | Y | | | Y | | Y | Y | Y | | Y |
| China Ministry of Construction Green Building System** | China | | | Y | | | | Y | Y | | |

| Tool | Countries | Applicable sectors | | | | | Award types | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | General civil infrastructure | Transport or hydro only | Buildings | Public Realm | Community / precinct | Design | As built | Operation * | Planning | Other |
| DGNB - the German Sustainable Building Certificate | Germany & International | | | Y | | Y | P | Y | Y | | |
| Envision | United States | Y | | | Y | | Y | D | D | | |
| Estidama & the Pearl Rating System | Abu Dhabi | | | Y | | Y | P | Y | D | Y | |
| Green Building Index | Malaysia | | | Y | | Y | P | Y | Y | Y | |
| Green Globes | Canada and USA | | | Y | | | D | Y | Y | | |
| Green Star (Au) | Australia | | | Y | | Y | Y | Y | | D | |
| Green Star (NZ) | New Zealand | | | Y | | | Y | Y | Y | | |
| Green Star (SA) | South Africa | | | Y | | | Y | Y | D | | |
| GreenLITES | New York State, US | | Y | | | | Y | | Y | D | |
| Greenroads | USA - piloting internationally | | Y | | | | | Y | | | |
| Greenship | Indonesia | | | Y | | | P | Y | Y | | |
| GRIHA | India | | | Y | | Y | | P | Y | | |
| HQE Amenagement*** | France | | | Y | | Y | | P | Y | Y | |
| Hydropower Sustainability Assessment Protocol | Globally applicable | | Y | | | | not applicable | | | | |
| Infrastructure Sustainability | Australia | Y | | | | | Y | Y | D | | |
| INVEST | USA | | Y | | | | P | P | Y | Y | |

| Tool | Countries | Applicable sectors | | | | | Award types | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | General civil infrastructure | Transport or hydro only | Buildings | Public Realm | Community / precinct | Design | As built | Operation * | Planning | Other |
| | | | | | | | | | | | |
| [LEED](#) | Developed in the US, now international | | | Y | | Y | | Y | Y | | Y* |
| [NABERS](#) | Australia, expanding to New Zealand | | | Y | | | | | Y | | |
| [NatHERS](#) | Australia | | | Y | | | not applicable | | | | |
| [SBTool](#) | Europe | | | Y | | D | not applicable | | | | |
| [STAR Community Rating System](#) | USA (primary base) and Canada | | | | | Y | | | | | Y |
| [STARS](#) | USA | | Y | | | | Y | | | Y | |

* Note: The term "operation" is used here in reference to awards that are typically for "existing buildings". An existing building award is for the building, but the assessment is based on aspects of its operation (rather than elements of its construction).

** Summary not reviewed

*** No summary currently available (2012) for this tool

# Appendix B - Water Related PIEVC Case Studies

| Host/Partner | Infrastructure Category | Title of Report |
|---|---|---|
| City of Portage la Prairie, MB | Water Resources – Potable water system | City of Portage la Prairie Water Resources Assessment - Phase II Pilot Study (November 2007) |
| Metro Vancouver, BC | Stormwater/ Wastewater | Vulnerability of Vancouver Sewerage Area Infrastructure to Climate Change (March 2008) |
| Government of Newfoundland and Labrador – Department of Environment and Conservation, Placentia, NL | Water Resources – coastal structures | Case Study – Placentia Coastal Infrastructure (March 2008) |
| Metro Vancouver Sewerage and Drainage Division, Vancouver, BC | Stormwater/ Wastewater | Vulnerability of Fraser Sewerage Area Infrastructure to Climate Change (December 2009) |
| Toronto and Region Conservation Authority Toronto, ON | Water resources - dams | Vulnerability of Claireville and G. Ross Water Control Dams (June 2010) |
| City of Castlegar, BC | Stormwater | Vulnerability of Stormwater Treatment System (October 2010) |
| City of Calgary Water Calgary, AB | Water resources | Vulnerability of Calgary's Potable Water Collection, Treatment and Distribution System (May 2011) |
| Town of Prescott, ON | Stormwater/ Wastewater | Vulnerability of Sanitary Sewer System – Separated Town of Prescott (June 2011) |
| District of Shelburne, NS | Stormwater/ Wastewater | Vulnerability of Shelburne Sewage Treatment Plant (STP) Upgrade (August 2011) |
| City of Laval, QC | Stormwater/ Wastewater | Storm water collection system evaluation in the city of Laval – Belgrand overflow structure (September 2011) |
| City of Toronto Department of Transportation Toronto, ON | Roads and associated structures | Assessment of three road culverts (December 2011) |
| Town of Welland, ON | Stormwater and Water Resources | Assessment of Town of Welland's Stormwater and Wastewater Systems (February 2012) |
| City of Trois Rivieres, QC | Stormwater/ Wastewater | Assessment of Stormwater/Wastewater Network (March 2012) |

| Host/Partner | Infrastructure Category | Title of Report |
|---|---|---|
| Toronto Hydro Electrical System Limited, Toronto, ON | Electrical distribution | Assessment of Toronto Hydro Electrical Distribution System – A Pilot Study (September 2012) |
| City of Trois Rivieres, QC | Potable water supply | Study of the potable water supply, treatment and distribution for the City of Trois Rivieres (April 2013) |
| Leamington/Essex County, ON | Potable water supply | Assessment of the Union Water Supply System (May 2013) |
| City of Nelson, BC | Stormwater management system | Assessment of City of Nelson Stormwater Management System (February 2014) |
| Greater Toronto Airport Authority, Toronto, ON | Airport infrastructure | Climate Change Vulnerability Assessment for Selected Stormwater Infrastructure at Toronto Pearson International Airport (August 2014) |
| Mik'Maq Communities, Cape Breton/Unamaki, NS | Stormwater and Wastewater, Potable Water | Unama'ki Water and Wastewater Vulnerability Assessment and Adaptation (in progress) |
| Quebec City, QC | Stormwater | Study of a planned (i.e. not yet built) stormwater management system in the d'Estimauville eco-neighbourhood (in progress) |
| Province of Ontario (Ontario Power Authority), ON | Electrical transmission | Enhancing Resilience to Severe Weather and Climate Change – Transmission Sector (in progress) |
| Toronto Hydro Electrical System Limited, Toronto, ON | Electrical distribution | Enhancing Resilience to Severe Weather and Climate Change – Distribution Sector (in progress) |
| Halton Region and Credit Valley Conservation Authority, ON | Stormwater and water resources | Climate risk assessment of wastewater, stormwater and potable water systems (in progress) |
| City of Mississauga and Credit Valley Conservation Authority | Stormwater and water resources | Climate risk assessment of wastewater, stormwater and potable water systems (in progress) |
| City of Montréal, QC | Stormwater and wastewater | Climate risk assessment of stormwater and combined sewers systems (in progress) |

## Appendix C - Vulnerability of Vancouver Sewerage Area Infrastructure to Climate Change (2008)[1]

Metro Vancouver used the PIEVC Protocol to assess the vulnerability of their infrastructure in the Vancouver Sewerage Area (VSA). The vulnerability assessment included all Metro Vancouver infrastructure and operations within the VSA. This catchment encompasses the City of Vancouver, the University of British Columbia (UBC) campus, UBC Endowment Lands, part of the City of Burnaby and part of the City of Richmond as shown on Figure C-1. The VSA has an approximate area of 13,000 hectares.


Figure C-1. Vancouver Sewerage Area study location map.

Years 2020 and 2050 were selected for analysis of climate change effects. Much of the combined sewer system that makes up the VSA dates to the 1960s or earlier. 2020 represented an early design life boundary for much of the oldest piping and appurtenances. A key operational target was Metro Vancouver's commitment to the elimination of combined sewer overflows (CSOs) in the VSA by 2050. Since the single largest impact of climate change on the VSA was expected to be increased rainfall (and therefore wastewater flow), a 2050 assessment of climate change was considered crucial for Metro Vancouver's sewer separation planning.

The VSA is largely a combined sewer system. Combined sewers are an older type of collection system that carry both wastewater and stormwater in the same pipe. Combined sewers were less expensive to install and maintain when they were built, generally prior to the 1960's.

[1] Unless otherwise indicated, the source of figures and tables is the project report: *Vulnerability of Vancouver Sewerage Area Infrastructure to Climate Change*, report to Metro Vancouver by Kerr Wood Leidal Associates Limited and Associated Engineering, May 2008)

During heavy rainfall, combined sewers can overflow directly into a nearby waterway such as the Fraser River or Vancouver Harbour, producing a CSO. This overflow provides a “safety valve” that prevents back-ups of untreated wastewater into homes and businesses, flooding in city streets, or bursting underground pipes. Metro Vancouver’s plan is to reduce, then eliminate, CSOs through the process of gradual conversion to a separated sewer system. Metro Vancouver committed to the elimination of CSOs by 2050 in their 2002 Liquid Waste Management Plan (LWMP). The LWMP also commits Metro Vancouver to upgrade the Iona Island Wastewater Treatment Plant (IIWWTP) to full secondary treatment no later than 2020.

The VSA is served by the IIWWTP, the second largest wastewater treatment plant in Metro Vancouver. The design peak wet-weather flow (PWWF) of the IIWWTP is 17 $m^3/s$. The plant provides primary treatment to wastewater from approximately 600,000 people before discharging it through a 7 km, deep-sea outfall into the Strait of Georgia. The plant opened in 1963 and has been expanded six times for growth and treatment upgrades allowing more than 200 billion litres of wastewater to be treated here in 2001.

Figure C-2. Iona Island WWTP (Photo courtesy of Metro Vancouver)

For this project, climate change modelling was performed by Ouranos (a Montreal-based climate science research consortium) using the Canadian Regional Climate Model to quantify expected changes to various climate factors. In general, all precipitation indices suggested an increase in total rainfall amount, and in the frequency and magnitude of rainfall events. In addition, modelling projected consistently increasing temperature trends at both the 2020 and 2050 horizons, implying that snowfall would decrease.

The estimated global sea level rise was 0.14 m by the 2050s and 0.26 m by the 2080s. Locally, in research conducted by Natural Resources Canada, it was reported that the Fraser

River delta areas (Richmond and Delta) were sinking at a rate of 1 mm/yr to 2 mm/yr, while other areas (Vancouver, Burnaby, Surrey, Tsawwassen Heights) were uplifting at a rate of 0 mm/yr to 1 mm/yr. Therefore, for certain areas of the VSA such as Iona Island, global sea level rise would be aggravated by a sinking land surface, increasing the relative sea level rise.

Monthly average minimum and maximum temperatures were predicted to increase by 1.4°C to 2.8°C by the 2050s. A summary of climate events used in the study is outlined in Table C-1.

Table C-1. Summary of Climate events

| Climate Event | Expected Change |
|---|---|
| Intense rain | Increase in 1-day maximum rainfall: 17% by 2050 * |
| Total annual / seasonal rain | Increase in total annual precipitation: 14% by 2050s |
| Sea level elevation | Increase in global sea level elevation **: 0.26m by 2080s (Ouranos) to 1.6m by 2080s (Rohling et al., 2007[2]) |
| Storm surge | Not quantified. Likely to increase *** |
| Floods | Not quantified. Likely to increase |
| Temperature (extreme high) | Increases in monthly maximum temperature: 1.4°C to 2.8°C by 2050s |
| Drought | Modeling inconclusive for trend. Average maximum length of dry spell may increase by 0.25 days by 2050s |
| Wind (extremes, gusts) | Not quantified. Likely to increase. |

Notes:
* Estimate is based on total precipitation, which is assumed to be approximately equivalent to rainfall in the VSA.
** Does not include local effects such as subsidence and atmospheric effects
*** Storm surge is a significant contributor to the extreme high water events and therefore lack of quantitative data is a critical information gap.

In general, the study noted that Vancouver rarely experiences extreme or catastrophic weather events such as ice storms, tornadoes, drought or extreme cold. Perhaps the greatest magnitude threat is flooding of the Fraser River, and many predict this risk to decline in response to climate change. A sample of the highest risks identified by the study is shown in Table C-2.

The climate factors identified as threats to infrastructure vulnerability will be evidenced as gradual changes. In fact, the greatest pressure to initiate adaptive action comes not from climate change, but from timing of planned infrastructure improvement plans such as the treatment plant upgrades and combined sewer separation program. So while climate change effects may reveal vulnerabilities, Metro Vancouver is in an ideal position to proactively mitigate and adapt to these challenges.

The PIEVC Protocol suggests the following recommendation categories:

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[2] Rohling E.J., Grant K., Hemleben Ch., Sidda M., Hoogakker B.A., Bolshaw M. and Kucera M., "High rates of sea-level rise during the last interglacial period." Nature Geoscience #16, December 2007

- Remedial engineering or operations action required
- Management action required
- Additional study or data required
- No further action required.

Table C-2. Climate effect ratings greater or equal to 36

| Infrastructure Component | Climate Variable | Priority of Relationship |
|---|---|---|
| **COLLECTION SYSTEM** | | |
| Combined sewer trunks | Intense rain | 42 |
| Combined sewer interceptors | Intense rain | 42 |
| Sanitary mains | Intense rain | 42 |
| **TREATMENT (IIWWTP)** | | |
| **Process** | | |
| Effluent disposal | Storm surge | 36 |
| **Hydraulics** | | |
| Effluent disposal | Storm surge | 36 |
| Buildings, tankage and housed process equipment | Storm surge | 36 |

Following are some of the conclusions and recommendations from the study.

- The key priorities in the collection system focus on increased rainfall and the associated potential increase in sewer flow, both under combined and separate sewer configurations. Accelerated separation may be necessary to achieve the target of CSO elimination by 2050. The vulnerabilities judged to be of the highest priority at the treatment plant are those associated with the effluent disposal system and the IIWWTP site itself because of the storm surge climate variable.

- While ranked as lower priorities, the potential impacts of an increase in average sea level on the IIWWTP site and associated infrastructure were considered important due to the significant uncertainty and wide range in predicted future increases in mean sea level. The study identified the need for more detailed information and analyses in the context of these potential vulnerabilities.

- The 2008 capacity of standby power available at the IIWWTP was deemed a vulnerability at the time of the study, and was anticipated to be further aggravated by changes in future climate.

- Given the age of the IIWWTP infrastructure, the project team identified the need for additional studies to consider the remaining service life of the components in the context of other potential issues (e.g. seismic). Even if climate change-related vulnerabilities were deemed to exist, they might be overshadowed by other hazards that, when resolved, could simultaneously address climate vulnerabilities.

# Appendix D - City of Calgary Potable Water Collection, Treatment and Distribution System (2011)[3]

The City of Calgary, through its Water Resources and Water Services divisions, partnered with Engineers Canada to assess the potential vulnerability of its water supply infrastructure to climate change using the PIEVC Protocol.

The scope of the vulnerability and risk assessment covered the entire water supply infrastructure within the City of Calgary boundaries that is owned and operated by the city. In addition to the physical assets, the study included design processes, construction practices, operations and management of the infrastructure. The study also considered infrastructure not owned or operated by the City in the watersheds but deemed critical  in terms of impacts on both the quality and quantity of water available at the intakes.

Calgary has two sources of drinking water:

- The Elbow River, which is 120 kilometers long and passes through four sub-climates before it enters the Glenmore Reservoir, is the source for nearly half of the city's water supply.  The Elbow valley watershed covers an area of 1,210 km2.
- The Bow River originates on the Blow Glacier north of Lake Louise and is one of the three main tributaries of the South Saskatchewan River.  The Bow River watershed covers an area of 7,770 km2.

The City's water supply infrastructure includes the Bearspaw and Glenmore water treatment plants, the raw water pump stations at Glenmore (Elbow River) and Bearspaw (Bow River), and secondary pump stations and water storage reservoirs around the city.   The Glenmore Water Treatment Plant, located on the Elbow River, was constructed in 1933 and expanded in 1957 and 1965.  The Bearspaw Treatment Plant, located on the Bow River, was built in 1972 and expanded in 1984.

Following treatment, the potable water flows to high-lift pumps.  The pumps push water through transmission mains, which transport large volumes of water to strategically located storage reservoirs and pump stations.  In 2011, the city owned 4,678 kilometers of water pipe infrastructure. Additional elements of infrastructure in the water supply system included:

- Infrastructure elements in the Bow and Elbow River Watersheds
- Raw water sources (Bow River and Elbow River)
- Raw water intakes
- Storage at Glenmore Reservoir
- Water treatment plants (Bearspaw and Glenmore)
- Treated water reservoirs
- Pump stations
- Feedermain network, plus water mains critical to hydraulic conveyance

[3] Unless otherwise indicated, the source of figures and tables is the project report: *City of Calgary Water Supply Infrastructure: Climate Change Vulnerability Risk Assessment*, report to the City of Calgary by Associated Engineering, May 2011

At the time of the study, the City was conducting system upgrades to gain sufficient capacity to meet the requirements of projected population growth up to at least 2021.  Thus the study addressed the potential impacts of future climate change for the years 2020 and 2050.

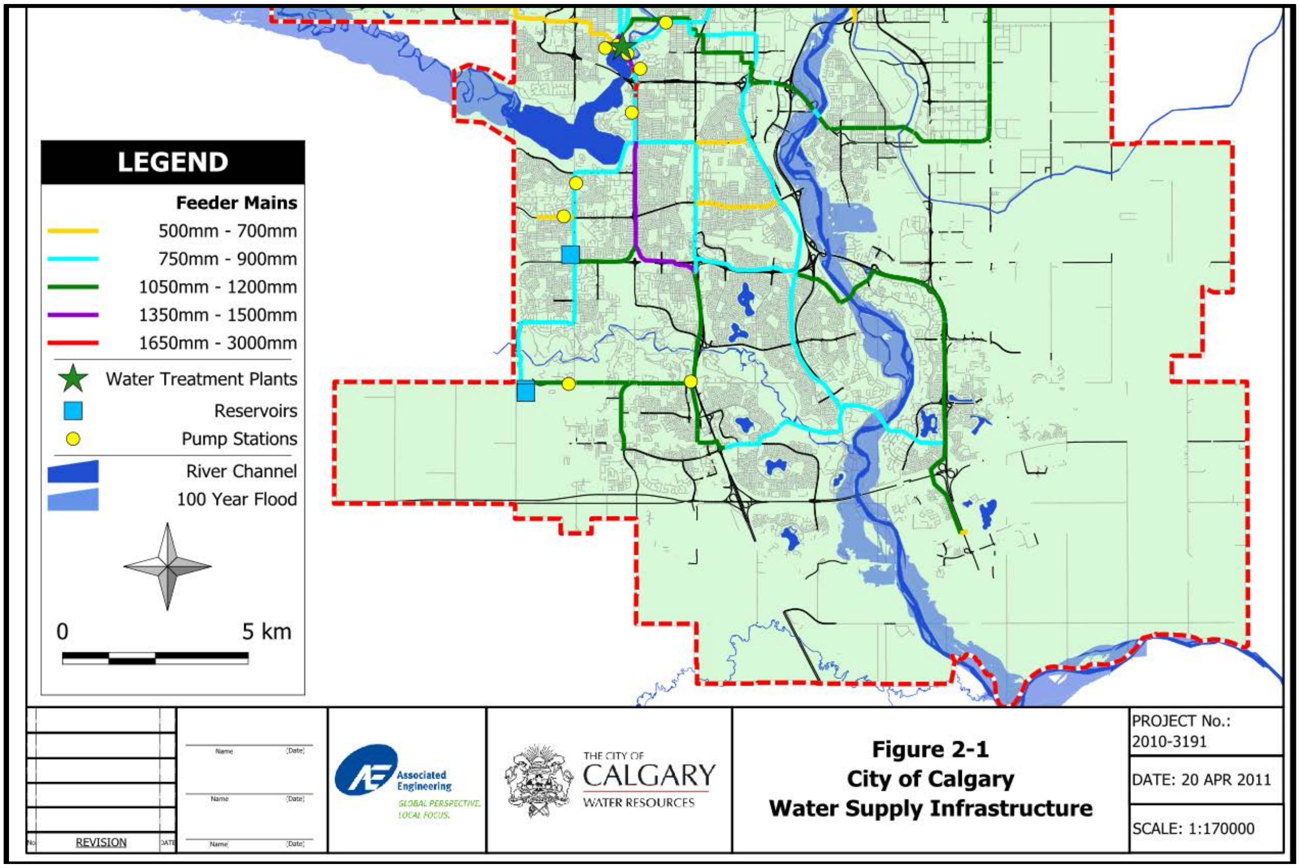


Figure D-1. Illustration of a portion of the water supply infrastructure considered in the study.

Based on available climate projections from various sources, the study identified the expected climate changes for the Calgary area and Bow and Elbow Basins, which included include:

- Increased temperatures
- Decreased snowpack
- Earlier melt and earlier onset of spring freshet
- Shorter, warmer winters
- Extended drought conditions
- Changes in precipitation type
- Decreased rain in the summer
- Increased rain in the fall, winter and spring
- Increasing frequency of extreme weather events.

Table D-1 provides a list of the precipitation changes expected for the study area by 2050.

Table D-1. Summary of Precipitation (and precipitation derived) Parameters Expected by the 2050s. Changes Shown are the Ranges that were Derived for Calgary Airport and the Basin.

| **Climate event** | **Expected Change by 2050** |
|---|---|
| Total precipitation | Increase: year (3%), winter (28 - 31%), spring (4%) and fall (1 - 2%)<br>Decrease: summer (3%) |
| Total rain and snow | Increase: rain (4%)<br>Decrease: snow (3 - 4%) |
| Very wet days | Increase of 2 - 16% by 2050 |
| Frequency of precipitation | Increase: year (1 - 4 days), winter (1 - 3 days), spring (2 days) and fall (0 - 1 days)<br>Decrease: summer (2 days) |
| Frequency of rain | Increase: year (10 - 12 days), winter (3 days), spring (6 - 8 days) and fall (2 - 4 days)<br>Decrease: summer (2 days) |
| Frequency of snow | Decrease: year (6 - 10 days), winter (0 - 2 days), spring (4 - 6 days) and fall (2 - 3 days) |
| Consecutive dry days | Increase: year (1 - 2%) |
| Maximum 5-day precipitation total | Increase: year (5 - 8%) |
| Precipitation days >10 mm/day | Increase: year (16%) |
| Simple Daily Intensity Index (SDII) | Increase: year (5%) |
| Snow depth | Decreasing: year (-2.6 to 0 cm) or up to 25%, winter (-7.4 to 0 cm) and spring (-10.5 to 0 cm) |

Some of the conclusions and recommendations from the study follow.

- The study found that, in general, the City of Calgary was fortunate to have robust treatment processes in addition to two raw water sources and redundancy within the distribution system. Operation and management plans were in place to reduce both the probability and severity of negative climate-infrastructure interactions occurring. The climate changes identified as having a negative impact to infrastructure will be seen as gradual changes, and ongoing monitoring can identify trending of changes and be incorporated into long-range plans. The vulnerabilities judged as the highest priorities were those associated with extreme events such as flooding (as witness during the 2013 floods), drought, and compounding events.

- As climate change occurs, it is anticipated that the watersheds may change as well, in terms of the quantity of water available and its quality. Changes in temperature and precipitation may both impact the water quality and level of contaminants from forest fires, algae, increased runoff, etc. in the raw water source to the drinking water facilities.

Continued monitoring and studies to address the potential for change was recommended.

- The study noted that the Glenmore Reservoir had limited storage capacity, and limited ability to mitigate potentials for flooding. The reservoir was not designed as a flood control structure. However, as future climate projections predict a potential for increased storm events and increases in the maximum instantaneous flows for the Elbow River, the study team recommended the City should give some consideration to the functionality of the reservoir. During drought conditions The City has water conservation measures in place to reduce demands on the system.

- Recent (as of 2011) and planned upgrades to the treatment facilities provided for robust systems, with adaptive capacities to withstand many of the potential impacts of climate change. The study indicated that increased precipitation and storm events leading to a potential for decrease in water quality (increased turbidity, pathogens from runoff) were expected to be handled adequately by the upgraded pre-treatment systems.

- At the time of the study, pump stations within the distribution system had experienced increased loadings, compounded with increased temperatures, resulting in overloads and tripping of breakers. Increased operator/maintenance attention was required to install temporary fans during high heat periods. The study recommended a review of the HVAC systems of some of the older facilities with remedial actions as required.

- Though some staff had been prevented from accessing facilities in the past due to storm events, the City had reduced the risks of impacts to the water supply system, due to staff being unavailable or unable to get to the facilities through cross training programs. Supporting facilities had also experienced increased loading of the HVAC systems during high temperature periods.

  As climate change models project an increase in the extreme daily temperatures and increased heat wave durations, the study recommended consideration be given to review of HVAC design codes and an assessment of existing facilities to identify remedial actions. An increase in temperature/heat duration presents potential impacts related to HVAC systems/electrical and controls and the availability of standby generation at all facilities including the water treatment plants.For example the Glenmore Water Treatment Plant had limited operational capacity while functioning on standby power.

  A review of standby power capacity at critical facilities was recommended.

# Appendix E - District of Shelburne (NS) - Vulnerability of Shelburne STP Upgrade (2011)[4]

The PIEVC Protocol was used to assess the vulnerability of the Sandy Point Sewage Treatment Plant Upgrade to the effects of climate change. The assessment was conducted in response to growing concerns about the vulnerability of public infrastructure located in coastal areas of Atlantic Canada to the expected local impacts of climate change. These potential impacts include: increasing storm frequency and intensity; rising sea levels; storm surges; coastal erosion and flooding.

This case study was the first application of the PIEVC Protocol at the pre-design stage of the project, rather than conducting the assessment on existing infrastructure. It is also an application to a small wastewater treatment plant in a rural community, with a view to learn about the scalability of the Protocol and to develop recommendations for how it can best be used to assess other infrastructure of a similar scale.

The Sandy Point STP was originally constructed in 1969 to provide primary wastewater treatment to a small development area that included residential, industrial and institutional development. The facility had a capacity of 30,000 USGPD and had been extensively studied since 2001 when deficiencies in treatment effectiveness were first identified. In response to previous studies and the *Canada-wide Strategy for the Management of Municipal Wastewater Effluent,* endorsed by the Canadian Council of Ministers of the Environment (CCME) in 2009, the decision was taken to replace the existing plant with a new secondary treatment facility which would both expand the capacity of the existing plant, and incorporate a more suitable and sustainable treatment technology.

Part of the study was to assess the adequacy of several potential locations for the new sewage treatment plant. Available records (topographic mapping, property mapping and aerial photography) have been reviewed in conjunction with the Atlantic Canada Wastewater Guideline Manual (ACGWM) separation distance requirements in preparation for locating the proposed STP Upgrade.

In total, three (3) sites were considered as illustrated in Figure E-1.

- Site #1 was located at the south end of the industrial park.
- Site #2 was located east of the Shelburne Industrial Park and Sandy Point Road.
- Site#3 was located east of the old boy's school.

The initial phases of the STP Upgrade could be accommodated on all three sites without encroachment on neighbours. Future expansion at Site #1 posed some encroachment concerns on neighbours to the south. Site #1 was more susceptible to the effects of climate change (sea level rise, storm surge, erosion, etc.). Site #3 was at a slightly higher elevation than Site #2 which may have affected the sizing of the pumps, length of access road required and further extension of power. Considering the above and other factors, Site #2 (approximately 1km in direct line from the existing plant) was selected as the preferred option for locating the proposed STP upgrade.

[4] Unless otherwise indicated, the source of figures and tables is the project report: *Vulnerability of Sandy Point STP Upgrade to Climate Change* report to the Municipality of the District of Shelburne by ABL Environmental Consultants Limited, August 2011.

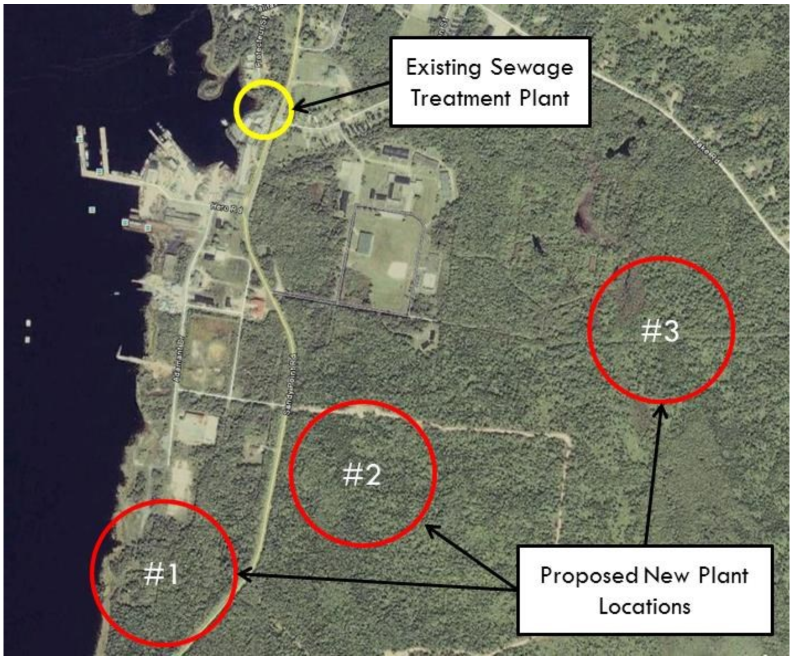



Figure E-1 Location of existing STP and proposed locations for the new plant.

Another innovation realised in this project was the use of the PIEVC Protocol in support of the selection of the technology for the sewage treatment. MDS requested the proposed STP Upgrade be designed to achieve a secondary level of treatment, which could be accomplished by a wide range of technologies available at the time of the study. However, given the design criteria, high rates of extraneous flow and the requirement for modular growth, some of the available options were quickly ruled out due to economic considerations. Based on experience of the team members, the most applicable technologies evaluated included lagoons, Sequencing Batch Reactors (SBRs) and Extended Aeration (EA) plants. The factors considered in the evaluation of alternatives included:

- Ease of operation & maintenance
- Capital & operating costs
- Impact of peak flows (I & I) on process
- Reliability (consistently meet effluent discharge limits)
- Sludge production and management
- Septage handling capability
- Susceptibility to climate impacts (PIEVC)
- Social implications (land, odour, noise)

All treatment processes investigated carried a number of common components, including as a minimum:

- Pumping station (located at existing STP)
- Screening and/or grit removal
- Flow measurement
- Maintenance (blower) building
- Disinfection
- Ocean outfall

The process resulted in the selection of a lagoon (complete with future cell) with ultraviolet treatment as the best suited to the Sandy Point system. Lagoons are typically the preferred treatment option for systems prone to peak (I & I) flows. They often cost less to construct, operate and maintain than other wastewater treatment systems; they are simple to operate/maintain and often only require part-time supervision.

In parallel with the technology and site selection process, the PIEVC Protocol was used to define the categories and components of system for assessment, which included the new treatment facility and the existing collection system. Historical climate data as well as climate change model predictions for 2020, 2050 and 2080 were also gathered with support from Environment Canada. Relevant climate parameters were identified for the region and included:

- Precipitation as rain
- Precipitation as snow
- Sea level elevation
- Wind speed
- Frost
- Fog
- Storm surge
- Ice
- Temperature

The study reports that regional trends in seasonal temperatures for Atlantic Canada show an overall warming of 0.3ºC from 1948 to 2005, with summers showing the greatest increase in temperature (+0.8ºC mean). Warming characterizes springs (+0.4ºC) and autumns (+0.1ºC), whereas winters have become colder (-1.0ºC). Daily minimum temperatures show a slight increase (+0.3ºC), but daily maximums have decreased more (-0.8ºC). Precipitation increased in Atlantic Canada by approximately 10% between 1948 and 1995 a trend that continued through the 1990's.

The projected changes in minimum and maximum temperatures and precipitations for various locations in Nova Scotia are shown in Table E-1.

The vulnerability (risk) assessment was conducted to identify interactions between infrastructure components and climatic events which could lead to vulnerability. The risk assessment included screening of the interactions by the engineering team, as well as a workshop that included participation from the Municipality of Shelburne, Environment Canada, Nova Scotia Environment, Municipality of Yarmouth, Emergency Measures Organization (Eastern Shelburne County) and ABL Environmental Consultants Ltd.

The risk assessment identified a total of eleven (11) interactions which were deemed to be high risk as shown in Table E-2.

Much of the data required for the Engineering Analysis did not exist or was difficult to obtain, but professional judgment and experience was employed where data were not available. For the thirty-five (35) components for which potential vulnerabilities were identified, the analysis resulted in twenty-one (21) remedial engineering actions and four (4) management actions being recommended. Many of the recommendations were combined and are summarized as follows:

- Reduce inflow and infiltration (I&I) into the collection system
- Install backup power supplies at the pumping stations
- Ensure the process building meets code for hurricane resistance
- Install a radio communications system at the pumping stations and process building

- Install high level pump shutoffs at the existing pumping station
- Install a bypass on the grit removal system
- Implement a policy to protect staff from hurricanes, storm surges and ice storms
- Discuss safe conditions for deliveries with septage haulage companies
- Adjust scheduling to accommodate required maintenance

Table E-1. – Annual Projected Change Fields[5] - Yarmouth data selected for the study.

| | Minimum Temperature | | | Maximum Temperature | | | Precipitation Amount | | |
|---|---|---|---|---|---|---|---|---|---|
| Tri-decade | 2020s | 2050s | 2080s | 2020s | 2050s | 2080s | 2020s | 2050s | 2080s |
| Units | Δ°C | Δ°C | Δ°C | Δ°C | Δ°C | Δ°C | % | % | % |
| Greenwood | 1.8 | 2.7 | 4.1 | 1.5 | 2.6 | 4.1 | 7.5 | 7.0 | 4.5 |
| Kentville | 2.2 | 3.1 | 4.6 | 1.6 | 2.7 | 4.3 | 8.0 | 7.0 | 4.0 |
| Shearwater | 1.9 | 2.7 | 4.0 | 1.2 | 2.1 | 3.5 | 17.0 | 14.0 | 11.0 |
| Yarmouth | 0.8 | 1.3 | 2.0 | 1.0 | 1.6 | 2.3 | 7.0 | 6.0 | 3.0 |

Table E-2. Interactions with Priorities Greater than or Equal to 36

| Infrastructure Component | Climate Variable | Priority of Relationship |
|---|---|---|
| **Admin / Operations** | | |
| Personnel | Hurricane Event | 36 |
| **Conveyance System** | | |
| **Existing Gravity Collection** | | |
| Sanitary MH | Heavy (Intense) Rain | 42 |
| Sanitary Gravity Mains | Heavy (Intense) Rain | 42 |
| Pipe Connection & Fittings | Heavy (Intense) Rain | 42 |
| **Existing Pumping Station** | | |
| Power Supply | Hurricane Event | 36 |
| | Ice Storm Event | 36 |
| **New Pumping Station** | | |
| Power Supply | Hurricane Event | 36 |
| Power Supply | Ice Storm Event | 36 |
| **Treatment System** | | |
| **New Treatment System** | | |
| Ocean Outfall | Sea Level Elevation | 36 |
| **Process Building** | | |
| Structure | Hurricane Event | 36 |
| UV Disinfection | Sea Level Elevation | 36 |
| Power Supply | Hurricane Event | 36 |
| | Ice Storm Event | 36 |
| **End Users** | | |
| End Users (Res., Ind., Inst.) | Hurricane Event | 36 |

[5] Lines, G.S., Pancura, M., Lander, C., Titus, L., *Climate Change Scenarios for Atlantic Canada Utilizing a Statistical Downscaling Model Based on Two Global Climate Models.* Environment Canada, Meteorological Service of Canada, Atlantic Region. Science Report Series No. 2009-01, January 2009.

## Appendix F - City of Welland (ON) Stormwater and Wastewater Infrastructure Assessment (2012)[6]

This study included both an application of the PIEVC Protocol and an update of the City of Welland's vintage Intensity-Duration-Frequency (IDF) rainfall data, as a co-operative initiative between the City of Welland, the Region of Niagara, PIEVC and the Ontario Ministry of Environment. The principal objective was to identify those components of the City of Welland's wastewater and surface drainage collection systems that were at risk of failure, damage and/or deterioration from extreme climatic events or significant changes to baseline climate design values. The approximate study area is shown in Figure F-1.

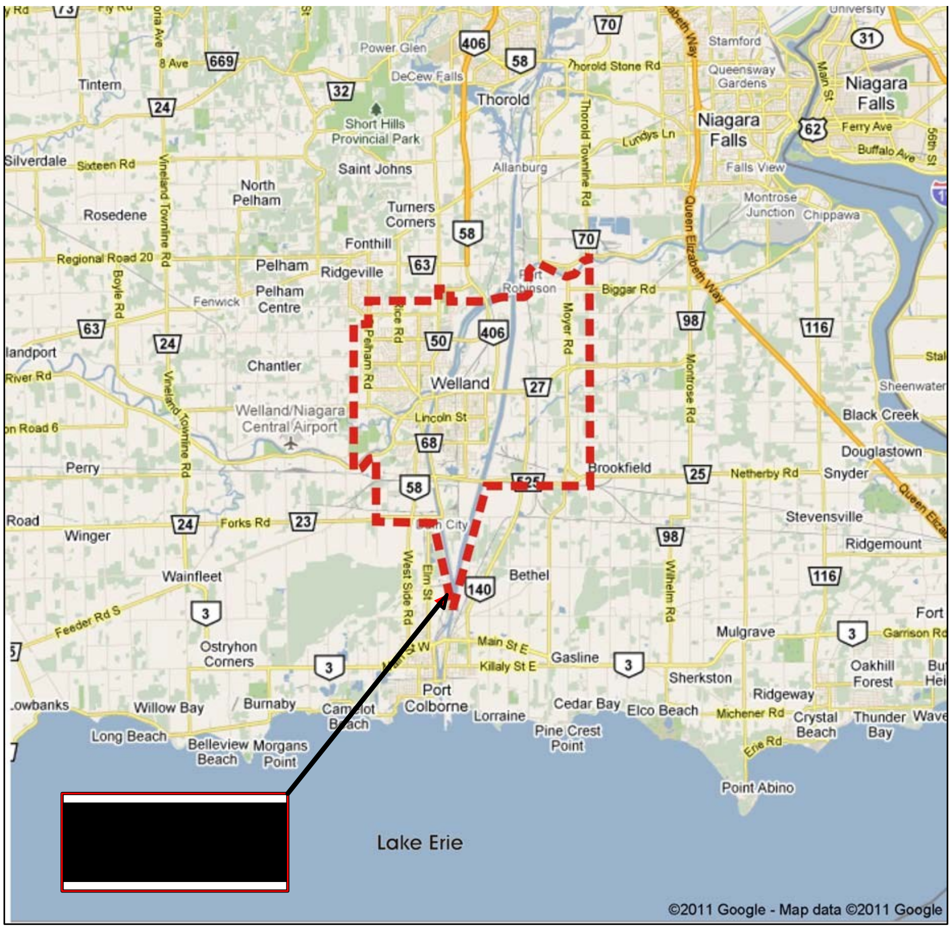



Figure F-1. Location of the City of Welland and approximate study area.

The identification of the infrastructure components to be considered for evaluation focused on:

- What are the infrastructure components of interest to be evaluated
- Number of physical elements and location(s)
- Other potential engineering / technical considerations

[6] Unless otherwise indicated, the source of figures and tables is the project report: *City of Welland Stormawater and Wastewater Infrastructure* Assessment, Report to the City of Welland by AMEC Environmental and Infrastructure, February 2012.

- Operations and maintenance practices and performance goals

Table F-1 presents a summary of the storm and sanitary systems information collected for the study. The existing wastewater treatment plant services Welland and the communities of Pelham, Port Robinson, and South Thorold, in addition to a number of non-residential sources. The Welland WWTP consists of a conventional activated sludge plant with effluent filtration, a parallel physical chemical treatment plant to provide treatment of storm flows, effluent disinfection by chlorination followed by de-chlorination, and biosolids stabilization in a two stage mesophilic anaerobic digestion process. Stabilized biosolids are stored on site prior to being hauled to the Region's centralized biosolids processing and storage facility at Garner Road. Treated effluent is discharged to the Welland River, a sensitive receiver tributary to the Niagara River.

Table F-1. Summary information on the storm and wastewater systems in the City of Welland

| Descriptor | Storm | Sanitary/Combined |
|---|---|---|
| # of Pipes | 1717 (Laterals)<br>2906 (Mains) | 17161 (Laterals)<br>3789 (Mains) |
| Total Length | 186 km | 268 km |
| Maximum Size | 3000 mm | 2700 mm |
| Minimum Size | 150 mm | 125 mm |
| Average Age of Pipes | 30 years | 42 years (Sanitary)<br>66 years (Combined) |
| Oldest Pipes | 106 years | 111 years (Sanitary)<br>110 years (Combined) |

In addition to the physical infrastructure, the following operational aspects of the subject infrastructure were considered:

- Administration/Personnel
- Power
- Transportation (primarily related to supplies delivery)
- Communications

In regards to the climate parameters considered, the following we identified:

- High/Low Temperature
- Heat & Cold Waves
- Extreme Diurnal Temperature Variability
- Lightning
- Heavy Rain
- Daily Total Rainfall
- Winter Rain
- Freezing Rain
- Ice Storm
- Snow Accumulation
- Blowing Snow/Blizzard
- Hail Storm
- Freeze Thaw Cycles
- Hurricane/Tropical Storm
- High Winds
- Tornado
- Drought/Dry Period
- Heavy Fog

Additional issues reviewed for this assessment included Lake Erie water levels, local groundwater levels and flooding of the Welland River. Some general outcomes from this assessment included:

- The number of days per year with temperatures exceeding 35$^{O}$C is expected, on average, to remain unchanged from historic norms through the 2020 period. However, further into the future, through 2050, significant increases of about 4 time's present occurrence are projected.
- The number of days per year with temperatures below -20$^{O}$C will, on average, be in steady decline through 2050.
- The occurrence of heat waves (three or more consecutive days when the maximum temperature is 32°C or higher) is projected to remain static through 2020 but marginally increase through 2050.
- Days per year experiencing a freeze/thaw cycle (a maximum daily temperature above 0°C and a minimum temperature below 0°C) are in decline.
- Rainfall is expected to increase. This includes postulated increases in the occurrence of winter rain events and increases in the severity of individual rain events.
- An almost doubling of the occurrence of drought/dry periods (defined as 10 or more consecutive days without measurable precipitation) is projected through 2020.

The second objective of this study was the update the City of Welland's 1960's vintage Intensity Duration Frequency (IDF) rainfall curves. This objective was extended to also include development of future IDF data for the project time periods (2020 and 2050). The review of a compendium of past, present and future IDF data would establish appropriate direction for re-definition of rainfall design standards for the City of Welland.

A comparison between the 1963 City of Welland and 2000 Environment Canada IDF data for Port Colborne weather station and the projected future IDF data (for 2020 and 2050) show that (Table F-2) future period maximum IDF values are consistently greater than the corresponding 1963 values with some increases greater than 20%. The comparison of future IDF values with the 2000 Environment Canada IDF data for Port Colborne weather station shows consistent increases for all durations across all scenarios with maximum increases (as much as 54%) associated with shorter duration events.

The following are some recommendations made as an outcome of the PIEVC risk assessment of City of Welland infrastructure coupled with the development of current and projected IDF relationships for the Environment Canada weather stations at Port Colborne:

- The City of Welland municipal standards outline the design of storm sewers based on IDF curves (Rainfall Intensity Duration Frequency curves). Prior to this study, the City of Welland had used a 1963 based IDF relationship for storm sewer design. The study recommended that the implications (as related to performance and life cycle costing) of the application of the current Environment Canada (i.e., 2000) or the projected (i.e., 2020 and 2050) IDF relationships, developed for this risk assessment, be evaluated to determine long-term applicability for the storm sewer collection system design, operation and maintenance.

- At the time of the study, the City of Welland infrastructure design standards directed the use of the 2 year return period rainfall design event for design of storm sewers in the municipality. The project team recommended that the implications of a change in this design standard to a 5 year or a 10 year design rainfall event should be evaluated in the context of current sewer infrastructure capital plans, performance metrics and long-term sewer objectives.

Table F-2. Comparison of projected rainfall intensities to 2000 values

| Duration | 2020 | | | 2050 | | |
|---|---|---|---|---|---|---|
| | average | 90th percentile | maximum | average | 90th percentile | maximum |
| 5 minute | 112% | 122% | 144% | 117% | 130% | 154% |
| 10 minute | 110% | 119% | 139% | 114% | 126% | 148% |
| 15 minute | 111% | 118% | 137% | 114% | 125% | 146% |
| 30 minute | 110% | 119% | 137% | 113% | 126% | 141% |
| 1 hour | 110% | 119% | 139% | 114% | 128% | 143% |
| 2 hour | 110% | 120% | 139% | 114% | 128% | 143% |
| 6 hour | 110% | 123% | 145% | 116% | 129% | 150% |
| 12 hour | 103% | 113% | 134% | 106% | 120% | 136% |
| 24 hour | 110% | 118% | 138% | 110% | 124% | 142% |

## Appendix G - City of Nelson (BC) Stormwater Infrastructure Assessment (2014)[7]

Incorporated in 1897, Nelson has a population of 10,230 (2014) and a trading area of over 60,000 people. Within its municipal boundaries, the City's total area is 913.6 ha (2257.53 acres, or 7.2 sq. kms). It is located in the Southern Interior of British Columbia in a region called the West Kootenay. Nelson is in the Central Kootenay Regional District, one of 27 Regional Districts in the Province of BC and is most closely bordered by RDCK Areas E & F. The regional districts and municipalities function as a partnership to provide and co-ordinate services in both urban and rural areas.

The City of Nelson (BC) recognized the possibility of vulnerabilities to climate change and extreme weather in their stormwater infrastructure and adopted to the PEIVC Protocol to identify risks and propose adaptation solutions. The application of the Protocol was limited to specific locations within the City that had exhibited vulnerability in recent high intensity precipitation events and one residential neighbourhood with a history of flooding. The goal of the study was to provide decision-makers with adequate information form stormwater infrastructure upgrades. City of Nelson engineering and public works staff provided specific catch basins location information that historically had been overloaded during intense summer rains. The majority of the infrastructure assessed was located in the downtown area, with one neighbourhood area in Rosemont.

Figure G-1. Photos Showing the Geography of the City of Nelson

The stormwater management system of the City of Nelson comprises natural drainage channels that transition into a piped network with outlets on Kootenay Lake. The City has two classifications of drainage systems:

[7] Unless otherwise indicated, the source of figures and tables is the project report: *City of Nelson Stormwater Infrastructure Assessment*, report prepared for the City of Nelson by Focus Corporation, February 2014.

- Minor system
  Pipes, gutters, catch basins, driveway culverts, open channels, watercourses and stormwater management facilities design to carry flows with a (historical) return period of 1 in 10 years.

- Major system
  Surface flood paths, roadways, roadway culverts, swales, watercourses and stormwater management facilities designed to carry flows with a (historical) return period of 1 in 100 years.

The climate parameters considered in this study was limited to the following:

- Increased intensity of individual storms
- Increase in frequency of high intensity storms
- Seasonal shifts in high intensity storms
- Change in number of ground penetrating frost days

Figure G-2 below illustrates the impacts of the July 17 2012 storm recorded at one of the weather stations and the impacts on the stormwater infrastructure of that area of town.

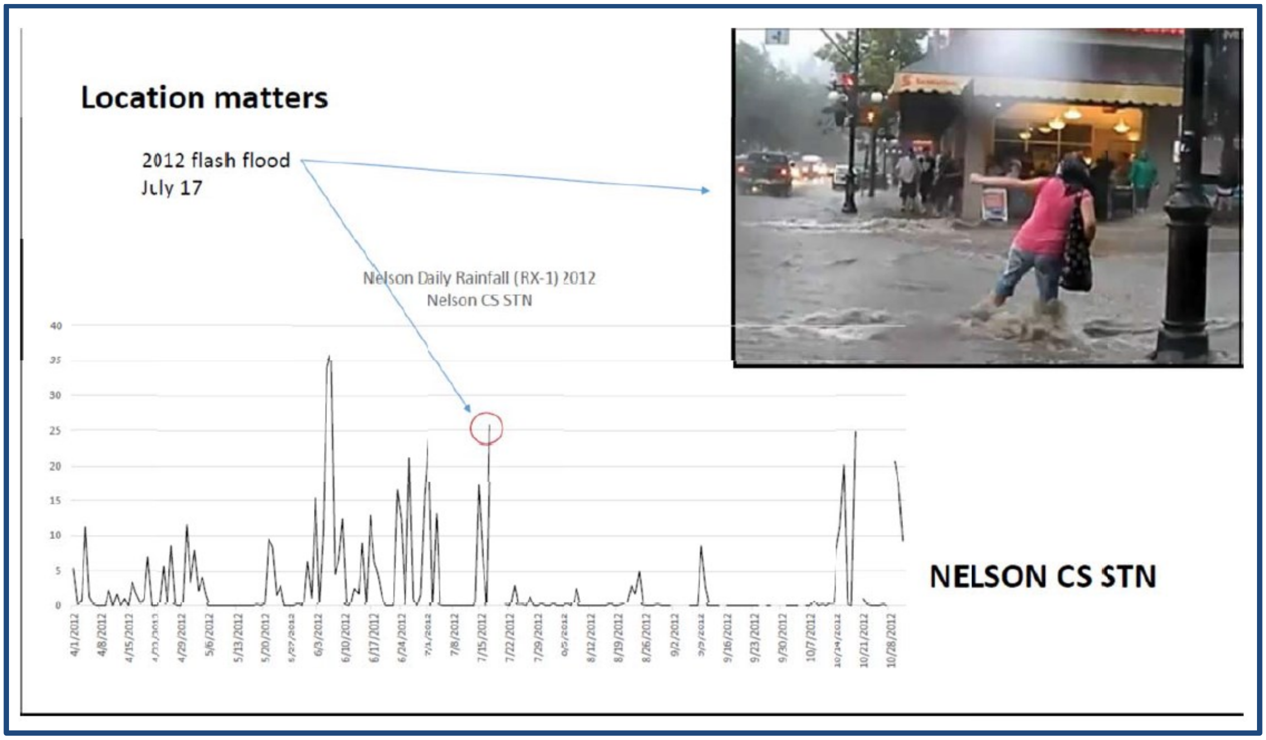



Figure G-2. Precipitation profile for the high intensity rain storm causing flooding at Ward and baker streets on July 17, 2012

The time horizon for the study was 2050. As in most applications of the PIEVC protocol, current (in this project 2013) vulnerabilities are established as the baseline for future risks.

Future climate predictions were made using Pacific Climate Impacts Consortium's (PCIC) Plan2Adapt, a regional climate change tool based on global climate models using projections for

1961-1990 baseline data. The median change in precipitations projections for the Central Kootenay Region (10th and 90th percentiles in brackets) were as follows:

- Annual: +5% (+2% to +12%)
- Summer: -8% (-8% to + 6%)
- Winter: + 7% (-2% to +15%)

The above predictions translate into the following trends that can impact the performance and integrity of the infrastructure:

- Extreme precipitation for one-day and three-hour events (return periods of 5, 10 and 25 years) are projected to increase by a frequency of 2 to 3 times at most locations;
- Mean annual precipitation is projected to increase, except for summers when precipitations is projected to decrease;
- Late spring frosts and ground penetrating frost days can be expected to decrease due to temperature increases; and
- High intensity precipitation is projected to increase.

The PIEVC Protocol directs the practitioner to confirm the infrastructure owner's risk tolerance thresholds prior to conducting the risk assessment. The Protocol suggests High, Medium and Low risk thresholds. Table G-1 outlines the risk thresholds used for this risk assessment.

Table G-1. Risk Tolerance Thresholds ..... report accessed at www.PIEVC.ca)

| Risk Range | Threshold | Response |
|---|---|---|
| < 12 | Low Risk | • No immediate action necessary |
| 12 – 36 | Medium Risk | • Action may be required<br>• Engineering analysis may be required |
| > 36 | High Risk | • Immediate action required |

The results of the risk assessment show that flooding due to extreme precipitation events compounded by high lake levels currently stress certain areas of the City's stormwater management system, affecting people and infrastructure. Increased frequency in storm intensity is the main climate parameter of concern. The application of the PIEVC Protocol provided a risk ranking of the five locations studied and therefore allowed to City to prioritize its interventions and investments. These recommendations included:

- Increase the capacity of the catch basins
- Prioritize effective maintenance practices
- Continue to collect and record local weather station data
- Install local weather stations at different elevations/locations within the City
- Update storm hyetograph tables/IDF curves based on climate change data
- Financing of stormwater operations, maintenance and renewal
- Engage property owners to develop effective flood mitigation measures
- Coordination with the BC Ministry of Transportation and Infrastructure (MoTI) and the Canadian pacific Railway (CPR) to develop flood mitigation options
- Explore opportunities for upstream flow diversion in the Wasson Street neighbourhood.

# Appendix A2

## CASE STUDY: COOKSVILLE CREEK INTEGRATED RISK ASSESSMENT FOR WATER INFRASTRUCTURE

## Background

Water sustainability plans are a means of integrating water management activities, including drinking water, wastewater, stormwater, and watershed management into one planning document. A crucial step in creating a water sustainability plan is the assessment of risks and vulnerabilities associated with water resources and water management decisions, for current and future conditions. Future climate change conditions are anticipated to have wide-ranging impacts on water resources; hence a risk assessment with respect to climate change is an opportunity to quantify potential future impacts on municipal water systems.

## Study Area: Cooksville Creek Watershed

### Cooksville Creek Watershed

The Cookville Creek watershed is located within the City of Mississauga, a lower-tier municipality located in the Region of Peel. Cooksville Creek is a small watershed (33.9 km$^2$ in area), which is approximately 15 km long and 2 km wide and outlets directly to Lake Ontario. The watershed is highly urbanized at 94%, with only 6% of the total area being open space, and is slated for further intensification as an urban growth centre within the Mississauga City Centre through the Places to Grow Growth Plan for the Greater Golden Horseshoe (MMAH, 2006).

On August 4, 2009, a storm event occurred over the Cooksville Creek watershed with a total rainfall depth of 68 mm in one hour; the resulting riverine and urban flooding caused damage impacting buildings, municipal infrastructure and fences, as well as incidences of basement flooding. On July 8, 2013, another high intensity-short duration rainfall event occurred in the area, with a total rainfall depth of 126 mm over a three hour period. The damages associated with this event were widespread and included power outages, basement sewer backup, flooding of streets and railways, and significant damage to property.

### Municipal Stormwater Management

The City of Mississauga has jurisdiction over stormwater management activities with the Cooksville Creek watershed, with the exception of regional roads, for which stormwater is managed by the Region of Peel.

The stormwater management system in Cooksville Creek consists of a dual drainage system, including major and minor systems to convey runoff from frequent storm events (i.e., 5 year storm and less), and larger, more infrequent storms, respectively. The typical design standard for storm sewers is the 10-year storm. The majority of Cooksville Creek was developed prior to flood and water quality control measures for stormwater management; as a result there are only a few stormwater management ponds located within the watershed, with several more planned for construction.

### Municipal Wastewater Management

Most properties within the Cooksville Creek watershed are served by sanitary sewers, which collect and transport wastewater to the G.E. Booth (Lakeview) Wastewater Treatment Facility, where wastewater is treated and discharged to Lake Ontario. The wastewater management system is managed by the Region of Peel.

As noted for the August 4, 2009 and July 8, 2013 storm events, basement flooding occurred during these events due to sanitary sewer backup. The Region of Peel has identified that inflow and infiltration occurs within parts of Cooksville Creek, whereby stormwater enters the sanitary sewer system, through manholes, directly connected downspouts and weeping tiles, and cracks in sanitary sewer pipes.

### Municipal Drinking Water

Drinking water to over 700,000 residents in Peel is supplied by the Lakeview Water Treatment Plant and the Lorne Park Water Treatment Plant. The Lakeview Water Treatment Plant is located adjacent to the

Cooksville Creek watershed. Both treatment plants and the water distribution system are managed by the Region of Peel.

**Cooksville Creek**

Cooksville Creek is a largely channelized stream through various stabilization measures over 92% of its total length. Due to the highly urbanized character of the watershed, water levels and flows in Cooksville Creek tend to be flashy, responding quickly to rainfall events. In some locations, Cooksville Creek can reach bankfull flow within less than 20 minutes of the start of a rainfall event. Floodplains are fairly flat, with 304 buildings in the middle and lower watershed within the regulatory floodplain (Hurricane Hazel). The creek itself is unstable, and significant downcutting and widening into the shall bedrock has occurred.

## Vulnerabilty Assesment in light of Climate Change

**Vulnerabilty Assesment**

Credit Valley Conservation, in partnership with the Region of Peel and City of Mississauga, undertook a vulnerability assessment of water infrastructure within Cooksville Creek in light of climate change. This assessment was intended not only quantify existing and future risks within the watershed, but also to highlight the challenges and opportunities of conducting an integrated, watershed-based assessment of risk and vulnerability.

**Integrated Assessment**

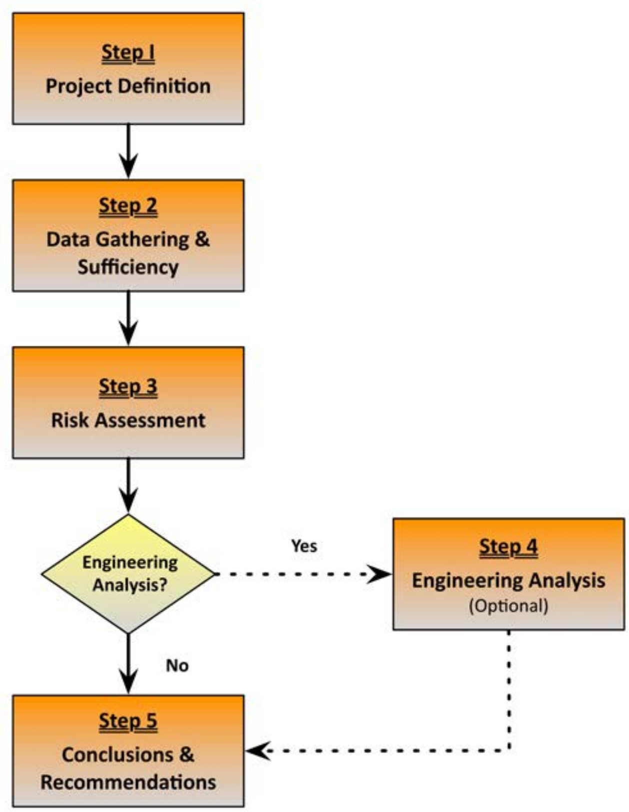
The project team applied an integrated approach to consideration of vulnerabilities with respect to the various water management systems within Cooksville Creek watershed. These systems include stormwater management infrastructure, wastewater collection and treatment infrastructure, drinking water treatment and distribution infrastructure, as well as the watershed itself.

**Watershed Approach**

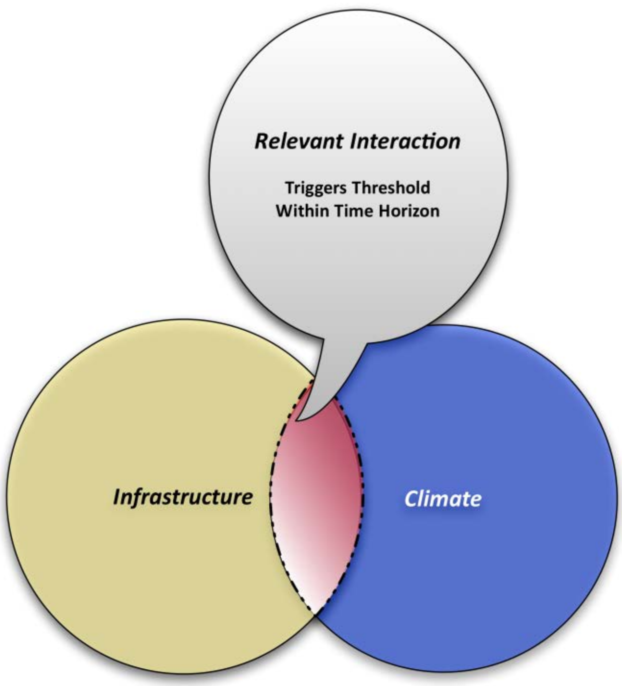
The Cooksville Creek watershed was selected as a study boundary in order to more easily integrate the different water management systems within the vulnerability assessment. Use of a physical boundary, as opposed to a political boundary, was found to be useful in understanding the physical interactions between the different water systems. The boundary was expanded slightly from the physical watershed boundary to include portions of sanitary sewersheds outside of the watershed, and to include the water and wastewater treatment plants, to incorporate interactions between these systems and the surface water and stormwater systems contained within the watershed.

**PIEVC Protocol**

The PIEVC Engineering Protocol was used to guide the assessment of risk with respect to climate change in Cooksville Creek watershed. The PIEVC Protcol was developed by Engineers Canada andconsists of five steps to determine the vulnerabilities of infrastructure systems.



The methodology of the PIEVC Protocol includes assessment of the physical infrastructure included in the assessment, the historic and projected future climate within the study area, and the historic and projected responses of the infrastructure to the climate. The protocol focuses on the areas where climate and infrastructure overlap.




Assessment of risks using the PIEVC Protocol determined as the product of the probability of a climate event occurring, and the severity of that event on an infrastructure system or component. Both probability and severity are scored on a scale from 0 to 7. The resulting risk scores therefore can range from 0 to 49.

As the study progressed, and additional considerations beyond engineered infrastructure systems were incorporated into the risk assessment, this scoring system began to become inadequate for scoring of some climate scenarios, as the highest severity score (7) represented loss of an infrastructure asset; however, some of the climate scenarios explored have potential to create more severe damages. Further discussion on this is provided in the Limitations Encountered section of this case study document.

The risk assessment using the PIEVC Protocol used three defined time horizons:

- Baseline climate;
- 2050s; and
- 2080s.

These periods were selected as they represent key planning and operational timelines for the infrastructure systems that were considered in the assessment.

## Risk Assessment Outcomes

**Risk Assessment Workshop**

A critical step in the PIEVC Protocol was a series of workshops were held in June 2015 for technical and decision-maker staff from City of Mississauga, Region of Peel, and Credit Valley Conservation Authority. These workshops were held to and review and refine the overall risk profile for water infrastructure within Cooksville Creek.

The workshops provided an opportunity for Mississauga, Peel and CVC Staff to interact and discuss their observations during past climate events. The key messages that were brought forward through the workshop included:

- Strong acknowledgement that there is a pattern of risk associated with high intensity-short duration rainfall events, with significant impacts on almost every infrastructure system within the watershed;
- Identification of impacts of storm events not related to infrastructure included emergency response during flooding events, and health impacts;
- Noting of uncharacterized risks, including "near miss" historic events, which may have been more severe had climate factors been slightly different, including impacts of contaminant plumes following rain events;
- Concerns regarding cumulative impacts over time, such as ice storm damage to green growth potentially reducing resiliency of the

watershed by clogging drainage systems and increasing runoff;
- Understanding that impacts on sensitive populations and areas, including seniors, medical cenres, and low-income neighbourhoods during flood events may be high;
- Uncertainty over the spatial distribution of high intensity-short duration storm events, and whether Cooksville Creek watershed is more or less likely to experience events like those experienced in the past;
- Concerns regarding the impact of algal growth on water quality in the watershed, and the antecedent conditions which could lead to algae growth during a changing climate;
- Discussion of the implications of unpredictable seasons on water management, operations and planning, and potential for reserve funding; and
- Discussion on incorporating legal risk issues related to climate change into decision-making processes.

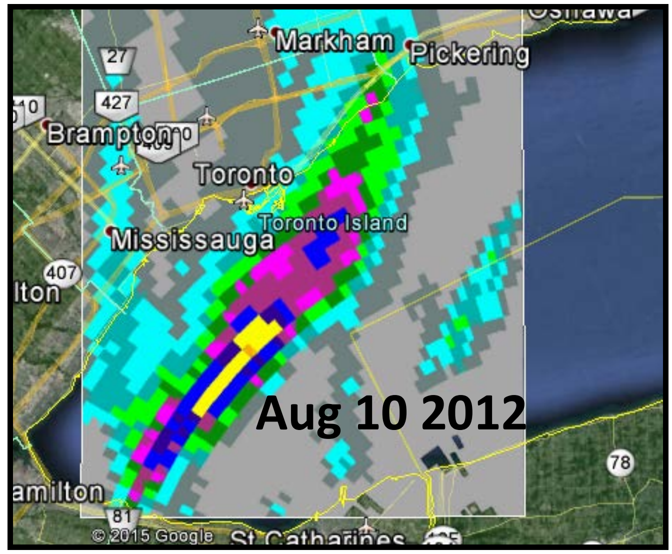
Following the workshops, the risk profile for Cooksville Creek watershed was refined. In some areas, further actions were identified to gain deeper understanding of risk associated with specific climate scenarios and/or infrastructure components, based on the messages presented during the workshop.

**Engineering Analysis**

A number of actions for further analysis were selected, including detailed engineering analysis, based on the key messages and questions raised during the workshops.

### Near-miss Climate Events

Climate events which could be considered "near-miss" include a storm which occurred overnight on August 10, 2010. The total rainfall was likely around 150-200 mm, with intensities nearing 200 mm/hr; however, impacts of this storm were not felt as the storm barely made landfall, instead tracking parallel to Mississauga's Lake Ontario shoreline approximately 15-20 km offshore.




An important message of this event is that high intensity-short duration events can happen at any time of day. During workshops there had been an assumption by many technical staff that these storms typically occur during late afternoon; the timing of the August 10 storm indicates this is not a valid assumption. The risks and means of responding to a flooding event during the early morning hours is quite different than would be the case for an afternoon event.

Another near-miss relating to high intensity-short duration rainfall events was the event of July 8, 2013, which resulted in flooding at a school in the Cooksville Creek watershed, with up to four feet of water in the kindergarten room in less than two hours. Had this event occurred only two weeks earlier before summer vacation, the impact of this event may have been much higher than was observed.

### Understanding Algae Growth

The factors contributing to growth of cladophora algae include climate factors and water quality parameters, which can be influenced by land use changes. Additional analysis was completed, including water quality modelling, to further the understanding of how climate parameters, including air temperature, wind, and cloud cover, and water quality parameters, including temperature, nutrients and solids, act together to produce algae.

### Sewage Bypass Events

A limited data set was analysed to determine if bacterial counts near water intakes at the Lakeview Water Treatment Facility are heightened following bypass events during extreme rainfall events. While limited monitoring data made it challenging to make a strong connection, it does appear that a correlation exists beween *E.coli* counts and sewage bypass volume from the G.E. Booth Wastewater Treatment Facility.

Sewage bypass data for a five year period was available for the G.E.Booth Water Treatment Facility, as well as for other nearby treatment plants. The results indicate that there is a correlation between bypasses and one day of rain, with bypass typically triggered within a few hours of the beginning of the storm.

### Vulnerability Mapping

One of the messages received during the workshops was regarding the wider range of impacts of flooding that were observed following the August 4, 2009 and July 8, 2013 storms. The impacts of extreme rainfall on vulnerable populations, including the elderly, children, and basement apartment-dwellers was noted through examples given by municipal staff. Mapping was created to overlay areas prone to flooding with these populations, as well as critical infrastructure such as schools, medical centres, evacuation centres, and emergency response services locations. A model was created using GIS software to develop a vulnerability ranking system for Cooksville Creek watershed in terms of vulnerable populations and infrastructure, to be used for prioritizing water management and emergency response during flood events.

## Challenges and Limitations Encountered

Limitations and challenges were encountered throught the Cooksville Creek watershed vulnerability assessment, some of which were related to the structure of the PIEVC Protocol, and to the increased scope of the assessment during the study.

### Climate Information Uncertainty

Complexities in the ability of the current science to predict future climate, particularly regarding extreme rainfall and wind patterns, was a limitation identified early in the project. Detailed analysis therefore relied heavily on forensic analysis of past meteorological events to determine impacts on infrastructure resulting from those events.

### PIEVC Scoring Methodologies

The PIEVC Protocol uses a scoring methodology developed to assess risk specific to infrastructure, with the highest severity score indicating loss of an infrastructure asset. The PIEVC Protocol does not directly assess risk relating to socio-economic issues, including property damage to third-parties, health impacts, or loss of life. These issues were brought forward by stakeholders during workshops, and therefore incorporated into the study; however, due to the scoring methodology, events resulting in non-infrastructure impacts, such as loss of life), score the same as an event which would only impact infrastructure directly.

To manage this limitation, the vulnerability mapping discussed in the previous section was completed, and rankings were developed which included the socio-economic vulnerabilities which exist in Cooksville Creek watershed, and increase the overall risk associated with high intensity-short duration storm events.

### Abundance of Data

As a result of the storm and flooding events which have occurred in the past within Cooksville Creek watershed, extensive analysis and study has occurred regarding water, and particular stormwater, management in the watershed. Consequently, there was an abundance of data available for technical analysis, including water quality and quantity monitoring data, meteorological data, models, studies and plans.

The workshops held in June 2015 were useful in scoping the engineering analysis portion of the assessment, by focussing on the key messages provided by municipal staff and stakeholders, using the data available.

## Lesson Learned

The lessons learned from the Cooksville Creek watershed apply to both the risk assessment process, as well as to integrated water management in genera.

**Importance of the Watershed**

Above all, the study underscored the benefit of using the watershed as the boundary for integrated water management. While the study area was expanded from the watershed to also include sewersheds and treatment plants outside the watershed boundary, the boundary was still geophysically based, rather than geopolitically. This study boundary made it easy to see interconnections between the different water systems, as they are all connected within the watershed boundary.

**Impacts beyond Infrastructure**

One of the unexpected messages received during the workshops was that the study should incorporate vulnerabilities beyond the original infrastructure-based focus of the assessment. Once some of the socio-economic implications of extreme rainfall events were brought to light, other linkages were made as well, thereby integrating not only the various water management systems within the Cooksville Creek watershed, but also different departments of Peel and Mississauga including Emergency Management, Planning, and Public Health.

**Too much data can be a challenge**

A challenge of the study was that an abundance of data was available for the study area, which initially made it difficult to determine where to focus efforts, particulary regarding technical analysis. This challenge also underscored the importance of having sufficient time in the schedule for data collection, which in this case included coordination between different departments at CVC, City of Mississauga, and Region of Peel.

**Importance of workshops to vet interactions and define scope**

The workshops held in June 2015 and again were crucial in refining the overall scope of the project, by giving municipal staff and stakeholders an opportunity to share the impacts they observed during past events. The discussions which took place brought forward connections between the different water systems which may not have been made otherwise. The questions received during the workshop provided the project team with a more defined focus for the detailed engineering analysis portion of the study.

**Third party helps to bring upper and lower municipalities together**

The structure of the study, being a partnership between Region of Peel, City of Mississauga, and Credit Valley Conservation, with CVC acting as project leaders, helped to facilitate discussion between the different groups.

## Next Steps

The results and recommendations of this study will help to inform water managers and planners across the three project partners to build resiliency to deal with today and tomorrow's challenges relating to water. The vulnerability maps developed through this study will continue to be improved and expanded to more fully capture the range of impacts of climate events, beyond impacts on infrastructure systems.

## Acknowledgements

Credit Valley Conservation would like to sincerely thank the following companies, organizations, and individuals for their support in the development of this case study:

- Region of Peel
- City of Mississauga
- Ontario Ministry of the Environment and Climate Change
- Toronto Region Conservation Authority
- Nodelcorp Consulting Inc.
- Risk Sciences International
- Matrix Solutions Inc.

# Appendix B

## INTEGRATED WATER MANAGEMENT

# Appendix B1

## TOOLS AND MODELS TO SUPPORT AN INTEGRATED WATER SUSTAINABILITY PLAN

## Appendix B1: Tools and Models to Support an Integrated Water Sustainability Plan

### Table B.1.1 Decision-making Tools that can Support an Integrated Water Sustainability Plan

| Tools | Description | Climate Change | Risk Assessment | Asset Management | CSO Performance | WW Treatment Performance | Collection Performance | SW Performance |
|---|---|---|---|---|---|---|---|---|
| **Envision** | A holistic framework for evaluating and rating the community, environmental, and economic benefits of infrastructure projects that evaluates, grades, and gives recognition to infrastructure projects that use transformational, collaborative approaches to assess the sustainability indicators over the course of the project's life cycle.[i] | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| **PIEVC** | A tool, the Protocol, to guide engineers working with other professionals in assessing the vulnerability of infrastructure and develop adaptation solutions. An engineering tool, the Protocol helps assess vulnerabilities in several related areas such as planning, operations and maintenance of the infrastructure. [ii] | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| **MRAT** | MRAT focuses on basement flooding risks, and more particularly on mapping vulnerable areas to flooding within a city. The tool uses data from municipal infrastructure (inventory and condition), land use, current and predicted future climate, and insurance claims.[iii] | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ |
| **CREAT 2.0** | The EPA's Climate Resilience Evaluation and Awareness Tool assists drinking water and wastewater utility owners and operators in identifying and assessing potential climate-related threats. CREAT provides adaptation options that enhance the utility's resiliency toward climate change challenges. Losses are evaluated in terms of financial impacts, equipment damage and environmental and public health consequences.[iv] | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| **ICLEI Framework** | 5-step process framework developed to guide local government practitioners through a process of initiation, research, planning, implementation and monitoring climate adaptation planning. [v] | ✓ | ✓ | ✓ | | | | |

**Appendix B1: Tools and Models to Support an Integrated Water Sustainability Plan**

## Table B.1.2 Watershed models that can Support an Integrated Water Sustainability Plan

| Model | GIS interface | Rainfall-runoff analysis | Pipe Flow | Overland flow | Control | LID and BMP measures | Water quality modeling | Water balance modeling |
|---|---|---|---|---|---|---|---|---|
| EPA SWMM | No | Single event and long term (continuous) | Yes | 1-D | SWM ponds and hydraulic controls | Yes | Yes | Yes |
| PCSWMM | Yes | Single event and long term (continuous) | Yes | 1-D and 2-D | SWM ponds and hydraulic controls | Yes | Yes | Yes |
| XPSWMM | Yes | Single event and long term (continuous) | Yes | 1-D and 2-D | SWM ponds and hydraulic controls | Yes | Yes | Yes |
| MIKE URBAN | Yes | Single event and long term (continuous) | Yes | 1-D and 2-D | SWM ponds and hydraulic controls | No | Yes | No |
| SWMHYMO | No | Single event and long term (continuous) | Yes | 1-D | SWM ponds and basic routing | No | No | No |
| Visual OTTHYMO | No | Single event and long term (continuous) | Yes | 1-D | SWM ponds and basic routing | No | No | No |
| QualHYMO | No | Single event and long term (continuous) | Yes (site plan) | Yes (site plan) | SWM ponds and basic routing | Yes | Yes | Yes |
| InfoWorks | Yes | Single event and long term (continuous) | Yes | Ye | SWM ponds and hydraulic controls | No | Yes | No |

## Appendix B1: Tools and Models to Support an Integrated Water Sustainability Plan

[i] http://www.sustainableinfrastructure.org/downloads/Envision_factsheet.pdf
[ii] http://www.pievc.ca/protocol
[iii] http://www.ibc.ca/on/disaster/water/municipal-risk-assessment-tool
[iv] http://www.epa.gov/crwu/assess-water-utility-climate-risks-climate-resilience-evaluation-and-awareness-tool
[v] http://icleicanada.org/programs/adaptation

# Appendix B2

## CASE STUDIES ON INNOVATIVE INFRASTRUCTURE, TECHNOLOGIES AND PRACTICES THAT REDUCE ADVERSE IMPACTS ON WATER

**Appendix B2*:* Case Studies on Innovative Infrastructure, Technologies and Practices that Reduce Adverse Impacts on Water**

The following excerpt is taken from the White Paper developed by University of Dalhousie: Low Impact Development within Integrated Water Management Systems: Barriers, Opportunities, And Risks – Centre for Water Resources Studies, Dalhousie University, Nova Scotia; 2015

## Case Studies in LID within Integrated Water Management

Three case studies, with a focus on high-level integration of LID approaches and features, have been summarized below. Case studies were chosen to illustrate LID integration within drinking water, wastewater, and retrofit systems. The three case studies provide examples of risk mitigation within integrated municipal water systems.

### 4.1 HALIFAX REGIONAL MUNICIPALITY, NS LID INTEGRATION WITHIN DRINKING WATER SYSTEMS

Halifax, Nova Scotia is an amalgamated municipality of the governments of the former cities of Halifax and Dartmouth as well as the town of Bedford and the County of Halifax. Covering approximately 5500 square kilometers, the municipality consists of more than 200 individual communities with the bulk of its 413,710 (as of 2013) residents centred in the urban areas (Halifax, 2014). Residents within the core service boundary are serviced by Halifax Water, the local integrated water, wastewater and stormwater utility. Halifax Water is a private, publicly traded utility with all its shares held by the municipality (Halifax Water, 2014). Outlined below are two case studies that illustrate the potential risks (Case Study 1), and benefits (Case Study 2) of integrated water management planning, with a specific focus on LID impacts on drinking water systems.

#### 4.1.1 CASE STUDY 1 - APPROACH

Beaverbank is a small suburban residential area located outside the defined core water service area of Halifax. Due to its location outside the core service boundary, developments in Beaverbank must be planned with private drilled wells for drinking water supply, and are not serviced by Halifax Water. Beginning in 2008, residents of two rapidly expanding residential subdivision developments, Monarch Estates and Rivendale, began running out of water (HRM, 2010). They lost the ability to water their gardens, launder their clothes, and even flush their toilets with regular frequency (CBC News, 2010). As per the minutes of a Halifax Community Council meeting related to this issue (2010), one resident drilled a secondary well at a depth of over 700 feet, only to experience the same water shortages again not long after. At the time there was no provision by the Halifax Regional Municipality (HRM) or Halifax Water in place to require a study of groundwater availability for residential developments in suburban and rural areas not serviced by municipal water, and no such study was conducted (HRM, 2010).

#### 4.1.2 CASE STUDY 1 - RESULTS

Residents petitioned the city to extend municipal water service to their subdivision, and there was significant negative media attention related to the problem. Residents won their battle to have municipal service extended, but at a cost of over $5M to Halifax Water, and an average cost of $20k to each homeowner for lateral connection fees (HRM, 2010). It must also be noted that this project drew resources and attention away from growth areas as directed by the Regional Municipal Planning Strategy (Regional MPS), and that installation of water infrastructure after construction has been completed is dramatically higher than installation prior to completion (Davis, 2014). While the residents of Monarch and Rivendale Estates now enjoy the benefits associated with municipal water service, they will experience a faster failure of their asphalt surfaces due to the disturbances associated with open trenching to lay water service pipe (Davis, 2014).

The Beaverbank case study is an example of what can go wrong when an integrated approachto water management is not considered in the planning stages of a residential development.There have, however, been some positive outcomes as a result of this situation. The Government of Nova Scotia passed legislation allowing municipalities to require groundwater planning studies prior to development approval. While HRM has not enacted this legislation, they do now require groundwater planning studies for new developments on a case-by-case basis (CBC News, 2010b). The groundwater planning studies consider how alterations to the landscape will influence groundwater recharge and availability. A relevant take-home message from this situation is that an understanding of how a development will impact all water resources and systems is imperative, and integrated management plans can help identify and reduce risks.

### 4.1.3 CASE STUDY 2 - APPROACH

The Seven Lakes development is a phased suburban residential development proposed to consist of 634 units located in an area known as Porters Lake within the municipality of Halifax (HRM). It is proposed as an Open Space design to be constructed in seven phases over 10 years in an area of approximately 256 ha. In HRM, Open Space design means that a portion of the lands are to be conserved as open space and specific to Seven Lakes 60% of the 256 ha must remain as common Open Space. Housing, services, and public and private parkland are to be located in the remaining 40% of the area. The development is proposed to be owned by one owner who will be responsible for water and septic systems, common open space and common accessory buildings (HRM, 2013).

Phase 1, which consists of 103 units, is currently under construction. This phase is serviced by a decentralized wastewater system and shared and/or individual groundwater wells. A stormwater plan is required for each phase of development and the first phase has been approved to include LID features such as retaining 60% of the original vegetation on each lot, bioswales and the construction of a stormwater wetland (HRM, 2013).

The Seven Lakes Developers, in corporation with Dalhousie University, the Department of Natural Resources (Provincial Government) and the Ecology Action Centre (NGO), received a grant to explore the effect of LID stormwater management techniques on groundwater recharge. The objectives of this research are to provide information to government and developers about LID stormwater management and its integration into drinking water supply management. This study was initiated, in part, due to the situation described in Case Study 1.

### 4.1.4 CASE STUDY 2 - RESULTS

The first phase of development is currently under construction. Groundwater wells were drilled at the site as part of the required Level 2 Hydrogeological Assessment (now a municipal requirement). This assessment is completed to characterize the groundwater aquifer and estimate a sustainable yield. Four wells have been designated as monitoring wells and loggers have been recording groundwater levels prior to and during construction. Recorded data was used to calibrate a groundwater model designed to test the sensitivity of both groundwater pumping and recharge rates on the groundwater level. Preliminary results show that groundwater levels are sensitive to pumping and recharge rates (Centre for Water Resources Studies, 2014), and that the incorporation of LID features has a positive impact on drinking water availability.

Dalhousie University continues to monitor groundwater and surface water flows and is developing water balance models of the development. Identifying potential risks to drinking water supplies as a result of facilitated recharge will be monitored and addressed in the study.

### 4.2 PORTLAND, OREGON, USA LID INTEGRATION WITHIN WASTEWATER SYSTEMS

The city of Portland, Oregon, has a combined sewer for wastewater and stormwater which discharges into local streams and rivers. As in most cities with combined sewer systems, large rain events overwhelm the treatment plants and untreated wastewater is discharged directly to the environment. In 2004 after investing billions of dollars to upgrade the sewer system, approximately 50 rain events caused overflows of polluted water into local waterways (CCAP, 2011). The city of Portland commissioned a financial valuation to determine the costs to upgrade the conventional system (e.g. the cost of increasing the pipe sizes) compared to the costs of implementing LID (from keeping trees to installing green roofs) across the city. The valuation accounted for the multiple benefits of LID including the cost of avoided damages and increases to property values in addition to the stormwater management value. Once the numbers were in, it was obvious that the role LID can play was not insignificant and the city began to invest in this approach (CCAP, 2011). It launched a campaign named “Grey to Green” focused on shifting the “grey” stormwater to “green” infrastructure. The city offers stormwater management fee discounts to property owners to include LID on their property, incentives for disconnecting downspouts and building green roofs in addition to investing millions of dollars into city owned LID projects (CCAP, 2011).

### 4.2.1 RESULTS

As of 2007, more than 44,000 homes have disconnected their downspouts, which has resulted in an estimated reduction of 1 billion US gallons of stormwater per year from the combined sewer system (US EPA, 2007). In 2011 alone, 288 green roofs, covering almost 14 acres, were installed (American Rivers et al., 2012). It is estimated that Portland's LID projects retain and infiltrate about 43 million gallons (163 million L) of water per year accounting for approximately 40% of annual runoff (CCAP, 2011).

All told, Portland was able to achieve $250 million in hard infrastructure cost reductions by investing $8.5 million in green infrastructure (US EPA, 2007).

The ability to compare the financial costs of LID with those of conventional stormwater management upgrades, and acknowledging the multiple benefits of LID implementation with a price, helped the city launch and evaluate the effectiveness of its LID campaign. Downspout disconnections do not come without risk, however. In order to minimize risks to individuals and property, homeowners are encouraged to anticipate where the disconnected downspout will flow to and direct them to gently sloped pervious areas, where possible.

## 4.3 SEATTLE, WASHINGTON, USA LID INTEGRATION WITHIN DEVELOPMENT RETROFITS

The City of Seattle has become a leader in the design and implementation of LID features and approaches, which are a part of their Natural Drainage Systems city strategy. This strategy was born out of concerns related to downstream environmental impacts (including impacts on sensitive fisheries streams), lack of municipal funds for installation of standard stormwater infrastructure, and an aging stormwater management system (including combined sewer systems).

As part of updating an outdated housing development, the City of Seattle took the opportunity to retrofit the area's stormwater management approach (which included a previously constructed dry retention pond) to incorporate LID features and approaches. The development was designed to standards above those typically set for developments, with additional requirements relating to reducing the overall quantity of runoff generated by the development area. This case study represents an approach that can be taken to retrofit systems that have existing end-of-pipe solutions in place (e.g., wet and dry ponds).

Features implemented include: street systems that are sloped towards gutters with curb cuts, allowing stormwater to collect in bioretention swales for infiltration of typical runoff events, disconnected downspouts which flow towards amended soil infiltration features, porous sidewalk surfaces, narrowed streets, and a conventional piped stormwater system which directs larger event flows to a dry pond for storage and release.

### 4.3.1 RESULTS

Through the combination of LID and conventional management features, a reduction in the size of the pond required was achieved. It was reported that if only conventional approaches were used, the dry pond would have required an addition 5x the volume of that of the combined system. In addition, it is reported that the project is meeting water quality related goals. The reasoning for the initiation of this project correlates well to those issues previously outlined in Section 1.1 (e.g., extensive infrastructure costs and receiving waters concerns), and as such represents an applicable analog for future implementation across Canada. A loan from a fund developed by the Washington State Department of Ecology (in place to promote such technologies and approaches) ensured the project could be completed, and illustrates how investment into these technologies can push forward adoption (City of Seattle, 2010).

# Appendix C

## FINANCIAL PLANNING

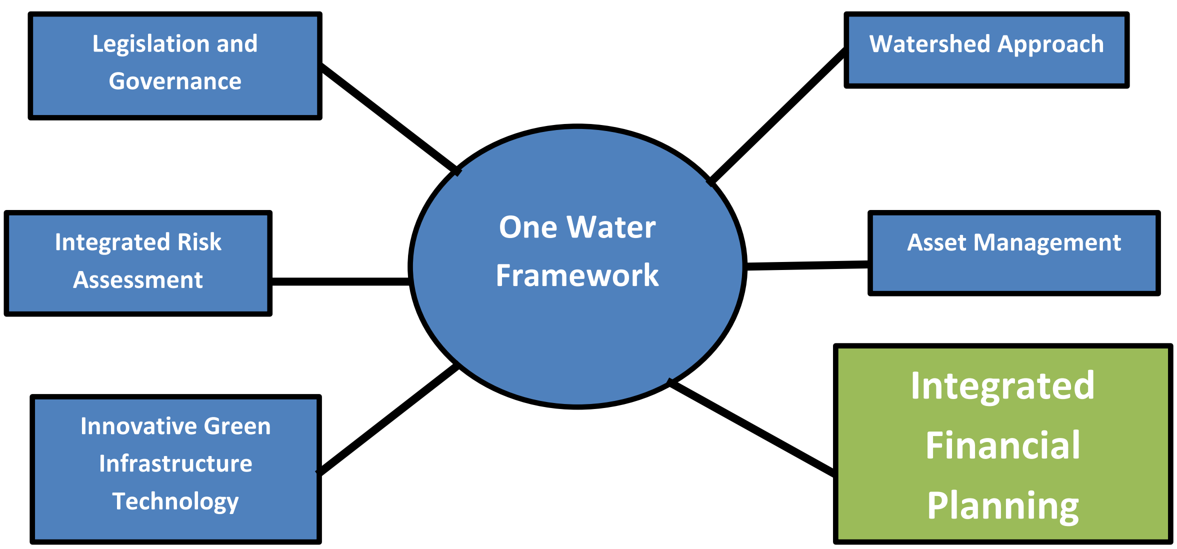
# Appendix C1

## INTEGRATED FINANCIAL PLANNING

***Chapter adapted from Report: DEVELOPING AN INTEGRATED RISK MANAGEMENT FRAMEWORK TO SUPPORT "ONE WATER" IN MUNICIPALITIES (Source: Credit Valley Conservation Authority, 2015)***

## Integrated Financial Planning

Integrated financial planning is the last tool within the one water framework. With an asset management plan prepared for water, wastewater and stormwater infrastructure, municipalities can develop a long-term capital budget to tackle future replacement needs and an operating budget to deal with critical maintenance that will help ensure infrastructure achieves or exceeds the anticipated useful life and level of service. With an integrated financial plan, municipalities can combine the physical inventories of the infrastructure into one database to forecast when the assets will reach the end of their service life. At that stage, municipalities can prepare cost estimates to replace the infrastructure or apply new technologies to optimize infrastructure, thus delaying the need for full replacement and deferring cost.




A detailed life-cycle cost analysis can accompany replacement decisions by highlighting the full range of direct and indirect costs and benefits, as well as support full-cost pricing. This is an important change that needs to occur to support an integrated risk management approach.

With asset management plans in place, small, medium, and large municipalities can optimize decision making and reduce environmental, social, and economic risks. Using a sound financial model, municipalities can tackle the infrastructure deficit to implement the recommendations of the asset management plan. Municipalities will have a long-term capital budget to tackle future replacement needs and an operating budget to deal with critical maintenance.

Figure 1 illustrates how the full cost and benefits of infrastructure solutions including externalities could be considered when comparing grey and green retrofit solutions for a municipal road retrofit.

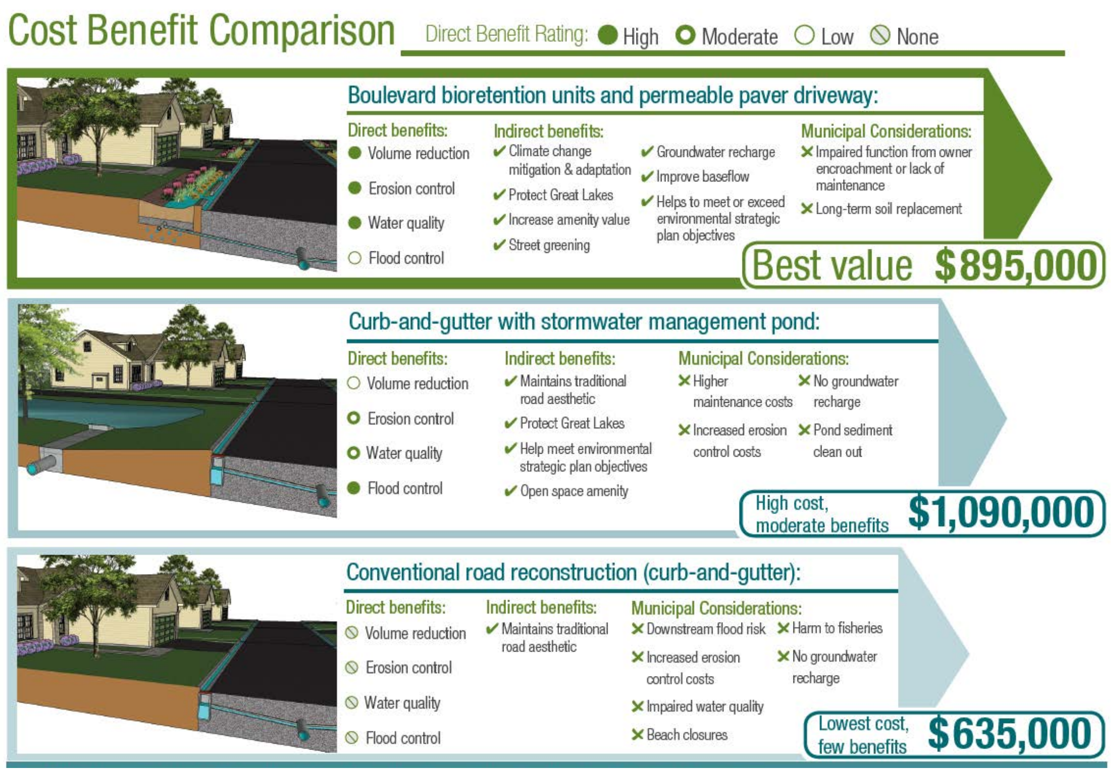



Figure 1: Comparison of road retrofit alternatives for a local residential road. Source: CVC

This chapter will highlight current approaches, tools, and strategies along with potential barriers to integrated financial planning. This includes approaches and methods on how to develop an integrated long-term capital budget and operating budget forecast which implements the asset management plan/strategy, considering the overall impact on service levels and rate payers.

## 1.1 Legislation that supports integrated financial planning

Since the Walkerton Inquiry, Ontario has adopted several pieces of legislation in an effort to support full-cost pricing, including the goal of implementing long-term asset management principles. The following proposed and interim legislation attempts to better define financial plans:

- O.Reg. 453/07- under Safe Drinking Water Act
- Water Opportunities Act - *enacted but no Regulations*
- Public Sector Accounting Board Reporting (PSAB)

### 1.1.1 Ontario Regulation 453/07 (O. Reg 453/07)

In 2007, O.Reg 453/07 was passed by the Ministry of the Environment and Climate Change, requiring the preparation of financial plans for water systems under the *Safe Drinking Water Act*. This was intended as an interim legislation so that municipalities could be licensed to run the water system until regulations for *SWSSA* came into effect.

The regulation only pertained to drinking water and didn't include wastewater and stormwater. These regulations only required municipalities to report on a financial statement basis with annual projections and did not embrace a forward looking approach. Financial statements typically take an accounting approach and follow a Public Sector Accounting Board (PSAB) reporting format.

O.Reg 453/7 was not as comprehensive as *SWSSA* because it didn't look at look at assets, new technologies, growth, impacts on rates, etc. Furthermore, the regulations only required a financial statement which tends to look backwards and not forward.

### 1.1.2 Public Sector Accounting Board Reporting

In 2009, municipalities began to move towards the Public Sector Accounting Board (PSAB) reporting. Municipalities started to integrate financial information such as the value of the assets, amortization, and depreciation to show the full financial picture. This ensured that municipalities developed more detailed records of their infrastructure assets. However, it recorded costs at a historic value. For example, the cost to build water mains 40 years ago is probably 10% of the cost of building them today. Once infrastructure reaches its useful life, the financial books do not accurately reflect the true replacement cost. It is very important that municipalities consider the true cost of replacing the infrastructure assets.

**Figure 2** illustrates the different financial approaches currently in use across Ontario. PSAB and O.Reg 453/07 support the preparation of financial statements that use a backward-looking approach. SWSSA, on the other hand, would have required municipalities to look at the replacement of the future value of the asset.

***Life-cycle costing***

*Life-cycle costs are all of the costs incurred during the life cycle of a physical asset, from the time of its acquisition to disposal. These are the stages of an asset's life cycle: specification, design, manufacture, installation, commission, operation, maintenance and disposal.*

*The life-cycle approach assesses the amount needed in reserves to save for the replacement, assuming inflation and investment rates. If municipalities are going to perform a life-cycle cost analysis to compare for example, grey and green infrastructure solutions, they will need life-cycle costing information. This information is readily available for grey infrastructure but not always for new and emerging green infrastructure technologies.*

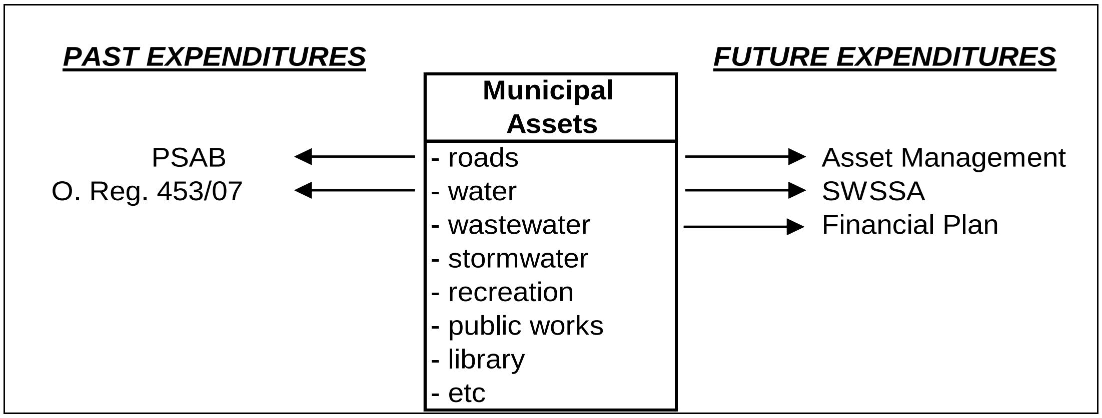



Figure 2: Comparison of different financial approaches.

### 1.1.3 Water Opportunities Act

In 2010, the government passed the *Water Opportunities Act*. The act was introduced to foster innovative water, wastewater, and stormwater technologies, services, and practices. This act also has provisions for the preparation of integrated financial plans. This is a forward-looking approach to improve the overall provision of services, embracement of new technologies, better environmental protection, and assessment of risks that could impact future delivery of services (i.e. climate change). The key drivers impacting today's municipalities (aging infrastructure, climate change, and population growth) must be factored into asset management plans so the financial plan can reflect the costs of dealing with the associated risks.

## 1.2 Elements of a Financial Plan

The 2012 CIRC indicates that of the 346 surveyed municipalities, only 4.5% use complete and reliable assessment data when evaluating stormwater system capacity. Many municipalities use age-based assumptions of condition when assessing the current state of infrastructure assets which presents a significant amount of risk.

Without an understanding of the physical condition of stormwater infrastructure, it is difficult to prepare a comprehensive financial plan that is also integrated with other water infrastructures. **Figure 3** illustrates the typical elements of a financial plan for drinking water infrastructure. The process looks similar for wastewater infrastructure.

Two additional boxes (light blue) highlight how financial plans also need to include a risk assessment and consideration of how new technologies can optimize infrastructure performance. Through a life-cycle cost analysis, municipalities could compare different infrastructure options and technologies to understand how to deliver service at the lowest life-cycle cost in order to understand the influence decisions have on both capital and operating budgets. Water and wastewater typically require a 10 years cycle of budgets, while many small municipalities complete a one-year budget. Integrated lifecycle costing is necessary to ensure that all assets have a comprehensive financial plan.

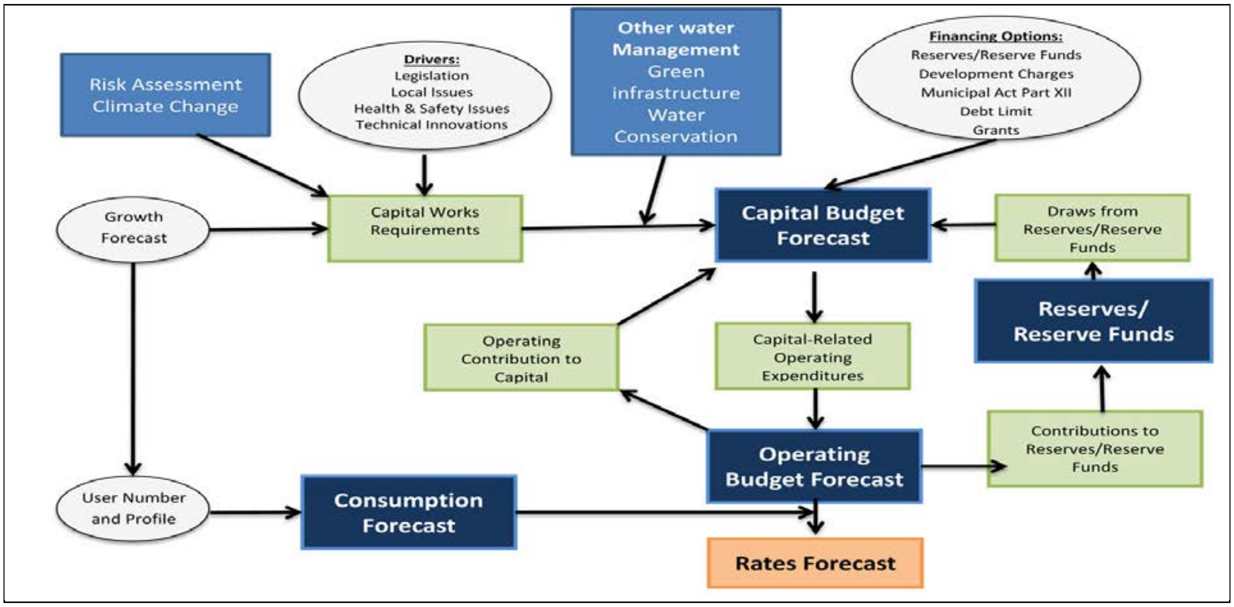



**Figure 3: Typical components of a financial plan with additional considerations to enhance integration. Source: Adapted from a chart provided by Gary Scanlan.**

### 1.2.1 Financing options

Stormwater funding mechanisms are currently in use across Canada and are important for securing a dedicated funding source for municipalities to achieve the required level of service for stormwater management.

**Table 1** outlines the different funding mechanisms in use across Canada for funding stormwater infrastructure.

## Appendix C1: Integrated Financial Planning

**Table 1 Summary of the different types of charge structures for stormwater management infrastructure. Source: Watson & Associates.**

| Type of Charge | Basis for Calculation | Ease of Calculation | Equity | Administration | Public Understanding | Revenue Stability | Revenue Stability Benefit | Economic Development Benefit | Other comments |
|---|---|---|---|---|---|---|---|---|---|
| Property Taxes | Assessment | Easy | Low | Easy | Easy | High | Medium | Tax bill | |
| Flat Rate per Property | Per lot | Easy | Low | Easy | Easy | High | High | Tax or rate bill | May be varied between residential and non-residential to reflect differences |
| Size of Property | Area of Property | Medium | Medium | Easy | Easy | High | Medium | Tax or rate bill | Often gaps in Assessment Data – need to supplement with GIS or site visit |
| Utility Rate | Water Meter Readings | Easy | Medium | Easy | Medium | High | Medium | Rate bill | |
| Run-Off Coefficient | Area and Use of Property | Difficult | High | Medium | Difficult | High | Low | Tax or rate bill | |
| Impervious Area of All Properties | Measured Impervious Area | Difficult | High | High level of maintenance | Difficult | High | Low | Tax or rate bill | Need to monitor building permits and update data – need detailed review every few years |

Funding for asset management plans can come from a variety of sources. The Federation of Canadian Municipalities outlines a variety of different options for finding funds to finance infrastructure renewal, including:

- Property tax
- Income tax
- Retail sales tax
- Land transfer tax
- Fuel tax
- Development charges
- Parking fees
- Hotel and accommodation fees
- Municipal financing authorities (CUPE 2014)

## 1.3 Potential barriers to integrated financial plans

***Governance***

Service easements for water, sanitary, and stormwater system within roads can cause challenges in integrating services between upper and lower-tier municipalities. Integrated financial plans would improve coordination between upper and lower-tier municipalities in terms of timing of construction (i.e. when services need to be repaired or replaced). Lack of funding adds to the complexity of challenges in terms of affordability for service.

***Legislation***

In Ontario, there is legislation for water and some emphasis on wastewater. However, there is very little legislation for stormwater. Usually legislation is focused on target and performance but does not have any direct requirement for asset management or financial matters. It is also focused on individual service and there is no legislation enforcing integrated financial planning.

***Cost and affordability***

Incorporating new technologies, building infrastructure resiliency, and increasing service performance requires additional budget. Newer technology may influence legislation, but implementation could be costly. Municipalities have invested a lot of money in water and wastewater. In communities with older infrastructure, the cost of replacement is very high. This makes adding newer technology challenging, especially when municipalities consider population growth, climate change, and aging infrastructure.

Other matters to consider include historic approaches that tend to be generic and not specific to areas and regions. Municipalities need to consider climate, population, and economic variation between different regions.

Eventually, integrated planning could become a requirement for provincial infrastructure funding. For example, the *Water Opportunities Act* (regulations pending) could require municipalities to prepare a sustainability plan in order to get access to provincial funding.

***Green Infrastructure Lifecycle Costs***

Information about infrastructure lifecycle costs is needed to support the preparation of integrated financial plans. To support life-cycle costing methods for comparing solutions (i.e. grey versus green infrastructure), it is important that practitioners have access to life-cycle costing data to make informed decisions. Monitoring demonstration projects such as one water projects and collecting data on performance, operation and maintenance costs will support decisions at both the municipal and provincial level. Decisions that can be made with fewer assumptions reduce risk and uncertainty and make the life-cycle costing approaches easier to apply to non-traditional infrastructure projects (i.e. green infrastructure).

## 1.4 Recommendations

In general, financial plans should reflect an understanding of how infrastructure optimization can be performed between the three infrastructure systems. For example, how can improved stormwater management impact downstream assimilative capacity for a wastewater treatment facility? Is it more cost effective to retrofit existing urban areas with green infrastructure or upgrade the WWTP facility to achieve stricter targets? In general, integrated financial plans should consider:

- The costs associated with dealing with risks that may interfere with current and future delivery of municipal water services, including climate change;
- Cost efficiencies and added value that can be achieved through collaborative planning within and between municipalities;
- Take into account cost comparisons (based on the entire life cycle) for conventional and innovative infrastructures, technologies and practices that promote efficient water use and reduce adverse impacts on water resources (e.g. green infrastructure, LID);
- Reflect the cost to properly integrate provincial and municipal plans and policies, land use planning and infrastructure planning;
- Costs needed to building capacity and resiliency in water, stormwater and wastewater management.

The social/economic and environmental return on investment (ROI) is a term that is not often reflected in financial plans and statements and provides a indication of how effective an organization uses its capital and other resources to create value for the community. The challenging part to calculating the ROI, is quantifying the financial benefits for public health, the economy and the environment.

**Appendix C1: Integrated Financial Planning**

Making the paradigm shift to a "one water approach" would require developing a financial plan that can answer questions such as:

- What are the "deferred or avoided capital expenditures" of taking a green infrastructure approach over a gray infrastructure approach? What are the savings in operation and maintenance costs?
- How can innovative water management approaches "extend the lifespan of existing conventional infrastructure"?

The ROI can help develop integrated financial plans that demonstrate an understanding of the full cost and benefits of infrastructure, including externalities. For example,

- How applying the "right water for right use "can reduce water treatment costs;
- How the recovery of valuable resources (reclaimed water, nutrients, carbon, metals and biosolids) from "wastewater" can offset potable water costs, fertilizers, and generating power;
- The value of harvesting stormwater for water supply, irrigation, and/or infiltration benefits;
- Demonstrating how multiple decentralized small water treatment and distribution systems combining local needs and the triple bottom line;
- How new infrastructure design technologies and strategies to address today's complex water problems.

Integrated financial plans are also an excellent to help justify budgets/investment, better focus on priorities and understand the risks/consequences of alternative investment decision.

# Appendix C2

## FINANCIAL TOOLS AND MODELS TO SUPPORT AN INTEGRATED WATER SUSTAINABILITY PLAN

## Appendix C2: Tools and Models to Support an Integrated Water Sustainability Plan

### Table C.2.1 Financial Tools that can Support an Integrated Water Sustainability Plan

| Tools | Description |
|---|---|
| STEP Low Impact Development Practices Costing Tool | A spreadsheet decision support tool based on the cost calculations, developed to assist industry professionals estimate the capital and life cycle costs of site specific LID practice designs. [vi] |
| Business Case Evaluator | Developed to enhance the Envision Tool by adding the ability for it to provide value based and risk adjusted analyses of infrastructure projects. [vii] |
| PRISM- A Triple Bottom Line Decision Tool | A comprehensive project/ program evaluation tool used extensively on a full range of transportation projects for evaluation TBL factors. The economic capabilities include cost benefit, and wider economic impacts resulting from improved regional accessibility. [viii] |
| Sustainable Return on Investment (SROI) | A framework that has been used to measure the triple bottom line impacts of a project. It determines full value of a project through a robust economic-based approach to estimating all relevant cost and benefits and develops tangible indicators to community the full value of the investment. [ix] |
| Zofnass Economic Process Tool | A platform that offers ways to achieve preliminary quantification of sustainability externalities in infrastructure projects based on the Envision ® rating system. [x] |

[vi] http://www.sustainabletechnologies.ca/wp/home/urban-runoff-green-infrastructure/low-impact-development/low-impact-development-life-cycle-costs
[vii] http://www.impactinfrastructure.com/businesscaseevaluator/
[viii] http://sustainableinfrastructure.org/downloads/index.cfm
[ix] http://www.hdrinc.com/about-hdr/sustainability/sustainable-return-on-investment
[x] http://economictool.zofnass.org/

# Appendix D

## OPERATIONS AND MAINTENANCE COSTS FOR LOW IMPACT DEVELOPMENT

# Appendix D1

## CASE STUDY: HALTON HILLS STORMWATER ASSET MANAGEMENT FRAMEWORK

## Background

The Water Opportunities Act specifies the need to develop Water Sustainability Plans, which include Asset Management Plans (AMPs) for all municipal water infrastructure including water, wastewater, and stormwater. Traditionally, stormwater has been treated as a waste product requiring rapid drainage away from roofs, lawns, driveways and other areas, and not as a resource that can be used to support both communities and the environment. At the same time, municipalities in charge of maintaining drainage for the protection of life and property are struggling with tremendous budgetary shortfalls as existing stormwater infrastructure reaches the end of its intended design life and requires replacement. This case study highlights how the small, lower-tier municipality of Halton Hills is taking steps to fully integrate stormwater within an asset management framework.

## Study Area: Town of Halton Hills

**Halton Hills**

Halton Hills is a two- tiered municipality located in the Region of Halton, which is in turn nested within the Greater Golden Horseshoe Area (GGHA). It is a community of several smaller towns, villages and rural settlements and is includes the amalgamated towns of Halton Hills, Georgetown and Acton. Halton Hills straddles both the Silver Creek and Black Creek sub watersheds.

The current population of Halton Hills is 59,008 (Statistics Canada, 2014). According to the Sustainable Halton Growth Plan, anticipated growth in the Town is expected to include an additional 40,000 residents, bringing the total population to 90,200 residents within the Town of Halton Hills by 2031. The increase in the total number of residents is anticipated as a result of a combination of normal growth rates as well as pressures owing to Ontario's Places to Grow Act, the Greenbelt Plan and recent Provincial Policy Statements.

**Vision Georgetown**

Using 14 guiding principles, the Town of Halton Hills has embarked on an ambitious, five-stage project expected to be completed by 2017. The project is called 'Vision Georgetown', and is described as follows:

***"The Vision Georgetown community is an inspiring new urban community; distinctive in the way it looks and functions, fostering healthy lifestyles, neighbourliness, economic prosperity, and local pride. It is a resilient, sustainable, complete, and compact community, with a thriving natural heritage system. It feels like a small town and is physically connected to the broader community of Georgetown and the Town of Halton Hills. It honours the rich heritage of the Town, emphasizes people, and provides choices for day-to-day living. Overall, the Vision Georgetown community is an exceptional, forward thinking, and innovative model for new community development."***

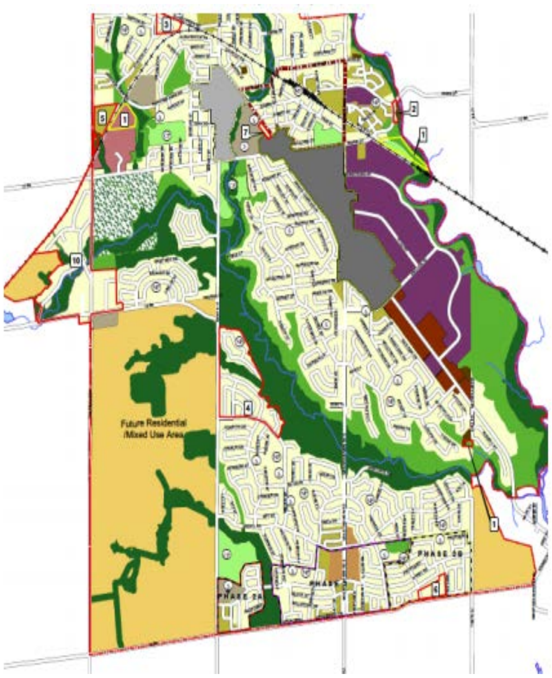
(http://www.haltonhills.ca/visiongeorgetown/index.php)

Halton Hills is preparing for the next phase of development through the Vision Georgetown initiative. The new community envisioned through this project will play a critical role in Halton Hills' ability to accommodate projected population growth by 2031. Georgetown is slated to receive an additional 20,000 residents along with businesses providing 1,700 jobs, a mix of single and semi-detached houses, townhomes and apartments.

**Municipal Water Systems**

All municipal wells within Acton and Georgetown are considered 100% consumptive as the water is pumped from groundwater and distributed for consumption by area residents before being discharged to Black and Silver Creeks via the waste water treatment plants in these areas.

A comprehensive infrastructure management program was developed for key greenfield growth areas in Milton and Halton Hills, and the common infrastructure requirements necessary for intensification and common capacity upgrades for treatment, pumping and storage were estimated. The total program was developed for each Growth Concept.



**Future Demands on Water Infrastructure**

Some factors influencing the future demand of infrastructure in Halton Hills include:

- Population Growth
- Environmental Factors
- Economic Factors

Population Growth: The addition of 20,000 residents to the area by 2031 will result in an increased demand for potable water, increase treatable wastewater volumes and contribute greater amounts of stormwater.

Environmental Factors: Climate change projections indicate that Halton Hills is situated within a region that will face an increasingly extreme climate in the future. Intense, short-duration rainfall events are expected to become increasingly common, and ~~are~~ will likely be interspersed with lengthening periods with little to no rainfall. Increasingly intense rainfall events have the potential to overwhelm stormwater infrastructure designed to accommodate historical conditions, resulting in damage to buried assets. Prolonged dry periods are expected to result in an increased demand for potable water, largely for lawn and garden irrigation.

Economic Factors: 1,700 new jobs will require that existing water infrastructure services be expanded. The businesses where they jobs will be located are going to require the installation of additional water utilities, further underscoring the need to plan for smart growth.

## Leadership in Stormwater

Through its forward-thinking policies surrounding LID and stormwater asset management, Halton Hills has positioned itself as leader in the arena of progressive stormwater management. This is particularly true when compared to similarly-sized jurisdictions. Municipal policies and directives have been invaluable in this respect because, given the fact that the Town is charting a new stormwater management process, political will and support are necessary to implement both green infrastructure as well as the policies surrounding it. Leadership is exemplified in several respects:

**Initiation of Pilot Projects and Case Studies**

The Halton Hills has encouraged the construction of new pilot projects aimed at finding innovative ways to manage stormwater as a resource, reduce infrastructure costs and protect the environment. Bringing together consultants, developers and Credit Valley Conservation (CVC), Halton Hills boasts a residential development project emphasizing the use of bioretention gardens, soak away pits and other green infrastructure as part of an approach that will enhance the performance of traditional conveyance and end-of-pipe systems.

**Progressive Attitudes and Thinking**

The Halton Hills administration encourages progressive thinking and innovative ways of leveraging existing resources in a number of respects. The Town has adopted an asset management framework to track and maintain infrastructure ranging from roads, bridges and culverts to manholes, storm sewers and stormwater facilities. This has allowed the Town to estimate future infrastructure costs several years in advance of any costs being incurred. It has also allowed for the efficient budgeting of staff time for maintenance activities and the maintenance of a high level of service from existing infrastructure.

**Coordination across Governments**

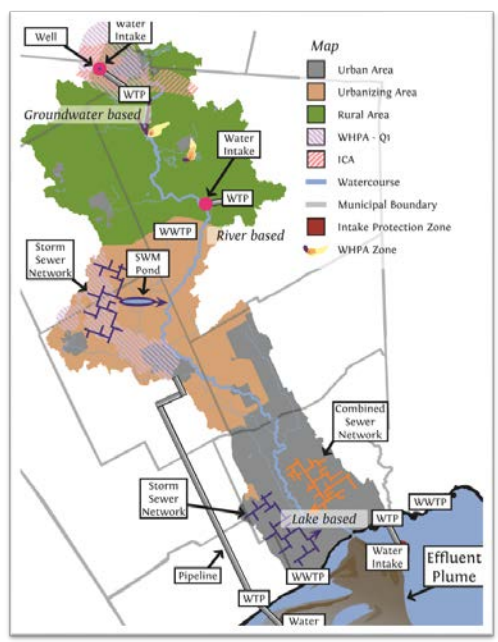
As a small municipality, Halton Hills has worked diligently to leverage existing resources through the formation of partnerships. The Town has partnered with the Region of Halton to conduct annual closed circuit television (CCTV) inspection of a limited number of stormwater pipe sections (approximately 5 km of pipe per year in Halton Hills). To support the needs of the capital program, collaboration has allowed Halton Hills to achieve an economy of scale while also allowing it to collect valuable data related to the condition of its buried infrastructure – something many small municipalities are unable to do. Halton Hills has also partnered with the Town of Milton and the City of Burlington to inspect and maintain all municipally-owned oil grit separators (OGSs). This is yet another example of how the costs of owning and maintaining infrastructure are being reduced through collaborative approaches to maintenance.

Above: Camera vehicle used for CCTV inspections

## A New Paradigm: The One Water Approach

Drinking water, wastewater and stormwater infrastructure have traditionally been managed separately form one another by different departments. This is further complicated by the fact that stormwater is managed locally while drinking water and wastewater services are provided at the regional level. Dividing responsibility for these services leads to management challenges wherever they various systems overlap and interact with one another.  For example; excess stormwater can enter sanitary sewers through directly connected downspouts and foundation drains, or through joints and cracks in buried subsurface pipe networks. Either of these issues can cause wastewater treatment plants to become overloaded during large rainfall events. Similarly, large amounts of stormwater runoff from urban areas and pollute receiving streams and lake environs, and this has the potential to impact drinking water treatment systems. These and many other issues underscore the need to manage water holistically using a One Water Approach.

Recognizing that water in all forms is connected and that management decisions in one area produce cascading impacts across all systems (below), the One Water Approach integrates the various water systems and leverages their interactions to produce desirable environmental and societal outcomes. One way in which is achieved is through the use of a combination of grey and green infrastructure management approach.



## Grey and Green Infrastructure

### Grey Infrastructure

Traditional or 'grey' infrastructure refers to the common elements associated with the movement, storage and treatment of stormwater, drinking water and wastewater. For drinking water and wastewater, grey infrastructure includes things like pumps and treatment plants. For stormwater, grey infrastructure includes things like oil and grit separators (OGSs) and catch basins. All water systems include buried pipes as part of their grey infrastructure complement. Halton Hills maintains an extensive system of stormwater infrastructure, including 189,750 m of pipe, 5,833 (182 ditch inlet CBs, 842 double CBs, 23 lawn CBs and 4,407 single CBs), 69 large culverts (>3 m), 1,898 driveway culverts, 42 stormwater ponds and 18 OGSs.

### Green Infrastructure

Green infrastructure (GI) uses vegetation, soils and natural processes to manage water and create healthier urban environments. At the watershed scale this includes natural areas like wetlands, floodplains and forests that provide groundwater recharge, stormwater treatment, flood protection and pollutant removal, in addition to the benefits of cleaner air and wildlife habitat (US EPA, 2014). At the neighbourhood or lot level, GI includes ~~things like~~ permeable pavements, bioretention facilities, rain gardens, soak away pits and others. Collectively the use of these features is referred to as low impact development (LID). The main difference between natural areas and the constructed lot-level controls is that the latter use engineering design principles and specially-selected plant species, soils and other elements to maximize the feature's ability to detain, infiltrate and clean stormwater as it is infiltrated back into the ground or discharged to receiving environs. Combined, all of these features are referred to as 'green' infrastructure, and can be expanded to include urban trees, parks and other features. Some examples of green infrastructure are presented below.

Top: Bioretention facility at Elm Drive Education Centre, Mississauga. Middle: Permeable pavement sidewalk and driveway at Meadows in the Glenn, Halton Hills. Bottom: Enhanced swale at Meadows in the Glenn, Halton Hills.

## Driving the Move to a New Approach

Asset management is the practice of taking stock of all the physical components of an infrastructure system, assessing their condition and determining the required maintenance schedule needed in order to maintain a desired performance level (US EPA, 2012). In practice this is an incredibly challenging task which is complicated by the fact that many assets are buried out of site, and hence do not lend themselves to straightforward inspections.

While traditional approaches to asset management have focused predominantly on grey infrastructure, the use of a One Water Approach requires that full consideration also be given to the full complement of green infrastructure mentioned previously. Despite the added complexity this adds, there are a number of reasons why municipalities should pursue the approach being developed by Halton Hills.

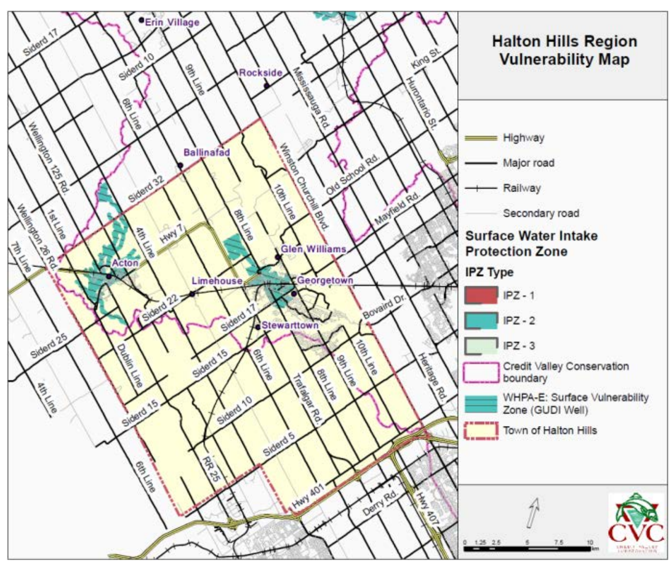
**1. Reducing Risk and Liability**

Any agency which manages infrastructure to provide a public service has a duty to minimize risks to area residents and the environment. The sources of risk are varied and take many forms; in Halton Hills it includes the following:

i. Climate Change
ii. Population Growth
iii. Aging Infrastructure
iv. Water Supply and Source Water Protection
v. Assimilative Capacity
vi. Public Health

As noted, climate change poses risks to Halton Hills existing infrastructure due to the fact that it may no longer be adequately sized to convey the peak storm flows or withstand the drought conditions anticipated under future climate scenarios. Furthermore, as the population in Halton Hills continues to grow – largely in response to Provincial Policy – increasing demands will be placed on all water infrastructure types, including stormwater.

As Halton Hills' stormwater infrastructure ages it will require ongoing maintenance, repair and – eventually – replacement. Without a proper asset management plan it becomes very difficult to plan for maintenance tasks at critical periods within an asset's life, or to budget for associated expenses. Halton Hills is situated within both the CTC and Halton-Hamilton Sourcewater Protection Regions (SPRs), and the Town's boundaries encompass two separate municipal drinking water recharge areas. This underscores the importance of Halton Hills' innovative stormwater approach; the use of LID and green infrastructure is necessary to capture, clean and infiltrate stormwater into the soil. Capturing, cleaning and reusing stormwater recharges groundwater supplies and provides the basis for sustainable drinking water. It also reduces impacts to receiving streams and provides the baseflow necessary to support the safe assimilation of wastewater discharges to receiving streams (often referred to as 'assimilative capacity'). In this way the efforts of Halton Hills recognize and support the One Water Approach. This also works to reduce the peak flows and potential for environmental damage in the Black Creek subwatershed, which encompasses a large portion of Halton Hills. Using well-maintained infrastructure like stormwater ponds in conjunction with LID, Halton Hills is able to capture large volumes of stormwater and release it slowly over time if at all, thereby reducing flood risk, maintaining water quality and protecting the waters of Black Creek.




Above: Wellhead Protection Areas (WHPA's) in and around Halton Hills.

Responsible management of stormwater assets can ultimately influence public health as well. The use of a stormwater treatment train that cleans and infiltrates stormwater on its path to receiving streams can help to both cool the water and remove sediments, metals and nutrients, in addition to reducing the total volume of water itself. Cleaning and cooling stormwater runoff before it enters streams helps to reduce the frequency and duration of beach closures, and it also works to suppress the occurrence of nuisance algal growth. Excess algal growth along the nearshore area of Lake Ontario can impact the operation of drinking water treatment plants, which underscores the need to pay attention to this important issue.

## 2. Meeting Current and Emerging Policies and Legislation

### Water Opportunities Act

The Province of Ontario through the Provincial Policy Statement (PPS, 2014) and Water Opportunities Act will be requiring municipalities to evaluate water infrastructure risks in light of climate change and optimize their management of infrastructure assets through integrating water, wastewater and stormwater management. Specifically, the Water Opportunities Act provides the Province with the authority to make regulations requiring municipalities to prepare Municipal Water Sustainability Plan that may require the development of asset management plans and an assessment of risks that may interfere with the future delivery of municipal service, including climate change.

### Provincial Policy Statement

The 2014 Provincial Policy Statement (PPS) includes a number of important directives which speak directly to the need to address climate change, environmental and infrastructure-related concerns at the municipal level. Together, Sections 1.1.1, 1.6.1, 1.6.2, 1.7.1 and 3.1.1 highlight the needs to promote development that conserves biodiversity and consider the impacts of a changing climate, demonstrate the financial sustainability of infrastructure through asset management planning and promote a mixture of grey and green infrastructure, amongst other aspects.

### 2031 Strategic Plan

Halton Hills has produced a comprehensive Strategic Plan to guide the Town's development up to 2031. While many aspects of the plan overlap with sustainable planning and the One Water approach, Goals B and H are particularly relevant:

**Goal B: Preserve, Protect and Enhance our Environment.** This Goal is comprised of six objectives related to the protection and conservation of water quantity and quality, protection of natural heritage systems and the adoption of an "environment-first" philosophy, amongst other objectives.

**Goal H: Provide Sustainable Infrastructure and Services.** Six objectives listed under this section have been designed to "maintain and enhance community infrastructure and services that support our quality of life".

### Sustainable Halton Plan

Broken into four discrete phases, the sustainable Halton Plan is comprised of 22 technical reports, 10 land use concepts, and 12 technical reports regarding the concepts plans as well as an overall fiscal affordability analysis. The process identified key features of both the environment and society requiring consideration through Sustainability Directions Report and ROPA 37: Official Amendment to the Regional Growth Plan.

### Halton Hills Green Plan

In 2008 Town Council approved Halton Hills' Green Plan, a document highlighting current responsible management initiatives as well as future directions for infrastructure, energy and other services. Mayor Rick Bonnette said at the time:

*"My concept for a Green Plan imagines Halton Hills to be a community of leaders – not followers"*
-Rick Bonnette, Mayor

The Green Plan provides Town residents with practical guidance related to home maintenance that can reduce risk to extreme weather while being sensitive to the operation of the towns energy and water infrastructure

### MOECC Bulletin

In February, 2015 the Ministry of Environment and Climate Change (MOECC) released a clarification bulletin regarding the management of stormwater in new development and redevelopment sites going forward. The bulletin emphasized the need to adopt LID in order to maintain predevelopment hydrologic conditions as follows:

> **Going forward, the Ministry expects that stormwater management plans will reflect the findings of watershed, sub-watershed, and environmental management plans, and will employ LID in order to maintain the natural hydrologic cycle to the greatest extent possible.**

## Applying an Integrated Approach to Stormwater Asset Management

Halton Hills has recognized the shortcomings of traditional approached to both the management of stormwater and the assets required therein, and has moved to develop a comprehensive plan to inventory and maintain assets and features owned by the Town, and also to develop fair and equitable funding mechanisms required to effectively manage assets capable of providing a desired level of service. Within the integrated approach taken by the Town, many novel innovations have been developed that leverage the resources of neighbouring municipalities and new developments stemming from growth policies, and these are summarized below.

### Policy Steps taken by Halton Hills

#### Stormwater Management Policy, 2009

The 2009 Stormwater Management Policy document released by Halton Hills is intended to implement the MOECC's SWM Practices Planning and Design Manual in order to achieve the highest level of aesthetics, environmental benefits, ease of maintenance and multifunctional utility for stormwater management facilities in the Town of Halton Hills. On top of providing clear planting guidelines for SWM facilities, this document requires that all developers submit the detailed engineering calculations used to design stormwater systems, in addition to both design and as-built survey drawings. It also requires developers to maintain stormwater ponds for two years and clean out accumulated sediments, if necessary, before ownership is assumed by the Town.

#### Low Impact Development Guidelines, 2014

In 2014 Halton Hills' Infrastructure Services Department released its Low Impact Development Maintenance Guidelines, which describe the structure, function and maintenance requirements of permeable pavement, infiltration gallery and sumpless catch basins, amongst other technologies. Using a combination of photographs and

#### Stormwater Management Facilities, 2015

In order to directly support the Town's asset management planning, this document identifies specific informaiton needs and current gaps inhibiting complete asset management planning

#### Stormwater Management Systems Update, 2015

In conjunction with the SWM Facilities update, this document is meant to highlight the specific data needed in order to enable asset management, with the distinction that this document is tailored to the management of linear conveyance infrastructure including pipes, catch basins, manhole and outfalls.

#### Asset Management Plan, 2014

In 2014 Halton Hills released its formal Asset Management Plan, which provides a framework for how the town will manage its bridges, roads and other major transportation-related infrastructure. This document supports the Town's Strategic Plan and includes detailed information on asset inventory, asset age distribution and a condition assessment, amongst other details.

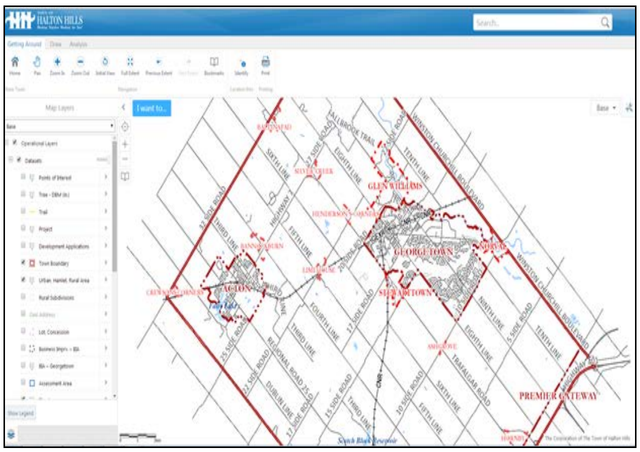
ASSET MANAGEMENT PLAN
FEBRUARY 2014

### Supporting 'One Water' Through Concrete Actions

As a small Town, Halton Hills has limited financial, staff and materiel resources. Facing these challenges the Town has developed innovative approaches to managing its stormwater assets, which are highlighted below

### MapLinks Data Portal

Halton Hills adopted a centralized data storage repository for the storage, display and management of all spatial and conditional data related to the Town's stormwater assets, including pipes, bridges culverts, OGSs, and ponds. This system has been expanded to include the Town's park and pavement assets as well. The database also includes basic characteristic information like diameters and sizes of pipes, pipe slopes, and so on. A screenshot of the MapLinks interface can be found below.



### Summer Student Asset Inventory Program

Halton Hills developed a summer student work experience program that involved hiring two students during the summer months tasked with pinpointing the GPS coordinates of all culverts in and around the Town of Halton Hills. Since the intention of this exercise was to build a database, representatives from the Town mapped drivable routes and the students incrementally traversed the entire Town, recording basic locational information for all culverts as they went. The collected data was used to populated the MapLinks data portal for these features (below)

Above: Infrastructure Planning Team Members Michelle Mathies and Steve Grace showcase asset data collected through the summer student work experience program.

### Coordinating Efforts to Leverage Resources

In order to achieve an economy of scale, Halton Hills has collaborated with both the regional and neighbouring municipalities to survey and maintain assets owned by these groups. One outstanding example of this is Halton Hills' partnership with the Town of Milton and City of Burlington to pool their OGSs into a single large contract for maintenance and cleanout.

Another example of this is the Town's CCTV partnership with Halton Region, which allows Halton Hills to survey 5 km of storm sewer pipe each year as part of the Region's larger CCTV survey contract. The coordination of these capital programs ensures that tax payers are receiving good value for their money. As noted, the Town has incorporated the asset inventory data from the Region into its MapLinks database, which informs decisions the Town makes regarding excavations and other intrusive work that could potentially damage infrastructure if its location is not noted. These initiatives have allowed Halton Hills to carry out activities to an extent which would otherwise be unaffordable, and they provide an excellent example of how and upper and lower tier municipality can coordinate their asset management plans.

### Funding Responsible Management: A Two-Pronged Approach

Owning, operating, inspecting, maintaining and, ultimately, replacing assets is a responsibility that is neither cheap nor straightforward. However, a proactive management system is significantly cheaper than a reactive approach to dealing with breakdowns and failures as they happen. By some measures, fixing failures is over 350% more expensive than monitoring the condition of buried assets and replacing them as they near the end of their useful life. In light of this, it is important to recognize that only smart development which is financially sustainable should be encouraged.

**Sustainable Funding for New Development**

In order to fairly capture the true costs of owning development stormwater facilities, Halton Hills has developed a process where the full lifecycle cost of stormwater facilities to be assumed by the Town through development and the estimated full lifecycle cost needs to be calculated in advance. After this number has been calculated, the net present worth of the future maintenance cost is computed assuming a useful service life of 50 years and a compound interest rate of 5%. This approach determines what the fair and transparent sustainable funding needs to be, and is described mathematically below.

$$PV = \sum_{t}^{T} [M \times (1 + r)^{-t}]$$

*Where,*

*PV =* *Present value*

*M =* *Sum of maintenance costs that are required to be performed every t years*

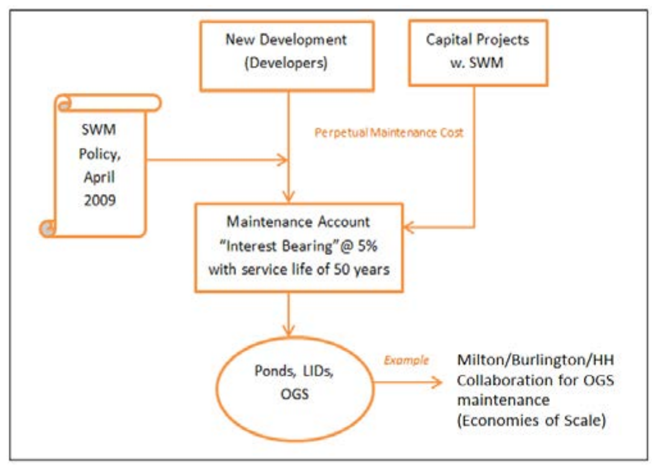
*t =* *The interval between maintenance activities in years (interval between maintenance is equal to the step of the summation; i.e. if the interval is 3 years, the summation proceeds with t = 3, then, t =6, then, t = 9, until t = T (where T = 50, the assumed service life of the SWMP)*

*r =* *Annual interest rate*

The maintenance cost, M, represents the costs to ensure the proper operation, longevity and aesthetic functioning of the stormwater control measures. The owner's Consulting Engineer is required to provide a report detailing the maintenance recommendations that determine the ultimate value of M, and this includes:

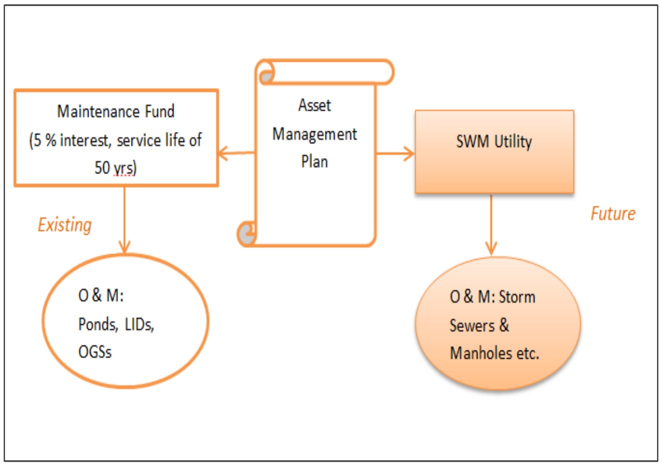
1) Inspection protocol (checklist) for all structures and how often inspections need to be done (minimum of once annually)
2) Sediment removal (frequency and volume)
3) Method of re-stabilization for all disturbed areas
4) Sediment testing requirements for the determination of method of disposal
5) Effluent sampling protocol

A predetermined procedure is followed to calculate the present value of maintenance costs for the SWM facilities and is submitted to the Town of Halton Hills for review and approval. This ensures that sufficient funds are available for perpetual maintenance of the stormwater management pond. The above calculations, actions and requirements mutually support Halton Hills' new stormwater policy via the following process flow diagram:




**Covering Existing Asset Liabilities**

As part of the Town's Asset Management Plan, it was recognized that there is no current mechanism in place to cover the maintenance and replacement costs of existing development outside of the general budget. In order to meet MEDEI asset management planning requirements and to ensure that the Town's pre-existing infrastructure is sustainably management going forward, Halton Hills is currently in the process of developing a stormwater utility with rates to be determined based on the ongoing maintenance requirements of the Town's existing infrastructure not captured by the new development charge. While not currently in operation, the conceptual framework governing the application of the stormwater utility is currently being reviewed, and is expressed as follows:




## Limitations of the Existing Framework

Halton Hills has made significant strides when it comes to the proactive management of its stormwater assets, something that is all too often neglected by small municipalities which lack the resources needed in order to undertake such an endeavor. However, despite the positive steps taken by the Town, work remains to be done and is summarized as follows:

- The Town has not yet implemented a stormwater utility rate system. This may be due to a combination of factors, including pushback from area residents, a lack of political will, a persistent need to inventory outstanding assets or other factors. Until a utility is operational, the management of stormwater assets will be incomplete.
- The current LID maintenance guide released by Halton Hills includes only a limited number of different LID feature types and is not comprehensive. The choice to include only certain features reflects the current inventory of LID the Town currently owns. However, not including a broader suite of LID can serve as an impediment to new the construction of a more fulsome complement of LID features types. As a remedy to this, Halton Hills could draw on the expertise of CVC and adopt items from its LID Construction and Maintenance Guide
- The Stormwater Facilities Management document does not currently include any guidance on how to complete a stress test. Stress tests are a useful tool for assessing the robustness of stormwater controls, and are useful for verifying the performance of stormwater infrastructure before ownership is assumed by the Town. Stress tests are unique for each type of infrastructure. For example; the stress test for an OGS could include the use of a tanker truck to pour a premade slurry of sediment-laden runoff in order to assess the sediment trapping efficiency of the unit. Ultimately, the use of stress tests will help to ensure that Halton Hills assumes ownership of only functional infrastructure, and that the public will not be 'on the hook' for the replacement of noncompliant features and facilities.
- While the MapLinks software used by Halton Hills has been expanded to include infrastructure from the Region of Halton, the Town's database is not currently shared with the Region. Information about green infrastructure (both LID and NHS) is currently not included within the MapLinks database. In the future, broader integration of agency assets within the database would benefit both Halton Hills as well its partners.
- The CCTV data can be better integrated within the existing asset inventory software, as it is currently stored on discs which are not readily accessible through a desktop computer. Better incorporation of the CCTV data will help to

## Lesson Learned

Through its 'Vision Georgetown' initiative, Asset Management Plan, Low Impact Development Guidelines and updated Stormwater Management documents, Halton Hills has demonstrated what can be achieved when visionary leadership is coupled with robust strategic thinking to leverage resources and move towards a sustainable future. The Town's willingness to adopt new software, partner with neighbouring municipalities and adopt new mechanisms to ensure sustainable infrastructure funding have positioned the Town's residents to be the benefactors of a sustainably-funded and well-managed community well into the future. Encouraging the adoption of LID features within new and existing developments can reasonably be expected to help ease the strain extreme events place on Halton's aging stormwater infrastructure. This is particularly important given that climate change is expected to exacerbate extreme events.

Another lesson learned through this comprehensive planning process is that new development applications are requiring all parties involved to develop an understanding of what the available infrastructure's capacity is. This is true not just for stormwater, but for municipal drinking water supplies, wastewater treatment facilities and other utilities in within the Town.

## Going Forward

Going forward, Halton Hills is well-positioned to capitalize on the integrated work that has already been done with the MapLinks software by continuing to draw in the asset inventory data of its partners. Including NHS and other infrastructure data from CVC and others – and sharing this data with relevant partners – will ensure that the location and basic characteristics of each party's infrastructure is known to all others. Knowing the location of critical buried utilities before excavations for the repair or replacement of adjacent services is undertaken can help to save significant cost through the avoidance of unintentional damage.


## Acknowledgements

The author would like to sincerely thank Steve Grace and Michelle Mathies from the Town of Halton Hills for their significant contribution of time to this case study. Their willingness to provide documents, information and insight have been invaluable in helping to develop an understanding of the Town's numerous activities related to integrated asset management, sustainability planning and the One Water approach.

# Appendix D2

## OPERATION AND MAINTENANCE COSTS FOR LOW IMPACT DEVELOPMENT

**Appendix D2 – Operation and Maintenance Costs for Low Impact Development Sites**

Typical operational costs for LID sites are summarized in Table D.2.1.

**Table D.2.1: Typical Maintenance Costs by Activity for LID Measures (Source: Aquafor Beech)**

| Activity | Maintenance Interval (years) | Unit | Cost Per unit |
|---|---|---|---|
| Litter Removal | ½ | ha | $ 1,000 – 2,000 |
| LID Litter Removal | ½ | $m^2$ | $ 0.20 |
| Weed Control | 1 | ha | $ 1,000 |
| LID Weed Control | 1 | $m^2$ | $ 0.20 |
| Landscape Restoration | 10 | ha | $ 1,000 |
| LID Landscape Restoration | ½ | $m^2$ | $ 0.20 |
| Sediment Removal and Disposal (Heavy machinery) | 10 | $m^3$ | $ 300-350 |
| Sediment Removal and Disposal (Vacuum Truck ) | ½ | $m^3$ | $120-250 |
| LID Sediment Removal (manual) | ½ | $m^3$ | $ 50-100 |
| Soil sampling and infiltration testing | 10 | L.S. | $ 1,000-1,200 |
| Inspection of Inlet/Outlet | 1 | L.S | $ 150 |
| Pervious pipe/ underdrain cleanout (8-10m/hr) | ** | hr | $ 850 |
| Infiltration media restoration (tilling and re-vegetation) | ** | $m^2$ | $ 150 |
| Shrub Replacement | ** | each | $ 20-40 |
| * Routine maintenance **when necessary (repair item)<br>(Source: MOE, 2003; Halton Hills, 2009, Aquafor Beech 2014) | | | |

# Appendix E

## WALKING THE WATER SOFT PATH

# Walking the Water Soft Path:

## York Region Water Strategy Puts Theory into Practice

By Patrick Gilbride and Carol Maas

POLIS Project on Ecological Governance
watersustainabilityproject

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# 1 Introduction

Communities around the world are recognizing the impending risks of a changing climate, limited financial resources, and large infrastructure deficits for water supply and disposal. Within this context, expanding centralized infrastructure and sourcing additional water when an alternative exists no longer makes economic or ecological sense. Several communities in North America have now acknowledged that current water-use patterns are unsustainable and are embracing a commitment to finding the water they need through conservation and recycling, a concept that proponents of the "water soft path" refer to as "No New Water." The water soft path is a water management strategy that prioritizes improving the efficiency and productivity of water use over developing new sources of supply. Unlike traditional water supply planning, the soft path approach begins with identifying a desired future vision, prioritizes collaborative decision-making, and considers ecological integrity a core value in that decision-making.[1] For example, the City of Calgary, Alberta is aiming to accommodate all population growth out to 2033 (an expected growth of 50 per cent over 30 years) with water conservation measures. This will require a reduction of total water demand by 33 per cent from 2003 to 2033, and Calgary is on track to meet its goal. The City of Vancouver, British Columbia has committed to serving its growing population in perpetuity using existing water supplies. Los Angeles, California is targeting 100 per cent of new demand for water to be met through water conservation and water recycling by 2030 (Maas and Porter-Bopp, 2010).

In 2011, York Region, Ontario set a forward-looking target of No New Water. York Region is also, to the authors' knowledge, the first community in North America to explicitly approach its water strategy planning process from a soft path perspective. This case study marks the first investigation into the successes and challenges of putting soft path principles into practice.

To glean insights from York's experience, the authors conducted one- to two-hour semi-structured interviews using a framework of key questions with the flexibility to ask new questions as a result

[1] Additional information on the water soft path can be found in Brandes and Brooks, 2007; Brooks et al., 2009; and Brooks and Brandes, 2011.

of what was said in the interview. Six participants involved in York Region's *Long Term Water Conservation Strategy (LTWCS)* planning process were interviewed:

- Tracey Carrigan, Manager, Environmental Education & Promotion, York Region;
- Theresa MacIntyre-Morris, Program Manager, Water Conservation and Efficiency, York Region;
- Tracy Patterson, Principle, Freeman and Associates;
- Lynn Barber, Lallibrook Consulting;
- Mary Ann Dickinson, Alliance for Water Efficiency; and
- Hilary Van Welter, Ascentia Consulting.

The participants shared what they perceived to be the strengths and weaknesses of the process, and noted factors they felt were critical to the success of, or a potential impediment to, implementation of the strategy. The information conveyed in the interviews, combined with a review of the LTWCS itself and one author's own experience of being involved in the process (Carol Maas was on the advisory panel), was assembled into core themes that describe:

a) soft path principles in action throughout York Region's process; and
b) the governance structures that continue to inhibit integrated solutions.

The recommendations at the conclusion of this report offer suggestions for overcoming the challenges and for sharing insights with other municipalities that may consider undertaking a similar process. To afford the reader a full appreciation of York Region's experience, the report begins with a discussion of the circumstances that led the Region to engage in a soft path process in 2010.

# 2 The Impetus for Change

Carrigan and MacIntyre-Morris became interested in the soft path for water after attending a workshop in 2008 at the Briarhurst Institute for Science, *From Soft to Smart: How to Shift Water Soft Paths Philosophy Toward Hard Policy*. They planned to further investigate the approach during the five-year review cycle of York Region's 10-year *Water for Tomorrow* conservation and efficiency plan, but their timelines were shortened and anticipation about their work was significantly increased when the Ontario Ministry of the Environment became involved in 2010.

The Province's desire to harness the power of innovation to devise new solutions to old problems is evident both in the recently passed *Water Opportunities Act* (2010) and in the requirement to consider innovative wastewater treatment solutions for the Upper York Sewage Solutions project (Freek, 2012). Consistent with this innovation agenda, the Ministry required York Region to develop a water conservation strategy. The requirement was a Condition of Approval for an expansion of sewage flow capacity in the York Durham Sewage System's Southeast Collector Trunk Sewer and an intra-basin transfer of drinking water from Lake Ontario to the communities of Aurora, Newmarket, and East Gwillimbury. As part of the strategy, York Region needed to conduct a comprehensive study of best-in-class strategies from around the world, undergo a peer review, and deliver the final strategy to the Ministry of the Environment within a mere 12 months.

For much of 2010, Carrigan and her combined team of more than six full-time and four part-time staff and industry experts worked to meet Ministry requirements. As a result, they successfully crafted what is now considered one of the most progressive water conservation strategies in Canada. The details and nuances related to applying the soft path for water through this 12-month process are explored in the next two sections.

# 3 Soft Path Principles in Action

## 3.1 Long-Term Integrated Planning

As part of the movement towards sustainability, urban planners and engineers are increasingly incorporating longer planning horizons (30 years to 50 years) into strategic and master planning processes. Long-term planning can reveal the cumulative environmental, health, and financial impacts of development and infrastructure expansion that may not be readily apparent in the near term. At the same time, extended planning horizons offer the latitude to consider transformative changes that are often necessary to move towards long-term sustainability. In York Region, Carrigan credited York Regional Council and senior management for recognizing the value in establishing a corporate-wide sustainability agenda that emphasized long-term integrated planning. For example, the need to include sustainability principles in the updates to York Region's water and wastewater master plans was identified as imminent in the *York Region Sustainability Strategy* (York Region, 2007). This foresight is also behind existing initiatives for supporting water conservation and building efficient and environmentally sensitive water infrastructure in York Region (York Region 2002; York Region 2011).

Developing a 40-year LTWCS allowed for the water efficiency and water and wastewater infrastructure planning to become better aligned—a process that remains separate in many Ontario communities today despite the obvious relationship between water efficiency and long-term water projections.

Despite this, there was a serious disconnect between the planning horizons of the water and wastewater master plans and the water efficiency plan. "The water and wastewater infrastructure master plan spans 40 years, while the water efficiency plan stopped after 10 years," reported Theresa MacIntyre-Morris. Developing a 40-year LTWCS allowed for the water efficiency and water and wastewater infrastructure planning to become better aligned—a process that remains separate in many Ontario communities today despite the obvious relationship between water efficiency and long-term water projections. Conventional water efficiency plans typically span five to 10 years, making them amenable to detailed programmatic analysis, quantitative cost-benefit

Policies and programs take time to develop … York Region's 40-year planning horizon "helped to open the process up to possibility, instead of focusing on the constraints." As a result, many of the "off-the-table" options suddenly became viable.

analyses, and implementation plans that catalog specific water reduction measures achievable by the local municipality (e.g. rebates, leakage reduction). However, a narrow focus on measures under the control of the municipality ignores the impact of changes in the marketplace, such as more efficient fixtures and technology, or changes to provincial building codes. Furthermore, a short-term approach hampers the ability to include projections for long-term water demand reductions into water and wastewater infrastructure plans. The disconnect in planning horizons impacts everything from revenue forecasting and rate setting, to infrastructure needs and planning because water demand projections can be grossly overestimated (Gleik, 2009). In contrast, York Region had its project team review hundreds of water conservation practices from around the world and, when additional insight was required, conducted interviews with key informants. The Region performed an intentionally high-level qualitative screen of these practices to develop a suite of potential options for its long-term strategy (LTWCS, page 20). The scenario planning also considered provincial water efficiency initiatives, such as changes to the building code. This qualitative screening necessitated a deferral of detailed quantitative analysis to a secondary implementation planning phase following completion of the LTWCS (refer to section 4.1 for further discussion), but ultimately provided a more comprehensive perspective on future water use. Long-term thinking allowed York Region to move from a reactionary position of striving to meet near-term demand constraints (typical of many water efficiency programs today) to a much more holistic, strategic mindset.  By setting its sights 40 years ahead, York Region was able to establish an aspirational goal, and enable sufficient time to make the necessary governance, societal, and structural changes necessary to achieve it. Policies and programs take time to develop and, according to Carrigan, York Region's 40-year planning horizon "helped to open the process up to possibility, instead of focusing on the constraints." As a result, many of the "off-the-table" options suddenly became viable. MacIntyre-Morris added, "a long-term planning horizon allowed us to incorporate technology 10 years out, knowing it will evolve from where it is today."

## 3.2 Moving to a System of Governing Ecologically

Oliver M. Brandes, co-director of the University of Victoria's POLIS Project on Ecological Governance, suggests that changing how we think about water starts us on the soft path, "but fundamentally changing the power structures and collective decision-making processes—and the inevitable wider ecological and societal implications of reducing water use—begins moving us to a system of governing ecologically" (Brooks et al., 2009, p. 65). Ecological governance looks beyond government bodies and regulatory processes as the sole decision-makers, and implies roles for individuals, corporations, non-governmental organizations, and community groups. It is through meaningful public participation that objectives can be reached in a manner consistent with community values (Brandes & Brooks, 2007, p. 14). Ecological governance is about whole-system change in an incredibly complex system. For example, just within the realm of water planning bureaucracy there are numerous insular departments spread across multiple levels of government: drinking water and wastewater is a regional-municipal responsibility, stormwater management is addressed at the municipal level, and the Province controls plumbing and building code regulations. A lack of communication or collaborative relationships also exists within the boundaries of municipal government: water supply, water efficiency, finance, economic development, and building departments rarely collaborate in meaningful ways despite the connected nature of their long-term mandates.

Embracing this complexity, and with it a certain degree of messiness, is strongly advocated within soft path approaches as a necessary way to reform governance structures (Brooks et al., 2009, p. 65). The pragmatic challenge of achieving coordinated action in such a system requires, among other things, elevating stakeholders to the level of empowered partners.

### 3.2.1 Reinventing Stakeholder Engagement

Early on in York Region's process, staff realized that stakeholders needed to be defined broadly—everyone from industry to youth has an intimate connection to water in their daily lives. Accordingly, York Region aimed to engage sectors of its economy where coordinated action would be necessary to meet the objectives of its LTWCS. However, the challenges to be overcome in designing a successful engagement were asserted as many, including (LTWCS, p.53):

- a history of public consultation being adversarial;
- "plan fatigue" from repeatedly seeking input on numerous plans;
- saturation with "environmental" and "sustainability" messaging; and
- the prevailing myth of water plenitude and a lack of urgency to change things.

Given this context, York Region decided that a new approach to consultation was critical to its success in legitimately involving stakeholders. Consequently, they enlisted the services of Hilary Van Welter of Ascentia Consulting, who specializes in using leading-edge methodologies to actively engage the public. Van Welter brought forward the concept of "social innovation"[2] as a way to deliver upon the transformative change that was needed to move towards governing ecologically by empowering the public to actively participate in shaping their water future (see Box I, Section 3.2.2). The underlying concept was to establish "a new public"—a group of individuals that resonated with the notion of being a change agent—using traditional pathways, such as media (e.g. print, video, web), street-level engagements at public events, as well as more in-depth, focused workshops. Van Welter and Carrigan concluded that to reinvent stakeholder engagement it was critical to not have a preordained plan but rather to remain open-minded and invite meaningful public participation.

Shifting the public attitude from passivity to participatory was one of the key success metrics defined in the LTWCS. "Rather than pointing the finger at government to say 'you make the policy,' the success criteria for the public focuses instead on a 'what I can do policy'" (LTWCS, page 64). However, one of the more unexpected outcomes of a successful public consultation campaign was the ongoing resources and staff time required to maintain these newfound relationships. Carrigan reported, "now that we have a newly engaged public with community groups wanting to be involved, we have raised expectations. We need to continually engage people in a different way, because people want to do something. This requires us to rethink how we implement programs and initiatives to include staff time dedicated to partnership development and public engagement."

### 3.2.2 Articulating a Collective Vision for a New Water Future

Engaging the public began with outreach at community events in an effort to identify a collective vision for the future of water in York Region. Booths were set up at events across the region including the Harvest Festival, the Apple Festival, Taste of the Hill, Oktoberfest, and the Woodbridge Fall Fair. At each event, artists encouraged children to paint their impressions of water. This drew parents in and gave outreach staff opportunities to talk with them. But rather than merely asking people for their opinions around water conservation, instead staff presented open-ended, value-laden questions such as "How do you want to live in the future?" Box I describes the

[2] Social innovation in this context is defined as: new ideas that meet social needs more effectively than existing methods and/or new social processes (e.g. relationships or collaborations) that improve the capacity to act.

approach behind the public engagement; this process offers an exemplary model for the collective determination of a desired water future, a core element of the soft path approach.

Figure 1. A collaborative painting depicting a desired vision of the future, drawn by six children at the Markham Apple Fest. Image: LTWCS, Appendix 5, p.4.

Insights from the public events set the stage for a deeper dialogue around these concepts. Through York Region's connections and Van Welter's extended network, a diverse group of stakeholders were invited to participate in a series of four Water Cafés, workshops that examined the value of water from various perspectives. Themes ranged from the perspective of First Nations' cultures to the role of water in reimagining York Region's many suburban neighbourhoods. Woven throughout was the underlying theme of the role of water strategies in achieving a vibrant, sustainable future.

The objectives of the cafés included exploring best practices, attitudes towards the value of water, how people will live and work in 2051 as a context for future water use, and how new water strategies could bring visions for York Region to life (LTWCS, page 57). The Water Cafés ultimately led to the assembly of a "complex set of ideas for water management and a water future for York Region" (LTWCS, page 43). The vision of this water future (Figure 2) includes ideas such as "water neutral," "ecological diversity and economic prosperity," and "leaders in water sustainability." Collectively, the vision represents the stakeholders' view that "over the course of the LTWCS, achieving sufficient reduction in per capita water use through regulations, outreach and education, new technology, financial mechanisms, and matching the water source with the quality of need will ultimately result in no new water takings despite growth in the Region" (LTWCS, page 43). The result was a "collective" vision across York Region for No New Water.

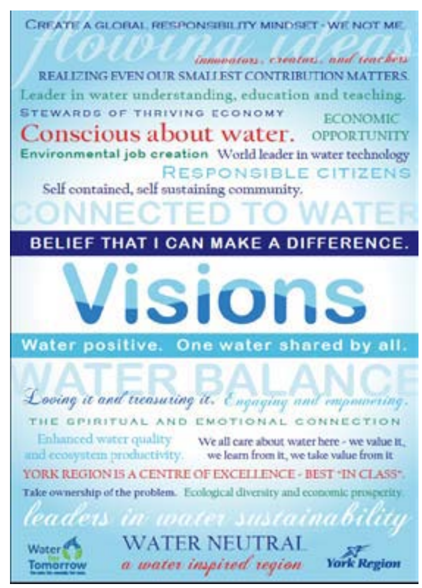


Figure 2. Visions for York Region's *Long Term Water Conservation Strategy*, words taken from conversations with stakeholders during visioning process. Image: LTWCS, p.60

***Box I. Setting the Stage for Effective Public Engagement***

*"The public events provided key learning for the more in-depth public engagement. It was confirmed that if one merely poses open questions about how people feel about water or their thoughts about the future of water, the conversation is very monochrome and deals with water in the taps and toilets. In order to help people tap into a broader conversation about the future of water, a new context needed to be provided, along with different questions that probed areas like 'how do you want to live in the future?' Asking these philosophical, belief-based questions set the stage to zero in on individuals ideal water future and to explore specific water-related issues. The conversational setting of "Water Cafés" was employed to facilitate the deeper exploration of water issues. The general objectives of the cafés were as follows:*

- *To generate ideas using design or creativity methods to deepen the probe and widen the menu of options available for consideration for the future of water.*
- *To inspire new visions, perspectives, contexts, patterns and possibilities for the future of water."*

*(Excerpted from the LTWCS, Page 57)*

### 3.2.3 Choosing a Desired Destination… First

No New Water states York Region's intention to use the same amount of water in 2051 as in 2011, in spite of a population growth of 60 per cent over the next 40 years. Without water conservation, York Region predicts that at the current rate of consumption its water demand would increase from 400 million litres per day (MLD) in 2011 to 645 MLD in 2051. Therefore, a 38 per cent decrease over 40 years is required to achieve the goal of No New Water. To arrive at this declaration, the Region did not forecast its future demand. Instead, it flipped the conventional planning cycle on its head by first developing a vision (use the same amount of water in 2051 as in 2011) and then working backwards to determine the steps needed to reach it—a technique known as backcasting. Soft path literature uses planning a vacation as a metaphor to explain backcasting; when planning a holiday "you do not leave home and drive aimlessly. Rather, you first choose a destination and figure out how to get there" (Brandes and Brooks, 2007, p.13). By first defining a sustainable and desirable future vision, it provided valuable clarity on the scope of the policies and programs needed to achieve No New Water in York Region.

With vision in hand, the stakeholder consultation shifted its focus to the scenario planning process, in which the actions necessary to achieve the desired future vision were backcast from 2051 to today. In a series of workshops, participants took cards printed with the identified best-in-class practices, along with the home-grown conservation ideas that had evolved out of earlier discussions, and placed them into buckets representing various implementation horizons (LTWCS, pg 59). There were approximately 60 attendees at the scenario building sessions from every major sector across York Region, including school boards, farmers, the general public, developers, non-governmental organizations, and business people.

During the sessions, soft path consultant Lynn Barber observed “peoples’ initial instinct was to put everything in the zero-to-five years timeframe, but soon enough, they could clearly see that the buckets were overflowing. People then reevaluated and redistributed the cards into a more realistic spread. In the end, the level of consensus on the initiatives and their implementation horizons was remarkably consistent.” For example, testing and showcasing individual and communal greywater systems in an older community was an action slotted into the five-to-ten years timeframe (LTWCS, Appendix 6, pg 4). The outcomes from these sessions informed the development of scenarios for the LTWCS (York Region, 2011, p. 59).

Opening the planning process up to actively involve stakeholders required significant trust, since it involved relinquishing control of some of the outcomes.

The bucket exercise is a good example of the open-mindedness that was required to make the visioning and backcasting successful. Opening up the planning process to actively involve stakeholders required significant trust, since it involved relinquishing control of some of the outcomes. Despite this uncertainty, York Region staff viewed the expanded participation as a real strength. Sharing the responsibility amongst many helped expand the possibilities to what could be accomplished through collaborative effort. Furthermore, by inviting participants to co-create a shared vision for York Region’s water future, the process helped to excite and mobilize stakeholders toward actualizing the interim steps needed to realize the 2051 target.

Social innovation also places value on “creative action” that is optimized when “people are connected across sectors in meaningful ways” (York Region, 2011, p. 53). This was particularly evident in future scenario planning exercises in the Water Cafés, such as the bucket example above. By bringing people together from diverse backgrounds to work collaboratively, it created an atmosphere where creativity could flourish. As a result, many of the recommended action items put forth in the LTWCS were identified as a direct outcome of the stakeholder consultation process. By treating the public not just as passive consumers, but as active "stakeholders," York Region was able to tap into the collective ingenuity of its citizenry.

### 3.2.4 Leveraging Community Partnerships

Both the water soft path and social innovation endorse building open partnerships as a method to achieve efficiency gains and propagate innovation. The efficiency gains stem from knowledge-sharing between social networks[3] and building on existing expertise external to the municipality. The innovation is borne from leveraging existing networks to put ideas into practice, learning from implementation, and then cycling new knowledge back into the broader social networks. In this way, municipalities can move beyond the boundaries of their direct networks of influence by working with champions in a variety of industries and sectors. The upshot is a process that effectively propagates innovation to networks ranging from building professionals, to the manufacturing sector, to faith communities.

Working partnerships are described as the "collaborative delivery infrastructure" that is tasked with operationalizing the vision across a variety of sectors in York Region's economy (York Region, 2011, p. 63). York Region hopes that a commitment to pilot projects will help build upon the relationships made in the planning process and turn them into functioning partnerships. Pilot projects, such as a priority approvals process for green building construction, will strengthen the relationships between municipalities and the building community and are therefore seen as a vehicle for nurturing innovation.

## 3.3 Ecological Integrity is Not a Number

A fundamental pillar of the soft path approach is living within ecological limits. Ensuring the viability of freshwater resources into the future differentiates soft path planning from water efficiency programs that, despite reducing harm to ecosystems, do not necessarily embed the environment in decision-making processes or place a value on ecological goods and services. In much the same way that stakeholder engagement broadens the conversation around water to the wider community, soft path apportions a voice to ecosystems as an equal stakeholder and legitimate user of fresh water.

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[3] Social networks are defined in this context as: a network of friends, colleagues, or other personal relationships.

However, in a complex watershed such as the Great Lakes Basin with vast quantities of fresh water, there is an obvious logistical challenge in personifying that voice and quantifying those limits. Several interviewees suggested that this particular soft path principle was "great in theory, but difficult in practice." Constructing a future water-use target that ensures ecological integrity is preserved was noted by interviewees as "challenging to explain" and "difficult to define" because "the science and numbers aren't yet available" to make decisions based on ecosystem needs. This suggested a perception that identifying an ecologically based future water-use target was contingent on ensuring enough water remained in the river and lakes for ecosystem needs.

Proponents of the water soft path view the impacts of conventional centralized infrastructure on ecological integrity as something far more pervasive than water withdrawals alone; there are also implications for water quality and system resiliency. For example, in the natural world, water is consumed close to its point of origin and wastes are returned to the land close to the point of consumption making for a closed-loop recycling of water and nutrients. Continuing along a trajectory of centralized water and wastewater treatment breaks down this natural process and results in greater and greater amounts of nutrients being delivered to a single body of water, which can result in damaging algal blooms. The Great Lakes are the largest group of freshwater lakes on earth, yet in the 1960s and 1970s their water quality was severely degraded due to an overload of nutrients and resulting algal blooms, illustrating that even this large water system is not invincible. Ecological limits do indeed exist. While hard numbers are difficult to come by, the necessity of an intra-basin transfer to bring water from the Lake Ontario watershed to supply communities in the Lake Huron watershed (where York Region is situated), such as Aurora, Newmarket, and East Gwillimbury, intuitively suggests that areas within York Region are already at the limit of their local ecological capacities.

In an effort to embrace the principle of preserving ecological integrity, York Region is looking to new innovations that more closely mimic natural cycles. Moving away from extracting source water from farther and farther afield, towards a model that includes using (e.g. rainwater harvesting) and re-using (e.g. grey water and wastewater recycling) water closer to its point of origin, is one such innovation that is anticipated to reap ecological benefits. Given the near impossibility of a comprehensive quantitative evaluation of ecological integrity, a precautionary approach of targeting No New Water was a prudent decision in York Region, keeping with the spirit of a soft path approach.

# 4 Compartmentalized Governance Impedes Integrated Solutions

## 4.1 Local Government

York Region is an upper-tier municipality comprised of nine local municipalities. The Region is a wholesale supplier of drinking water to the local municipalities, which are the retail delivery agents to the water customers. Throughout York Region's soft path planning process there was no concerted opposition among the lower-tier municipalities. This was due, at least in part, to the absence of any direct commitments placed upon them, and through their active participation in the plan development. MacIntyre-Morris also noted, "the Ministry of the Environment requirement for a progressive plan as a condition of approval helped to convince municipalities of the importance and urgency to move forward with a LTWCS."

Although there was little opposition to the plan, significant inroads with local municipalities needed to be made to shift towards a more integrated approach. For example, the local municipalities are responsible for their own distribution networks and for all water billing (York Region, 2011, p. 126). Due to a lack of standardization in data collection, obtaining and compiling the information proved exceedingly difficult for meaningful analysis. Without this data it was impossible to create a region-wide breakdown of current water demand, either by sector or time of year.

When York Region released its LTWCS, staff still did not have sufficient access to the data to make comprehensive projections. Coordinated action was therefore required between the two tiers of government to collect, standardize, and analyze the data to inform decisions. Lynn Barber, soft path consultant, who worked extensively on the data collection and evaluation recommended "a dedicated person to coordinate all of the data and work with lower-tier municipalities on its sourcing."

Mary Ann Dickinson, President and CEO of the Alliance for Water Efficiency, led a peer review of York Region's plan and concluded, "without this information it's impossible to effectively evaluate the costs and benefits of any given program, get buy-in from the public for the changes that need to happen, and to target sectors of the population where changes could have the greatest impact on water use." This hurdle led to one of several recommendations for future provincial legislation to require standardized data collection, reporting, and billing of water use at the municipal level (York Region, 2011, p.29). At the time this case study was written, York Region was working on developing a detailed implementation plan, which will allow them to evaluate the water savings, costs, and benefits of each proposed program.

The phased approach of looking at hundreds of best practices from around the world, doing a qualitative analysis, and then crunching the numbers posed challenges, but at the same time it allowed the space for innovative ideas to emerge and an opportunity to rethink the programs during implementation planning. Hence, the necessity to defer the cost-benefit analysis turned out to be an unexpected conduit for fostering innovation.

## 4.2 Senior Government

The ability of the LTWCS to meet the target of No New Water is predicated upon updates to provincial policy. For example, to achieve the No New Water scenario the Ontario Building Code (OBC) must mandate water efficient fixtures in new homes to bring indoor water use down to 175 litres per capita per day (lcd) by 2016 and to 150 lcd by 2021 (LTWCS, page 69). The Province also has the authority to set the policy agenda through directives and overarching legislation, such as the *Water Opportunities Act* and Water Technology Acceleration Project (Water TAP). Furthermore, guidelines for technologies, such as rainwater harvesting, wastewater recycling, and low impact development approaches, have the power to alleviate concerns around liability and reduce risk for municipalities, builders, plumbers, and engineers but are also typically within the jurisdiction of senior government.

As evidenced in York Region's best-in-class study, leadership from senior levels of government, as is the case in Australia, England, Germany, and California, serve to expedite approvals and act as an important market driver for water conservation practices and technologies (York Region, 2011, p. 125; York Region, 2011, Appendix 1). "In all places with progressive [water conservation] measures there was a state regulatory framework to support it," said Lynn Barber. As noted above, the leadership of the Ministry of the Environment in mandating York Region's plan was cited by interviewees as helping to build consensus on the need for aggressive action among the lower-tier municipalities.
Developments that signal positive steps towards required top-down leadership include:

- announcements that the Ontario government has become a WaterSense partner;

- more stringent water-use efficiency specifications for fixtures in recent OCB consultations;
- pending regulation for municipal water sustainability plans;
- ongoing activities of Water TAP; and
- the Showcasing Water Innovations grant program.

These policies and programs all have the potential to assist in meeting York Region's (and other Ontario jurisdictions') long-term water-use reduction targets. For example, it is estimated that with the use of WaterSense and ENERGY STAR labelled fixtures and appliances, the target of 150 lcd is an achievable target for indoor water use in new homes (Maas, 2009). Coincidentally, this is York Region's projected residential target necessary to reach its goal of No New Water by 2051 (down from an estimated average of 250 lcd in 2011).

Another challenge for municipalities arising from the provincial *Building Code Act* (1992: Section 35) is a provision that "the building code supersedes all municipal by-laws respecting the construction or demolition of buildings" (Building Code Act, 1992). The implication is that municipalities in Ontario are prohibited from requiring fixtures or designs within new buildings that exceed the standards in the OBC. Through creative policy application, the York Region municipalities of Markham, Vaughan, and East Gwillimbury have been successful in working to establish ENERGY STAR, and now LEED, as minimum standards for new residential development. The requirements were not established through the Building Department, but were instead implemented as a standard condition of draft plan of subdivision approval (City of Vaughan, 2007). These municipalities have become among the first in Canada to set efficiency standards for new development, and have been so successful that Markham is now considered one of the largest LEED communities in North America (Dupuis, 2011).

There was reportedly some uneasiness at the Ministry with the inclusion of measures in the LTWCS that were outside local authority, specifically around mandating efficiency within the building code and other actions currently under provincial control. MacIntyre-Morris hypothesized that this was attributable to a misunderstanding of intent. "Our intention with this plan was to bring many stakeholders together to collectively contribute to a systems-wide approach; it's possible that this was perceived by the Province as a punting of the responsibility."

# 5 Recommendations

The following recommendations for local and senior governments looking to further the principles of a water soft path were gleaned from suggestions made by interviewees and from the reported strengths and barriers of the York LTWCS process. In carrying out these recommended actions, both senior and local governments can begin to overcome the challenges associated with achieving the water soft path vision.

**Senior Government:**

- The Province has a key role to play in encouraging innovation at the municipal level. This can be accomplished through the Permit to Take Water process for new water takings, conditions of approval through the Environmental Assessment process for new infrastructure, and by including water efficiency and/or innovation as conditions for new infrastructure funding (refer to Maas, 2010 for more detailed recommendations). York Region has demonstrated that these conditions can work favourably to encourage and support innovation.
- Ensuring the Ontario Building Code keeps pace with water efficiency standards is essential to achieving the significant water-use reductions necessary to achieve long-term sustainability.
- The forthcoming Water Sustainability Plan regulations should encourage municipalities to shift towards more standardized and modern forms of data collection, ensuring that at a minimum the regional municipality has access to lower-tier data on an ongoing basis.
- Partnerships and collaborations should continue to be encouraged by the Province, as was the case with the Showcasing Water Innovation grant program. Showcasing Water Innovations was a future-looking granting initiative of the provincial government that funded water projects that took an integrated and sustainable approach using innovative technologies and approaches. York Region received funding from this program in 2012 to pilot an Innovative and Sustainable Development Approvals Pilot Project.
- Longer planning horizons encourage innovation by opening up possibility. The Province can encourage this when considering its criteria for water sustainability plans. This may necessitate separate long-term strategic plans and shorter-term implementation plans (as in York Region's case), which should consequently be recognized and supported by the Province.

**Local Government:**

- "Set ambitious targets but give yourself the necessary time to accomplish them," suggest York Region staff.
- Embrace the soft path principle of ecological integrity despite (or because of) lack of data. This principle should inform big-picture, integrated thinking combined with a precautionary approach that serves to protect water resources for generations to come.
- The public consultation process should not be an afterthought in planning. York Region offers a model for reinventing stakeholder engagement that involves legitimate public participation and initiates a process of mobilizing the public for action.
- "Do not try and do it alone," say York Region staff. Creating partnerships with the public, private, and academic sectors, and perhaps most importantly internally with other municipal departments, can lead to more readily achievable long-term goals.
- Ongoing review of best-in-class practices encourages openness and awareness to new ideas and fosters a culture of continuous improvement.
- Begin gathering, compiling, and analyzing data early—ideally before the planning process begins. Take into account that detailed cost-benefit analyses on programs are typically only accurate and relevant at shorter time frames. Cost-benefit analyses are therefore most logically completed as a subset of the full plan or as a secondary planning phase following long-term planning.
- When setting targets for future water use, consider the impacts of water efficiency requirements in the building code and market changes to avoid overdesign of new infrastructure.
- Champions in leadership roles are important at the level of program staff as well as at senior management levels. Granting autonomy to leaders to explore new ideas is crucial to nurturing innovation.

# 6 Conclusion

York Region has thus far been very successful in garnering support for what it defines as both a cultural and economic transformation. Its 40-year *Long Term Water Conservation Strategy* emphasizes not only the Region's infrastructure development, but also identifies water innovation as central in developing a 21st-century strategy. The construction, business, research, and technology communities are all seen as strategic partners in bringing about the transformation necessary to achieve the vision of No New Water. Significant financial, human, and educational resources will all need to be brought to bear to turn these commitments into reality. While some important groundwork has been laid in forging the necessary partnerships, it will take significant resolve and persistence to convince partners to back these initiatives up with their own resources and to demonstrate the relative cost benefits. Only after the LTWCS is implemented can a full assessment of the benefits of this approach be made.

Without doubt, York Region's vision of No New Water and commitment to an innovative process are laudable accomplishments in and of themselves. By designing their process to be flexible and embedding societal and ecological values within the decision-making, York Region hopes it has indeed created a model that is leading-edge and robust enough to meet the forthcoming challenges in water.

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## POLIS PROJECT ON ECOLOGICAL GOVERNANCE

Created in 2000, the POLIS Project on Ecological Governance is a research-based organization housed at the University of Victoria, British Columbia. Researchers who are also community activists work to make ecological thinking and practice a core value in all aspects of society and dismantle the notion that the environment is merely another sector. Among the many research centres investigating and promoting sustainability worldwide, POLIS represents a unique blend of multidisciplinary academic research and community action.

**www.polisproject.org**

## POLIS WATER SUSTAINABILITY PROJECT

The POLIS Water Sustainability Project (WSP) is an action-based group that recognizes water scarcity is a social dilemma that cannot be addressed by technical solutions alone. The project focuses on four themes crucial to a sustainable water future:

- Water Conservation and the Water Soft Path;
- The Water-Energy Nexus;
- Watershed Governance; and
- Water Law and Policy.

The WSP works with industry, government, civil society, environmental not-for-profits, and individuals to develop and embed water conservation strategies that benefit the economy, communities, and the environment. The WSP is an initiative of the POLIS Project on Ecological Governance at the University of Victoria.

**www.poliswaterproject.org**

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# Appendix F

## ADDITIONAL RESOURCES AND SUPPORT MATERIALS

Appendix F: Additional Resources and Support Materials

**Key Documents**

Ministry of the Environment: Stormwater Management Planning and Design Manual.
https://www.ontario.ca/document/stormwater-management-planning-and-design-manual

Ministry of the Environment and Climate Change: Interpretation Bulletin – Expectations re: Stormwater Management
http://www.sustainabletechnologies.ca/wp/wp-content/uploads/2015/02/MOECC-Interpretation-Bulletin-Stormwater-Management.pdf

Ministry of the Environment: Toward Financially Sustainable Drinking Water and Wastewater Systems
http://www.ontla.on.ca/library/repository/mon/18000/275984.pdf

Ministry of Infrastructure: Building Together Guide for Municipal Asset Management Plans

Ministry of Municipal Affairs and Housing: Provincial Policy Statement, 2014
http://www.mah.gov.on.ca/AssetFactory.aspx?did=10463

**Guidance Documents**

Credit Valley Conservation: Grey to Green Enhanced Stormwater Management Master Planning Guide to Optimizing Infrastructure Assets and Reducing Risk
http://www.creditvalleyca.ca/wp-content/uploads/2016/01/ORGuide.pdf

Toronto and Region Conservation and CH2M Hill Canada Ltd: Inspection and Maintenance Guide for Stormwater Management Ponds and Constructed Wetlands
http://www.sustainabletechnologies.ca/wp/wp-content/uploads/2016/06/SWMFG2016_Guide_June2016.pdf

**Climate Change Research and Data**

Statistics Canada: Climate Change Data in Canada
http://www.statcan.gc.ca/pub/16-201-x/2007000/10542-eng.htm

Institute for Catastrophic Loss and Reduction: Hazard Research Papers http://www.iclr.org/resourcecentre/hazardresearchpapers.html

Canadian Council of Ministers of the Environment (CCME): Implementation Framework for Climate Change Adaptation Planning at a Watershed Scale
http://www.ccme.ca/files/Resources/climate_change/Climate%20Change%20Adaptation%20Framework%201.0_e%20PN%201529.pdf

Canadian Council of Ministers of the Environment (CCME): Tools for Climate Change Vulnerability Assessment for Watersheds
http://www.ccme.ca/files/Resources/water/climate_change/pn_1494_vat.pdf

Appendix F: Additional Resources and Support Materials

**Asset Management Resources**

Canadian Network of Asset Managers (CNAM): http://cnam.ca/

Global Forum for Maintenance on Asset Management (GFMAM): http://gfmam.org/

Plant Engineering and Maintenance Association of Canada (PEMAC): http://pemac.org/

International Infrastructure Management Manual (IIMM): http://www.ipwea.org/Go.aspx?MicrositeGroupTypeRouteDesignKey=c650931e-6904-464d-80cc-2c48df735859&NavigationKey=0966dcb3-e9a7-4a29-a3ed-baffa0d0c83c

ISO AM Standard: http://www.iso.org/iso/catalogue_detail?csnumber=55088

Institute of Asset Management: https://theiam.org/

Municipal Legislation Review – Public Consultation Discussion Guide
http://www.mah.gov.on.ca/AssetFactory.aspx?did=10979

**Financial Mechanism Resources**

Federation of Canadian Municipalities and National Research Council: Water and Sewer Rates: Full Cost Recovery
https://www.fcm.ca/Documents/reports/Infraguide/Water_and_Sewer_Rates_Full_Cost_Recovery_EN.pdf

NRDC Report: The Green Edge – How Commercial Property Investment in Green Infrastructure Creates Value
http://www.nrdc.org/water/files/commercial-value-green-infrastructure-report.pdf

Credit Valley Conservation: Survey of Municipal Policies and Administrative Approaches for Overcoming Institutional Barriers to Low Impact Development
http://www.creditvalleyca.ca/wp-content/uploads/2012/04/SWMratesReport2008.pdf

**Water/Wastewater Resources**

United States Environmental Protection Agency: Planning for Sustainability – A Handbook for Water and Wastewater Utilities
http://water.epa.gov/infrastructure/sustain/upload/EPA-s-Planning-for-Sustainability-Handbook.pdf

Report of the Walkerton Inquiry
http://www.archives.gov.on.ca/en/e_records/walkerton/index.html

Freshwater Future Canada: Clean, Not Green – Tackling Algal Blooms in the Great Lakes
https://freshwaterfuturecanada.ca/wp-content/uploads/2015/03/AlgaeReport-FINAL.web_.pdf

**Risk Assessment Tools and Resources**

Institute for Sustainable Infrastructure: Envision Tool
http://sustainableinfrastructure.org/learning-center/

United States Environmental Protection Agency: Climate Evaluation and Awareness Tool (CREAT)
http://water.epa.gov/infrastructure/watersecurity/climate/creat.cfm

**Water Conservation Resources**

POLIS Project on Ecological Governance*:* Water Sustainability Project http://poliswaterproject.org/conservation

Conservation Ontario: Act for Clean Water – An Introduction to Source Water Protection
http://www.conservation-ontario.on.ca/media/ACT_For_Clean_Water_English.pdf

United States Environmental Protection Agency: Basic Guidelines for Preparing Water Conservation Plans
http://www.epa.gov/watersense/docs/part3_508.pdf

Ontario Water Works Association: Water Efficiency Committee
http://www.owwa.ca/committees/water-efficiency-committee/

Lake Simcoe Region Conservation Authority: Lake Simcoe Phosphorus Offset Program
http://www.lsrca.on.ca/watershed-health/phosphorus-offsetting-program

**Case Studies/Examples**

City of Ottawa: Water Efficiency Strategy
http://ottawa.ca/en/residents/water-and-environment/drinking-water-and-wells/water-efficiency-plan-phase-i

City of Hamilton: GRIDS planning process
http://www2.hamilton.ca/NR/rdonlyres/B008CE96-4C32-4BC3-9D12-2476FC432A77/0/10_GRIDS_DisplaysPARTA_1726425_391587.pdf

York Region: Sustainability Strategy
http://www.york.ca/wps/wcm/connect/yorkpublic/e6e04658-d63b-4dcf-a2da-0e4972c8029c/Final%2BSustainability%2Bdocument.pdf?MOD=AJPERES

York Region: Long Term Water Conservation Strategy

City of Mississauga: Living Green Master Plan
http://www.mississauga.ca/portal/residents/living-green-master-plan

Durham Region: Sustainable Municipal Water Management

Town of Oakville: Water Sustainability Plan (Draft)

Town of Markham: Green Print Sustainability Plan
http://www.markham.ca/wps/wcm/connect/markhampublic/f3327a2a-55b6-4e22-a36b-aedfe04f4f21/GreenPrint+FINAL+Plan_2011_Accessability.pdf?MOD=AJPERES&CACHEID=f3327a2a-55b6-4e22-a36b-aedfe04f4f21

Region of Peel: Water Efficiency Strategy Update 2013-2015
http://www.peelregion.ca/watersmartpeel/water-eff-strat.htm

**One Water**

Developing an Integrated Risk Management Framework to Support "One Water" in Municipalities
http://www.creditvalleyca.ca/low-impact-development/low-impact-development-support/one-water/

Webinar: Integrated Risk Management for Municipal Water – Legal Issues
https://meetings.webex.com/collabs/url/hhqdfXfFH9ATi8I8ur_otG4JwPqwQaJiMYyhaXaG3ue00000

Webinar: Integrated Risk Management for Municipal Water – Policy and Regulations Issues
https://meetings.webex.com/collabs/url/obmcNvF4K4YGUPaDdLFgKnB2HdE8rEwwrOg3s_z5Myq00000

Webinar: Integrated Risk Management for Municipal Water – Utilities
https://meetings.webex.com/collabs/url/hi-3TQuSGPJ6HP414FC8zmKpGUtAB2niL15S3rKipJ400000

Webinar: Integrated Risk Management for Municipal Water – Financial Planning
https://meetings.webex.com/collabs/url/PXoL7pFv4fE6SG546Nhf5Wdt0L689-7vaoALLFLgqBu00000

Webinar: Integrated Risk Management for Municipal Water – Technology and Service Issues
https://meetings.webex.com/collabs/url/sPZKaYZxZOzAYZ6t4iHwVCZHbK2VP2dDr1efQ0NpA0S00000

Webinar: Watershed Planning as the Basis for Integrating Municipal Water, Wastewater and Stormwater Systems
https://meetings.webex.com/collabs/url/fpC1rv_FtuYVVLFv30Fwf9ba4lYV1WBzsolmgUXKFj400000