2014 CANADIAN MUNICIPAL WATER PRIORITIES REPORT

TOWARDS SUSTAINABLE AND RESILIENT WATER MANAGEMENT

Canadian Water Network's
Canadian Municipal Water Consortium

contents

preface

Since 2009, Canadian Water Network's Canadian Municipal Water Consortium (Consortium) has been contributing to Canada's capacity to develop more effective policy and practice in managing municipal water supplies, advancing the protection and treatment of drinking water, and providing innovations for wastewater, stormwater and watershed management that contribute to more sustainable systems.

The Consortium's success stems from bringing together municipalities, industry, researchers, government and non-government representatives in a way that identifies the best potential approaches to address their collective goals. The Consortium identifies how and where innovations in governance, financing, management, technology, policy and practice can be effectively applied, with emphasis on the practical implications of research.

In 2014, the Consortium established a *Consortium Leadership Group* (CLG) of water leaders from across Canada. The CLG is the driving force behind defining national priorities for municipal water, highlighting where improved knowledge could lead to solutions.

Guided by the CLG, the Consortium is expanding its impact by providing an apolitical, high-level venue where change-makers can share issues and experiences with their peers and advance municipal water management in Canada through prioritization, action and investment in knowledge generation.

This inaugural *Canadian Municipal Water Priorities* report sets the stage for future work by laying out the overall approach taken by the CLG and lists four priority areas the group identified for knowledge generation.

executive summary

Where are we now?

Water impacts and connects our economy, our ecosystems and the health of our communities. This inherent nature of "connectedness" means that addressing the challenges of effective municipal water management requires a more holistic approach, recognizing it as a fundamental component of ensuring resilient, sustainable communities in Canada.

In 2014, the Consortium Leadership Group (CLG) identified where research and knowledge were most needed to support Canadian communities moving toward integrated approaches that encompass the spectrum of drinking water, wastewater, stormwater, and urban watershed management. They did so by asking *'where are we now?'* and *'what do we need to know to move forward?'*

The governance of municipal water in Canada is overwhelmingly a public exercise within a framework that includes federal, provincial and territorial government regulation. The vast majority of Canadian systems are owned and managed by local governments, each with the primary responsibility of managing water for their communities. As a result, there are a variety of approaches to water management, including integrated water management, that reflect local and historical factors, the involvement of multiple interests and the fragmented nature of the prevailing regulatory structure.

Canada's municipal water systems require increased investment to meet current and future demands. Municipalities are also exploring how to reduce deferred maintenance, prioritize investments, raise capital and fund solutions through innovations in governance and finance.

The narrative of low rates and prodigious consumption that has so strongly characterized municipal water management in Canada is changing. Canadian municipalities are in the early stages of both increasing water rates to levels that are more reflective of real costs, and looking to alternative financing structures.

Another trend in water management is exploring options for resource recovery. In Canada, the focus of much of this discussion is on resource recovery from wastewater, but it also includes cost-effective water conservation and reuse options. Many Canadian communities are seeking reliable sources of information on the full nature of the advantages and disadvantages of these options for their communities.

Planning to deal with change is one of the largest challenges facing municipal water management. While still a relatively new activity for most municipalities, innovating to adapt to climate-related change is beginning to appear more frequently as a component of municipal planning and policy development.

What do we need to know to move forward?

To identify where a national collaboration on research and knowledge could best support strategic planning and investment, CLG discussions have been structured around **a framework of key decision areas** that are critical to achieving effective, integrated approaches for safe, reliable and sustainable water systems.

Framework of Key Decision Areas

Determine drivers and constraints that impact success

Identify the full range of key drivers and associated risks that impact progress in municipal water management.

Address the real costs of the systems we need

Consider the true costs of operating and maintaining all the elements needed to achieve sustainable water systems and how to pay for them effectively and equitably.

Maximize resources through efficiencies, recovery and innovation

Recognize where options for resource efficiencies, recovery and innovations provide a truly viable approach.

Prepare for future challenges by developing resiliency and adaptation strategies

Increase resiliency and develop strategies for adapting to changing climate, demographics and socio-economic factors.

National Priorities for Research and Knowledge

By advancing priority knowledge needs within the key decision areas, the Consortium is working to improve Canada's ability to achieve sustainable and resilient municipal water systems.
The national priorities, identified by the CLG, will guide knowledge generation and the Consortium's future research and activities.

01
Develop

Develop an integrated risk management framework to support management of municipal drinking water, wastewater, stormwater and urban watersheds. It is crucial to explicitly identify the full suite of risks to be managed to achieve sustainable and resilient water systems. Determining the interrelated nature of these risks provides the basis for prioritizing concerns, actions and investments. Viable approaches and frameworks to support more explicit risk identification and management are needed to underpin integrated water management.

02
Assess

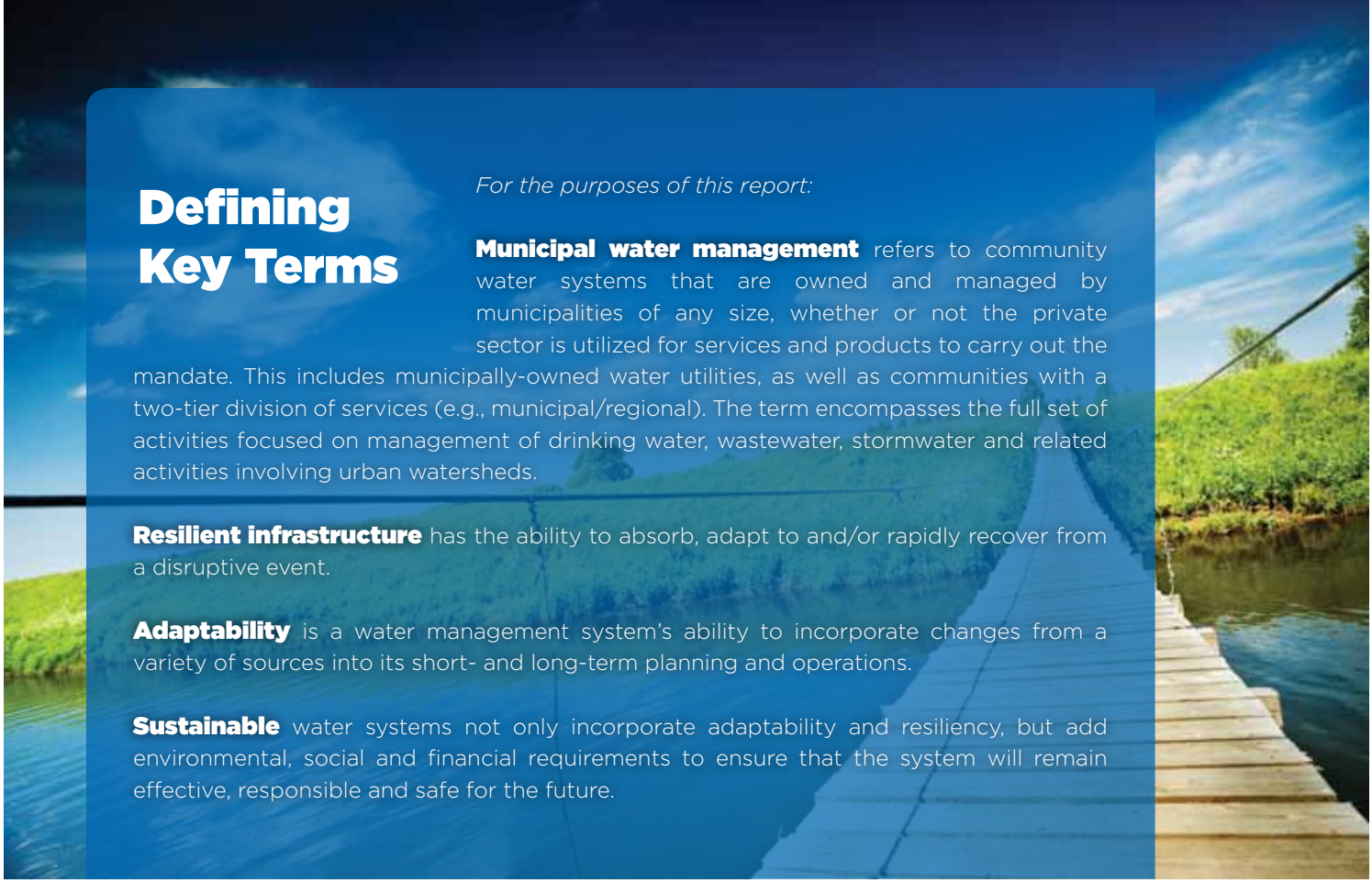
Assess the state of knowledge and practice for full cost recovery and financing for water systems. Research has the potential to inform and accelerate decisions around best options for full cost recovery. A presentation of options and innovations in rate structures and revenue generation models that can work in Canadian settings is needed; one that incorporates the full suite of costs incurred, as well as financing options to support large capital investments.

03
Identify

Identify the possibilities and implications of biosolids and wastewater resource recovery and reuse. Research and knowledge assessment are needed to advance the ability of communities to assess what resource recovery and reuse options are appropriate for them. A credible assessment is needed regarding the potential risks and benefits of biosolids management techniques and wastewater recovery and reuse technologies.

04
Determine

Determine what is practical and achievable in making municipal water systems more resilient to storms and extreme weather. Innovation in stormwater management will increase the resiliency of municipalities when dealing with the "new normal" conditions caused by climate change or other factors. Understanding what innovations can achieve, including expectations of system performance in the face of future challenges, will be an important ongoing discussion.



Defining Key Terms

For the purposes of this report:

Municipal water management refers to community water systems that are owned and managed by municipalities of any size, whether or not the private sector is utilized for services and products to carry out the mandate. This includes municipally-owned water utilities, as well as communities with a two-tier division of services (e.g., municipal/regional). The term encompasses the full set of activities focused on management of drinking water, wastewater, stormwater and related activities involving urban watersheds.

Resilient infrastructure has the ability to absorb, adapt to and/or rapidly recover from a disruptive event.

Adaptability is a water management system's ability to incorporate changes from a variety of sources into its short- and long-term planning and operations.

Sustainable water systems not only incorporate adaptability and resiliency, but add environmental, social and financial requirements to ensure that the system will remain effective, responsible and safe for the future.

While there is no single path to success in water management — and the path will look different for each jurisdiction and each community — there is much to be gained by framing approaches to common problems, pooling expertise, and collaborating to address key questions. The Consortium works to provide the core research and knowledge that will support the strategic needs of those involved in municipal water management in Canada. By addressing needs here at home, Canada can position itself to be a global leader in municipal water management. This inaugural Canadian Municipal Water Priorities report is intended not only to guide further Consortium work, but also to help inform national discussions among those interested in collectively advancing municipal water management in Canada.

introduction

In Canada, water is the invisible thread that connects our economy, ecosystems and the health of our communities. By virtue of this "connectedness," addressing the challenges of effective water management can provide an important and accessible entry point to the larger and even more complex goal of achieving resilient, sustainable communities.

Effective water management – including drinking water, wastewater, stormwater and urban watersheds – is an important determinant of socio-economic and environmental health. *The Canadian Municipal Water Consortium* (Consortium) is committed to the knowledge needs of those who support Canadian communities by maintaining reliable water quality, access and availability, with effective management and affordable systems.

As the first in a series of *Canadian Municipal Water Priorities* reports produced by the Consortium, this report "sets the scene" by conveying core challenges that municipalities face in managing the many facets of water. Addressing the question, **"Where are we now?"** ensures we identify not only the challenges, but the context within which solutions must be designed in order to be effective.

This inaugural report includes an overview of the current municipal water landscape in Canada, including water governance, infrastructure investment, financing approaches, resource recovery approaches and system resiliency. Examples of trends, progress and innovation give a sense of direction to discussion of the challenges municipalities are facing and the developing management concepts.

A summary of the prioritized areas for knowledge needs follows, as identified by the *Consortium Leadership Group* (CLG) in response to the question, **"What do we need to know to move forward?"** The approach used by the CLG reflects a need to understand what drives the risks in the system, the impact the risks can have on community concerns, and the practical consideration of where innovations make the most sense. Four national priorities were established by the CLG to provide a focus for future research. These priorities will help to advance national discussion, collaboration and action in municipal water management and will guide the Consortium's activities.

WHERE ARE WE NOW? CURRENT REALITIES AND CHALLENGES

2.1 THE MUNICIPAL WATER LANDSCAPE IN CANADA

Municipal water management in Canada is predominantly a publicly-controlled endeavour. Provinces and territories take the constitutional lead for most areas of water management. They shape much of the framework within which municipal water is managed through regulations and programs that vary from jurisdiction to jurisdiction. Federal legislation, such as the Fisheries Act, also comes into play, particularly in areas where the federal government has key identified responsibilities – for example, First Nations and international boundary waters, among others.

Municipalities are both the primary owners of the vast majority of water systems in Canada, and the entities responsible for making the front line decisions that address current and future water management challenges. Municipalities bear financial responsibility for their systems, though a number of activities are supported by federal and provincial government grants and programs. The private sector may be involved in various aspects of the delivery of services within municipal systems, although they typically are not the system owners (as may be the case in Europe and other countries). Increased investment in large water infrastructure by the private sector is an area being considered in Canada (e.g., Regina's new wastewater treatment facility), with debates focusing on the merits and pitfalls of various formulations of public-private partnerships[1] (P3s).

The complicated nature of Canada's water governance reflects the jurisdictional division of responsibilities between the different levels of government and variations of regulatory structure between jurisdictions. It is also a consequence of the sweeping relevance of water to so many decisions.

Drinking water, wastewater, stormwater and watershed management within municipalities have historically been managed and regulated as separate systems. In addition, overlapping activities related to protection of public, environmental and socio-economic health have typically been managed by different departments. The consequence of these realities has been the creation of "silos" in decision-making across many different government or municipal departments and levels. This creates a series of governance gaps, overlaps and challenges that require municipal water managers, watershed groups or conservation authorities, local businesses and governments to coordinate and consider decisions in the context of actions from various other groups and levels of government.

COLLABORATIVE WATER GOVERNANCE IN CANADA

Several Canadian provinces are experimenting with collaborative governance models. Although there is no single definition for collaborative governance, the concept is commonly regarded as an arrangement where one or more public agencies directly engage stakeholders in a collective decision-making process that is formal, consensus-oriented and deliberative, with the aim to make or implement public policy or manage programs or assets.

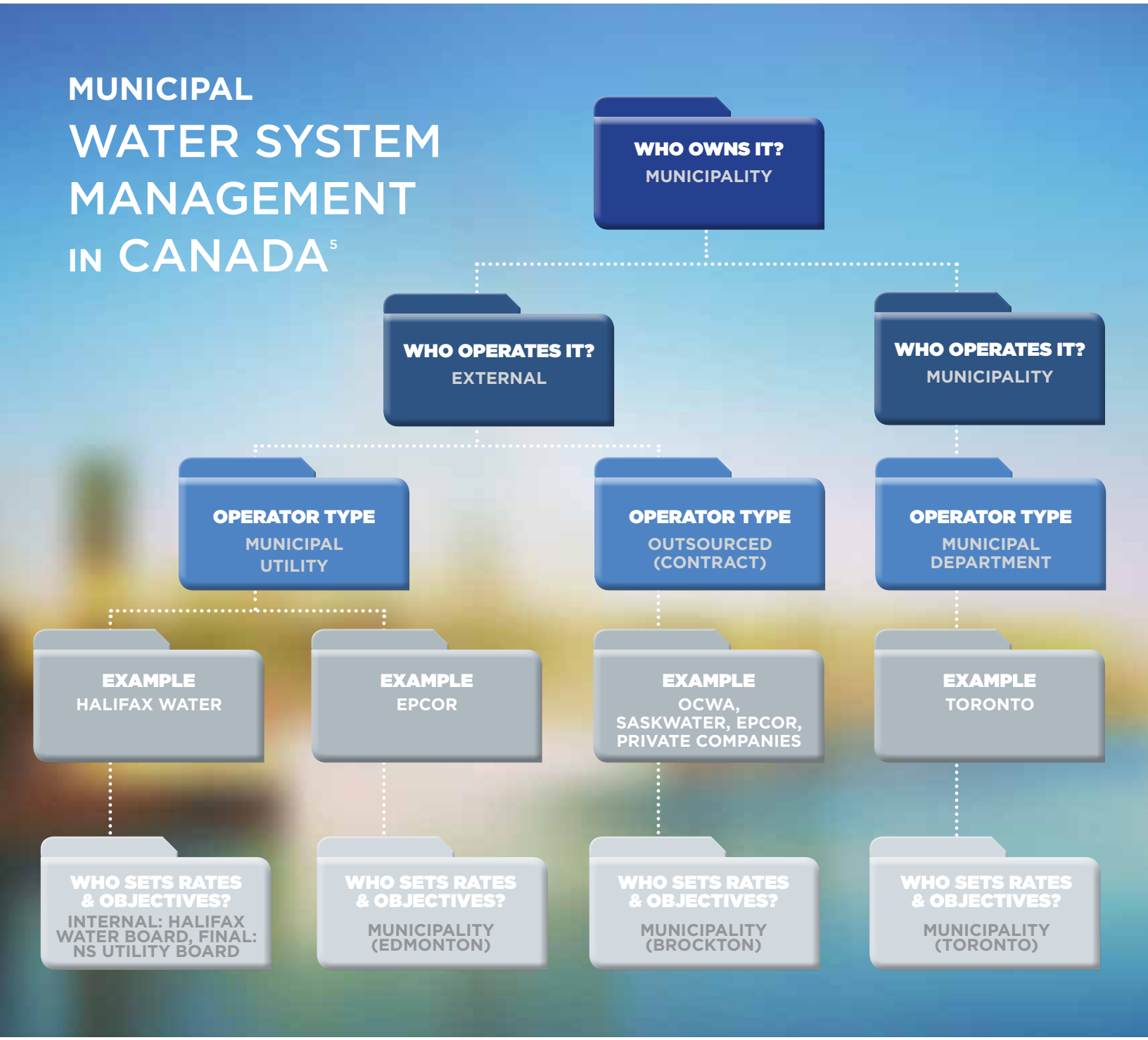
Examples of collaborative governance structures across Canada include watershed organizations in Québec, the water source protection committees in Ontario, Alberta's water planning advisory committees, the Fraser River Basin Council in British Columbia, as well as various Water Boards in the Northwest Territories, Nunavut and Yukon.[2]

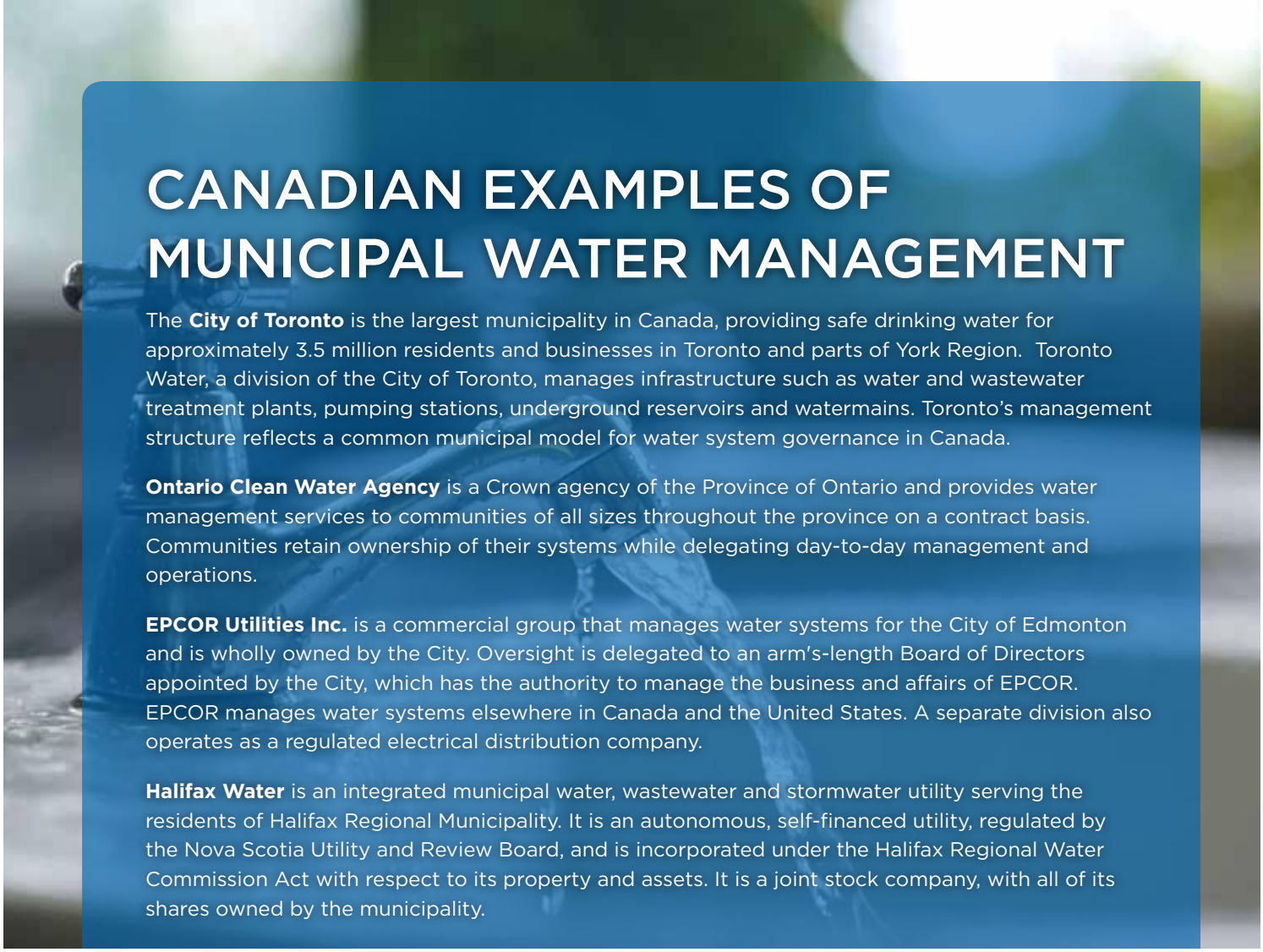
Coordinating water management decisions across complex systems can be challenging when seeking robust solutions and obtaining support from various levels of governments. It is for this reason that municipalities are moving toward more integrated, holistic frameworks to help identify inter-connections and better efficiencies.

A variety of governance models for the ownership and management of municipal water systems exists in Canada (see Figure 1). Close to 90 per cent of Canadians have municipal water service, from major cities with over a million people to small communities with populations of only a few hundred[3]. Each municipality typically manages its own system, resulting in several thousand independently operated systems across the country. The role of local government is an important aspect for decision-making within these models. The different management structures, as well as the practice and character of the communities themselves, results in significant variation in the degree to which locally elected politicians shape or drive management decisions.

In parts of Canada with two-tier municipal/regional governments, water system management is often divided into differing areas of responsibility between the two levels[4]. A common arrangement is for the upper tier (regional government) to deal with major issues related to securing public water supply and the operation of treatment facilities and large pipes, while the lower tier (municipality) provides local water distribution and wastewater collection.

Figure 1


MUNICIPAL
WATER SYSTEM MANAGEMENT IN CANADA[5]
WHO OWNS IT?
MUNICIPALITY
WHO OPERATES IT?
EXTERNAL
WHO OPERATES IT?
MUNICIPALITY
OPERATOR TYPE
MUNICIPAL UTILITY
OPERATOR TYPE
OUTSOURCED (CONTRACT)
OPERATOR TYPE
MUNICIPAL DEPARTMENT
EXAMPLE
HALIFAX WATER
EXAMPLE
EPCOR
EXAMPLE
OCWA, SASKWATER, EPCOR, PRIVATE COMPANIES
EXAMPLE
TORONTO
WHO SETS RATES & OBJECTIVES?
INTERNAL: HALIFAX WATER BOARD, FINAL: NS UTILITY BOARD
WHO SETS RATES & OBJECTIVES?
MUNICIPALITY (EDMONTON)
WHO SETS RATES & OBJECTIVES?
MUNICIPALITY (BROCKTON)
WHO SETS RATES & OBJECTIVES?
MUNICIPALITY (TORONTO)



CANADIAN EXAMPLES OF MUNICIPAL WATER MANAGEMENT

The **City of Toronto** is the largest municipality in Canada, providing safe drinking water for approximately 3.5 million residents and businesses in Toronto and parts of York Region. Toronto Water, a division of the City of Toronto, manages infrastructure such as water and wastewater treatment plants, pumping stations, underground reservoirs and watermains. Toronto's management structure reflects a common municipal model for water system governance in Canada.

Ontario Clean Water Agency is a Crown agency of the Province of Ontario and provides water management services to communities of all sizes throughout the province on a contract basis. Communities retain ownership of their systems while delegating day-to-day management and operations.

EPCOR Utilities Inc. is a commercial group that manages water systems for the City of Edmonton and is wholly owned by the City. Oversight is delegated to an arm's-length Board of Directors appointed by the City, which has the authority to manage the business and affairs of EPCOR. EPCOR manages water systems elsewhere in Canada and the United States. A separate division also operates as a regulated electrical distribution company.

Halifax Water is an integrated municipal water, wastewater and stormwater utility serving the residents of Halifax Regional Municipality. It is an autonomous, self-financed utility, regulated by the Nova Scotia Utility and Review Board, and is incorporated under the Halifax Regional Water Commission Act with respect to its property and assets. It is a joint stock company, with all of its shares owned by the municipality.

Canada's governance and management of municipal water is largely a public exercise. Provincial and territorial governments shape the majority of relevant regulations and municipal governments provide implementation for several thousand systems across Canada. Municipalities own the vast majority of systems, using different models of operation and involving varying degrees of influence on management decisions by elected local officials and other parties. The national collage of governance for municipal water management includes silos and overlaps that reflect local and historical factors, the influence and involvement of many interests, and the fragmented nature of the prevailing regulatory structure.

Because water management affects all sectors of a community's socio-economic status, including public and environmental health, leading municipalities are moving toward a more integrated management approach to ensure more efficient decisions. As a result, silos and interconnections can be more explicitly recognized and addressed in a way that ensures that solutions are appropriate and effective for local realities, and can be supported by all levels of government.

WATER INFRASTRUCTURE IN CANADA[6]

In 2012, the Canadian Infrastructure Report Card estimated the current value of Canadian water assets to be $362 billion. More than $80 billion will be needed to replace aging water infrastructure over the next 20 years. Another $20 billion is needed for upgrades of existing infrastructure to meet new federal wastewater regulations over the same time period.
This figure does not include investments to accommodate population growth, adapt to climate change or improve service.

CANADIAN MUNICIPAL WATER PROJECTS[7]

Lions Gate Secondary Wastewater Treatment Plant (North Vancouver, BC)	**$400 million**
Seaterra Wastewater Management Program (Capital Region District, Victoria, BC)	**$783 million**
Southeast Collector Trunk Sewer (York/Durham Region, ON)	**$546 million**
Woodward Ave Wastewater Treatment Plant Upgrade (Hamilton, ON)	**$332 million**
Regina Sewage Treatment Plant (SK)	**$224 million**

2.2 THE STATE OF OUR WATER ASSETS

Water management in Canada has been shaped by a long history of financial, environmental, governance, legal, economic and community investment decisions. Today's water managers are facing decades of underinvestment in water systems, which has resulted in aging infrastructure that may be inadequate to address current or future needs in many areas (See text box, page 14). Canada's municipal water systems require both an overall increase in investment to catch up on deferred maintenance, as well as newly-built elements and systems that can deliver the capacity and resiliency required to meet future needs.

Generating the necessary investments will challenge many communities in the coming years. The scale of water projects required is massive, as revealed by the size of those already being undertaken across Canada. The five largest infrastructure projects currently underway or in planning represent over $2 billion in investment in wastewater management upgrades (See text box, page 14).

One of these five projects is the multi-million dollar Southeast Collector Trunk Sewer in Ontario's York and Durham Regions. This project will provide York Region with a new 15 km trunk sanitary sewer to accommodate future growth. These projects are illustrative of the large investment required for sound management of municipal water systems.

Canadian municipalities own over $362 billion in assets related to their water systems. Historic underinvestment in many of these systems (particularly in smaller, remote and aboriginal communities), coupled with increasing demands for system performance has resulted in a significant infrastructure deficit in Canada, with system repair, replacement and upgrade requirements totalling tens of billions of dollars. Canada's municipal water systems require an increase in investment as a result. Municipalities are looking at how best to raise capital and prioritize these investments, and how innovations in technology and governance can help effectively implement them.

There are hundreds of additional smaller projects to maintain and improve water systems throughout the country. The existence of individual municipal management entities for thousands of smaller communities in Canada has resulted in a large number of systems that struggle to adequately support needed investments, or to maintain the necessary levels of expertise to operate systems effectively.[8]

Addressing the needs of Canada's small and aboriginal communities remains a major stumbling block. The provision of safe, potable water continues to be an issue in these communities due to challenges in the governance, design, construction, financing and operation of water systems.

KITCHENER'S STORMWATER MANAGEMENT UTILITY PROGRAM[9]

In 2010, following public consultation and input, the City of Kitchener, in southwestern Ontario, introduced a new structure for stormwater management under its Stormwater Management Utility Program. A tiered flat-fee stormwater rate is applied to properties based on their "impervious area," which directly correlates to a property's contribution of runoff volume to the collection system. This new rate structure encourages stewardship for property owners and allows them to qualify for stormwater rate credits.

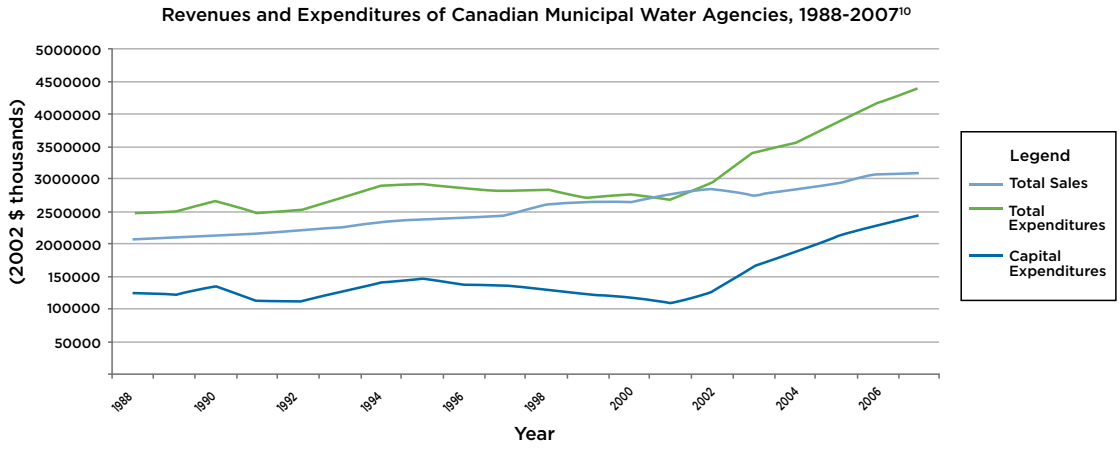
2.3 HOW WE PAY FOR OUR SYSTEMS

Water services in Canada have traditionally been funded through a combination of consumption charges and revenue from the property tax base. Total system costs have been escalating, and revenues have not been keeping pace (see Figure 2).

Like many other services, water utilities have been shifting over the past decade to a variety of approaches that achieve more revenue generation on a user-pay basis. Moving from a flat-rate fee model, or one depending primarily on property tax revenue, to systems that track and charge for the actual volume of water used by different customers, requires the use of water meters. Meters enable municipalities to better understand how and where water is being used (or lost from the system), and allow them to charge public and industrial customers proportionally for drinking water consumed and wastewater produced. Switching to metered systems requires considerable up-front costs and creates the potential for public resistance. In addition, the historically low rates charged for water actually work as a disincentive for metering, making it difficult to demonstrate a sufficient business case based on the anticipated financial benefits of more efficient billing and management.

Municipal water systems in Canada have traditionally relied on funding from a combination of property tax levies and flat-rate or volumetric charges based on water delivered to customers. The historically low rates have resulted in insufficient revenue and an inertia in moving to metered systems. Metering is increasing municipalities' ability to understand their systems, operate them more efficiently and move to more effective and balanced financing structures. Approximately three-quarters of Canada is now on metered systems. Declines in overall water demand due to economic changes, improved systems and the success of conservation campaigns over the past two decades, have highlighted the challenge of sustainably financing our systems when revenues are based largely on water service "sales" and low rates. Canadian municipalities are in the early stages of both increasing water rates and moving toward alternative financing structures that allow better and more sustainable financing.

Figure 2



THE DOUBLE-EDGED SWORD OF CONSERVATION

Water conservation campaigns provide benefits by reducing the amount of water and associated energy and chemicals needed for a project, as well as deferring costs of expensive expansion projects. However, in some cases a new challenge has emerged. While declining use is a desired goal, it also reduces revenues based on volumes consumed. This often necessitates further rate increases, or changes in rate structure to make up the shortfall.

For example, the City of Toronto experienced a 24 per cent decline in per capita water demand between 2005 and 2012. Most of the decline is attributed to increases in water rates that better reflect the true cost of providing water. During this period, rates increased between six per cent and 10.8 per cent per year to generate additional revenue needed for system enhancement.[11]

However, the rapid decline in per capita consumption resulted in lower than expected revenue increases and a deferment in some planned system improvements. As a result, Toronto revised both its water rates and capital planning to accommodate the changes.[12]

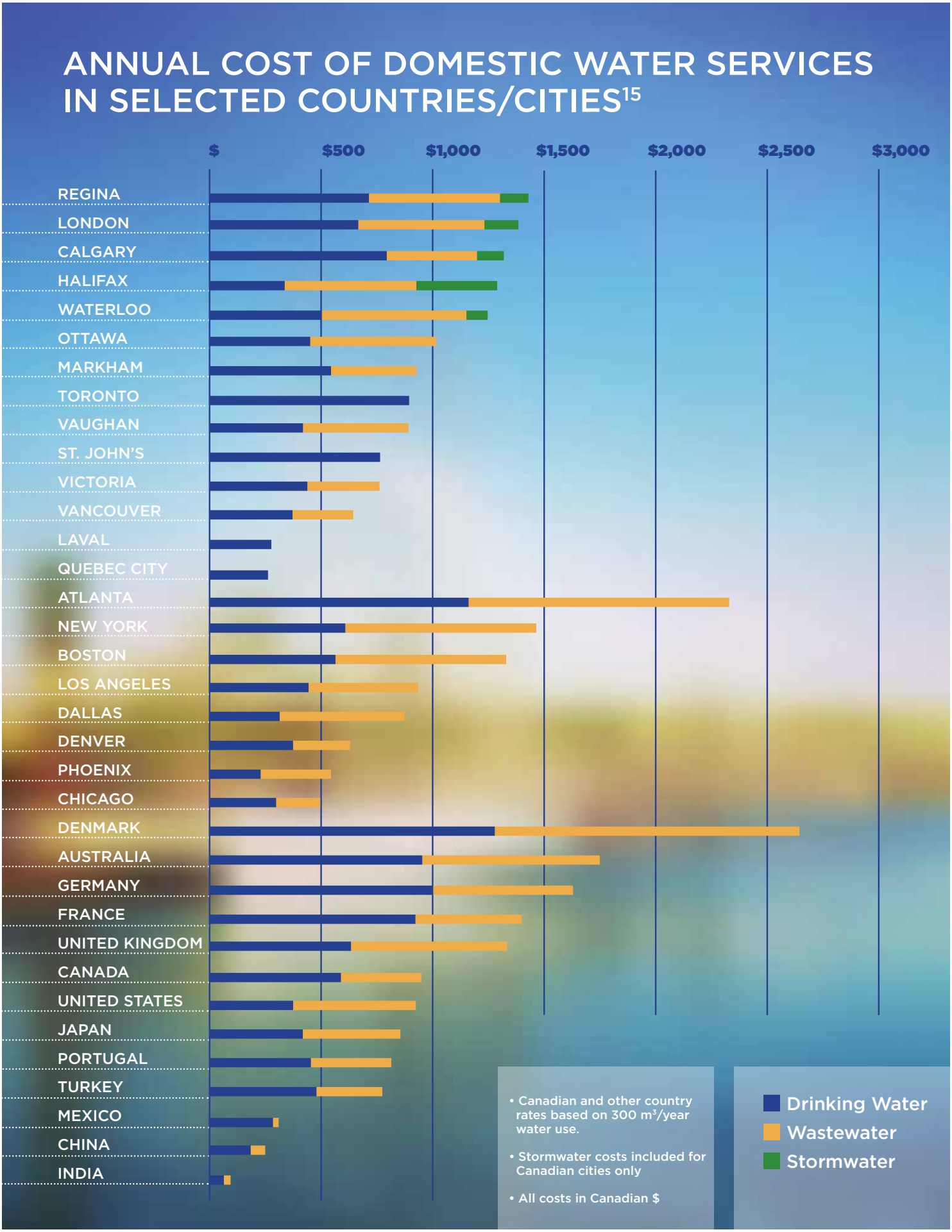
Despite these challenges, the trend in Canadian municipalities has been, and continues to be, increased use of meters. The last national survey conducted on the use of water metering by municipalities in Canada indicated an increase from 52 per cent in 1991 to 72 per cent in 2009.[13]

Many municipalities charge separate fees for drinking water and wastewater services. To further match revenue generation to the realities of where costs are incurred, some municipalities are also charging explicit fees for stormwater services, in addition to adding one-time connection or development charges (see text box, page 16).

With the increasing focus on the need to better match revenues to total expenses in water management, a significant shift has occurred over the past 10 years in the way water services are priced. In Canada, many communities have established rates that are no longer at the low end of the world scale. While the Canadian average is still low compared to other developed countries, a recent study of water rates around the world, combined with an informal literature review by the Consortium, revealed that the pricing level of some Canadian cities is now comparable to European levels that have traditionally been much higher (see Figure 3).

Recent rate increases reflect a trend toward more sustainable financing. Legislation such as the Safe Drinking Water Act[14] (Ontario, 2002) requires drinking water systems to become financially sustainable. Municipalities have taken flexible approaches to achieving financial sustainability for their water systems. The City of London, Ontario, is moving its entire water system along this path (see text box, p. 20). Plans like these explicitly address the need to catch up on deferred capital renewal over a number of years.

Figure 3


ANNUAL COST OF DOMESTIC WATER SERVICES IN SELECTED COUNTRIES/CITIES[15]
$
$500
$1,000
$1,500
$2,000
$2,500
$3,000
REGINA
LONDON
CALGARY
HALIFAX
WATERLOO
OTTAWA
MARKHAM
TORONTO
VAUGHAN
ST. JOHN'S
VICTORIA
VANCOUVER
LAVAL
QUEBEC CITY
ATLANTA
NEW YORK
BOSTON
LOS ANGELES
DALLAS
DENVER
PHOENIX
CHICAGO
DENMARK
AUSTRALIA
GERMANY
FRANCE
UNITED KINGDOM
CANADA
UNITED STATES
JAPAN
PORTUGAL
TURKEY
MEXICO
CHINA
INDIA
• Canadian and other country rates based on 300 m³/year water use.
• Stormwater costs included for Canadian cities only
• All costs in Canadian $
Drinking Water
Wastewater
Stormwater

LONDON'S WATER FINANCIAL PLAN

The City of London, Ontario, has developed a Water Financial Plan with the goal of becoming financially sustainable by 2018. The Water Financial Plan aims to have a reserve fund balance between $8 million and $10 million, along with achieving rate stability and affordability and reducing the infrastructure gap. Using an innovative approach to reduce future costs is inherent in the plan. The City recognizes risk reduction (health, environment and public safety) along with cost minimization as the drivers for financial stability.[16]

2.4 SHIFTING TO A RESOURCE RECOVERY APPROACH

The rising costs of water management and energy, concerns about environmental impact, and issues of water scarcity have influenced global conversations on resource recovery. However, although scarcity is a concern for some Canadian municipalities (most notably in southern Alberta and BC's Okanagan Valley), this issue has not risen to a level of national urgency as in drier areas of the southern United States, Australia, or the Middle East. As a result, the drivers for very high efficiency or full potable water reuse are limited in Canada.

Canadian municipalities are looking for options to reduce costs, address supply limitations and improve service through efficiencies and strategies that address water conservation and reuse. They are also considering opportunities to recover beneficial chemical components or energy from their systems. Innovative approaches and technologies are introducing options like water recycling, nutrient recovery (e.g. phosphorus and nitrogen), energy generation or recovery, and beneficial use of other materials.

Within the overall sphere of discussion on resource recovery, wastewater treatment is a primary focus for Canadian municipalities. A range of approaches are currently used across Canada related to biosolids recovered from wastewater treatment. These approaches range from land application and anaerobic digestion, to incineration and production of fertilizer (See text box, p. 22).

The ability to recover nutrients like nitrogen and phosphorus from wastewater can contribute to meeting environmental goals. Nutrient reuse reduces the amount of commercial fertilizers used in agriculture, and addresses concerns about nutrient overloading of Canada's surface waters. Managing nutrients is an important element of overall water management. Due to dwindling global sources of phosphorous, the European Union has identified phosphorous recovery as a critical process in sustainable resource management.[17]

In addition to resources that can be reused for benefit, municipal waste streams may also contain undesirable substances. Wastewater systems were not designed specifically to deal with these substances, which include an expanding list of chemicals of concern. As a result, the applicability of resource recovery approaches must continue to address the safety and viability of their use. Deliberations about the significance and safety of many chemicals, often present at very low levels, are an area of ongoing concern that research continues to address. The ability to detect a growing list of substances at ever decreasing concentrations has outstripped the ability to adequately assess the degree to which they may have a detrimental effect on humans or the environment in different recovery/reuse scenarios. This is an area of active discussion that includes both opportunities and challenges for science to support best policy and practice.

EXAMPLES OF BIOSOLIDS USE IN CANADA[18]

Peel Region, Ontario
Biosolids are digested anaerobically to create biogas for heating and electricity generation.

Metro Vancouver, British Columbia
Digested biosolids are used as a soil amendment and fertilizer.

Saskatoon, Saskatchewan
Nitrogen and phosphorus are recovered from wastewater for use as a fertilizer.

Niagara Region, Ontario
Biosolids are stabilized and applied to agricultural land.

Halifax, Nova Scotia
Biosolids are stabilized for reuse as a soil amendment and fertilizer.

Resource recovery has the potential to minimize the use of resources, increase efficiency and better protect human health and the environment. There is also potential for revenue through the production of marketable commodities. Yet, not all technologies or approaches provide an appropriate fit for every community, based on scale, social or economic setting, or the existence of appropriate markets for end products. Canadian municipalities experience a wide variety of drivers that affect these decisions, and many are in the process of seeking information on potential risks and benefits that will help to assess their best options.

Scarcity of resources, increasing costs, and concerns about environmental impacts are creating a global shift in water management thinking that puts a greater emphasis on resource recovery. In Canada, the focus of much of this discussion is on resource recovery from wastewater, as well as cost-effective water conservation and reuse options. However, different community settings and drivers for resource recovery, concerns about safety and variable product markets mean that decision-making is very community-specific. As a result, many Canadian communities are in an active phase of exploring resource recovery options to support sustainable water management.

2.5 ADAPTING TO FUTURE NEEDS AND CHANGE

Planning for future conditions (both anticipated and unpredictable) is a fundamental component of sustainable water management. Change can come from many different sources: regulatory, demographic, economic and environmental. The need to ensure systems are sufficiently resilient and able to adapt to changing circumstances is one of the biggest challenges currently facing municipal water management in Canada. Consequently, it is also one of the areas where innovative approaches are most needed and likely to have significant impact over the next few years.

Changes in prevailing regulations can dramatically shift costs leading to increasing operations and maintenance expenditures over the long term. Recent federal regulations requiring upgrades to many wastewater treatment plants across the country are estimated to cost in the vicinity of $20 billion.[19] Ontario regulations to improve protection and safety of drinking water supplies, implemented after the Walkerton tragedy in 2000, resulted in an estimated $800 million in additional capital costs, not including increased operating costs. [20]

Understanding how demographic change and population growth affect water systems has always been an important part of good management practice. Sudden or unforeseen changes in economic conditions or population trends can also usher in new challenges for water managers. The interconnectedness of water systems with community function become clear when water management issues, including the appropriateness of the basic design and operation of systems, are viewed in terms of their significance to development or other socio-economic concerns.

Climate change represents perhaps the largest component of uncertainty that municipalities face, as a result of variable hydroclimatic conditions (See text box p. 25). Changes due to varying climate will create new challenges for all sectors, but particularly for the long-term sustainability of our water systems.

In a recent *Climate Change and Water Technical Paper*, the Intergovernmental Panel on Climate Change concluded that "water and its availability and quality will be the main pressures on, and issues for, societies and the environment under climate change." [21]

In recent years, communities across the nation have increasingly begun to experience the impacts and significant costs of severe weather (See text box, p. 26). These impacts include floods affecting critical infrastructure and road systems, extreme weather events inundating coastlines and disrupting essential services, crop losses, water shortages and droughts leading to major wildfires.

As local governments are increasingly faced with these conditions, the need to respond to climate change challenges is recognized and a key consideration in city planning and policy making.

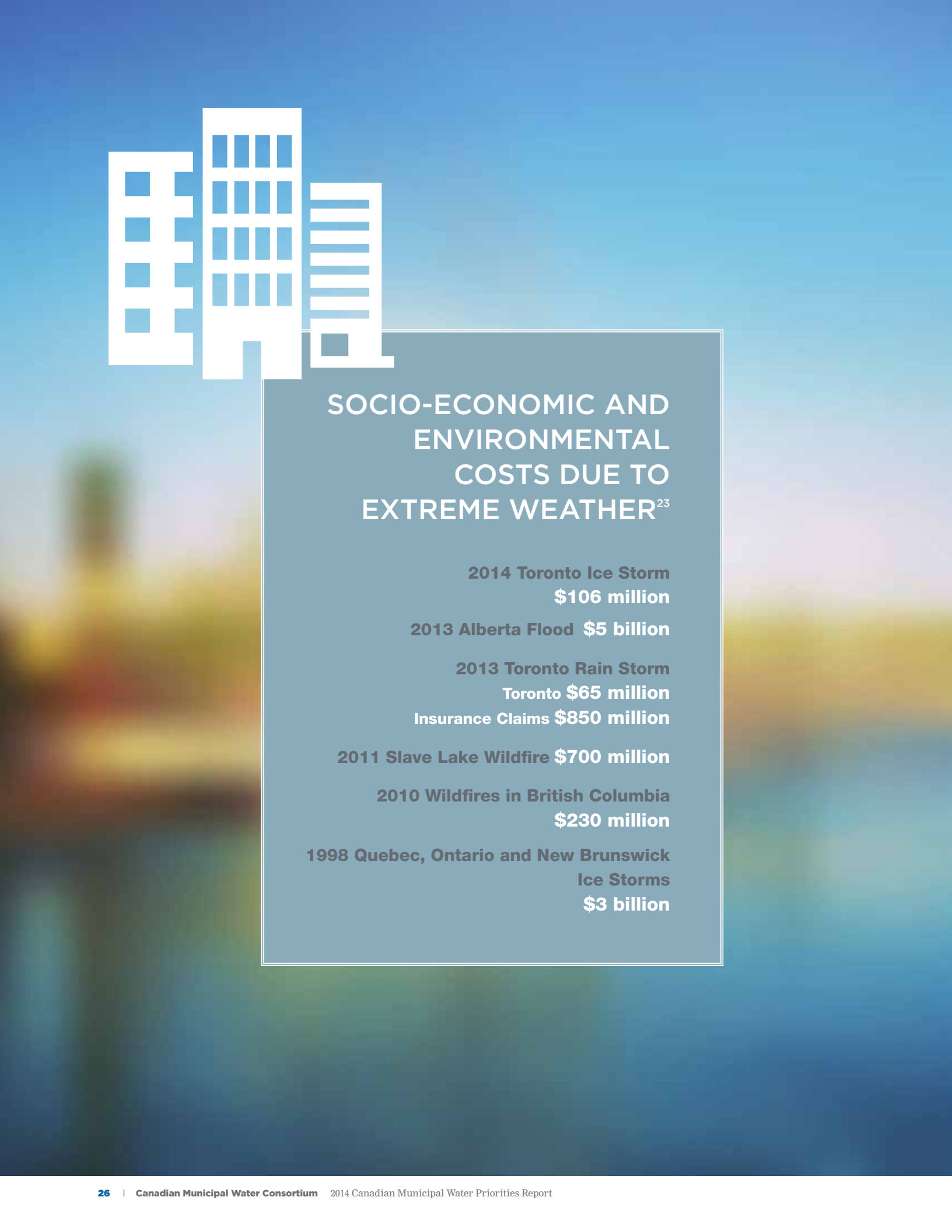
VULNERABILITY TO CLIMATE CHANGE IN THE WATER SECTOR[22]

- Precipitation, evaporation and runoff are changing, creating uncertainties about water supply and quality, flood management and ecosystem health;
- Extreme weather events will become more frequent, necessitating improvements in flood protection, drought preparedness and emergency response;
- Heavy rainfall may cause sewer systems and water treatment plants to be overwhelmed due to increased volumes of water, washing sediment, nutrients and pollutants into water bodies;
- Reduced stream flows in areas where hydropower is generated will reduce the amount of energy that can be produced;
- Lower water levels in water bodies will likely lead to higher pollutant concentrations, bacterial contaminants and algae resulting in taste/odour problems in municipal water supply.

The advent of "new normal" conditions (not anticipated at the time of system design) puts particular strain on municipal water management, challenging successful performance and changing the definition of what constitutes unusual events or disasters when compared to operational expectations. Extreme variability can render otherwise well-functioning systems inadequate. The infrastructure supporting municipal water management typically involves capital-intensive projects such as treatment plants and storm and sanitary sewers designed to last decades. It is expensive and difficult to adapt systems to new conditions over short time periods; hence the need for innovations that enable systems to be more resilient and adaptable, as well as a desire for improved predictions of the hydroclimatic conditions likely to be faced in the future.

Planning to deal with future changes, particularly the uncertainty associated with climate change, is possibly one of the largest challenges currently facing municipal water management. Demographic, economic and environmental change can all have significant impacts. Achieving resilient systems that can adapt to change is a major hurdle for an essential service that relies heavily on expensive infrastructure designed to last for decades and operate within a specified range of conditions. While it is still a relatively new activity for most municipalities, innovating to incorporate adaptation to climate-related or other changes is beginning to appear as a component of municipal planning and policy development.

With the potential for increased storm severity and frequency to significantly change the operating environment of existing and planned water systems, municipalities are looking at how to adapt to storm – and drought – events by increasing the resiliency of their systems. There is a growing interest in how strategies such as green infrastructure, targeted watershed management and innovative stormwater techniques can help to build this resiliency.



SOCIO-ECONOMIC AND ENVIRONMENTAL COSTS DUE TO EXTREME WEATHER[23]

2014 Toronto Ice Storm
$106 million

2013 Alberta Flood $5 billion

2013 Toronto Rain Storm
Toronto $65 million
Insurance Claims $850 million

2011 Slave Lake Wildfire $700 million

2010 Wildfires in British Columbia
$230 million

1998 Quebec, Ontario and New Brunswick Ice Storms
$3 billion

ADAPTING TO A CHANGING ENVIRONMENT[24]

Calgary — In 2013, Calgary experienced its largest flood in modern history, with damages to large portions of the city and the evacuation of thousands of people. Since then, the City has built on work started following an earlier (2005) flood, and is addressing flood recovery, mitigation and resiliency in order to deal with long-term community restoration and rehabilitation. The City has completed and planned water recovery and resiliency projects that include bank restoration, evaluating rivers and slopes, repairing stormwater outfalls, and short and long-term solutions for structural repairs and improvements. Calgary is also engaged in evaluating flood standards, flood/river monitoring infrastructure, and creating a strategy to ensure flood resilience continues to improve over the long term.

WHAT DO WE NEED TO KNOW TO MOVE FORWARD?

3.1 KEY DECISION AREAS FOR INTEGRATED WATER MANAGEMENT

There is a demonstrated need to manage water resources in a more holistic manner. As a result, many municipalities have moved to, or are considering, Integrated Water Resources Management strategies (also known as Integrated Water Management or One-Water). These approaches consolidate the management of separate water systems – drinking water, wastewater, stormwater, and source water – and consider a broad range of factors, such as planning, ecosystem health, community growth patterns and climate change.

In convening with peers to address Canada's needs, the CLG discussed the question **"Where are we now?"** to provide important context on the current realities of municipal water management. Addressing the subsequent question ***"What do we need to know to move forward?"*** the CLG identified what knowledge is most needed to facilitate Integrated Water Management and practical solutions. Discussions were framed in the context of **key decision areas** that are critical to achieving effective, integrated approaches for safe, reliable and sustainable water systems.

KEY DECISION AREAS

DETERMINE DRIVERS AND CONSTRAINTS THAT IMPACT SUCCESS
Identify the full range of key drivers and associated risks that impact progress in municipal water management.

ADDRESS THE REAL COSTS OF THE SYSTEMS WE NEED
Consider the true costs of operating and maintaining all the elements needed to achieve sustainable water systems and how to pay for them effectively and equitably.

MAXIMIZE RESOURCES THROUGH EFFICIENCIES, RECOVERY AND INNOVATION
Recognize where options for resource efficiencies, recovery and innovations provide a truly viable approach.

PREPARE FOR FUTURE CHALLENGES BY DEVELOPING RESILIENCY AND ADAPTATION STRATEGIES
Increase resiliency and develop strategies for adapting to changing climate, demographics and socio-economic factors.

3.2 CANADIAN MUNICIPAL WATER CONSORTIUM NATIONAL PRIORITIES FOR KNOWLEDGE

By advancing priority knowledge needs within the key decision framework described above, the Consortium is working to advance Canada's ability to achieve sustainable, resilient municipal water systems. The national priorities, as identified by the CLG in 2014, will guide knowledge generation and the Consortium's future research and activities.

NATIONAL PRIORITY #1:

Develop an integrated risk management framework to support management of municipal drinking water, wastewater, stormwater and urban watersheds.

Achieving sustainable and resilient water management requires a better understanding of how all facets of water management interact and which factors (e.g. land use changes, development decisions or climate variations) have the largest impacts on meeting system goals. Complete water management requires not only an understanding of the interplay among the physical elements (pipes, treatment facilities, etc.), but also the significance of health, social, economic, political and environmental factors.

Once the full suite of relevant factors impacting system goals has been identified, managing the variety of risks facing these systems can extend beyond the core concepts of ensuring regulatory compliance, treating water and wastewater to established objectives, and mitigating the impacts of floods and droughts.

For effective integrated water management, a crucial first step is to explicitly identify the full suite of risks to be managed to achieve sustainable and resilient water systems. Determining the interrelated nature of these risks and their relative importance to successful system management provides a basis to prioritize concerns, actions and investments. Developing viable approaches and frameworks to support more explicit risk identification and management is needed to effectively underpin integrated water management.

Typically, much of the focus in water management is on managing risks to public, environmental and economic health. As communities begin to address the full scope of water management challenges, some water utilities have gone to great lengths to identify, assess and manage a more complete set of interrelated risks to their organizations (see text box, p. 30). The goal is to move beyond examining the drivers and risks for each system component in isolation and begin drawing links between the various elements. This includes the consideration of external factors, both controllable – like planning decisions – and uncontrollable, such as changing weather or economic factors.

RISK IN WATER SYSTEM MANAGEMENT[25]

- Public Health
- Environmental
- Financial
- Employee Health and Safety
- Political
- Reputation
- Scientific
- Technological
- Project
- Engineering
- Specification
- Supply Chain
- Commercial
- International

ALBERTA DRINKING WATER SAFETY PLANS: SUPPORTING A "KNOW-YOUR-SYSTEM" APPROACH[26]

Alberta's introduction of Drinking Water Safety Plans (DWSP) to manage drinking water systems is an example of taking a broad approach to risk management in a key area (public-health risks from drinking water). It considers a specific water system's operating environment including source water, treatment methods, distribution system and storage system (if any). This approach was originally conceived by the World Health Organization (WHO, 2004, 2009) as an effective means of providing a holistic and proactive approach to protecting public health by ensuring safe drinking water systems worldwide.

The guiding principle within a DWSP is to "know your system," including the hazards it is facing, its capability to deal effectively with those hazards under all plausible scenarios, the means to validate the performance of the system, and appropriate responses when monitoring or other evidence signals problems.

DWSPs are developed locally (for each system) and require:

- collecting and evaluating the best information available about the water supply system
- analyzing and understanding potential risks
- correctly assessing risk mitigation, i.e. how to reduce risks to an acceptable level
- determining what resources and actions are necessary to ensure identified risks are reduced

Implementation plans are included, as well as audit and update processes to ensure that they remain current and incorporate best practices and new knowledge. The adoption of DWSPs in the province of Alberta reflects a potential paradigm shift in the province's water sector towards more sustainable, proactive and holistic water management.

NATIONAL PRIORITY #2:

Assess the state of knowledge and practice for full cost recovery and financing for water systems.

Canadians require water systems that provide safe drinking water, treat wastewater adequately, and manage stormwater in a cost-effective and environmentally sound manner. Achieving this requires clarity on the full scope of actions that need to be taken, determining their true costs, and finding an effective financing model to fund them. This includes a discussion about how to operate with finite resources, while considering the potential for recovery and reuse of water, energy and other valuable resources.

There has been substantial change in the way water systems are managed and financed in Canada over the last 10 years. This shift is most apparent in the burgeoning move towards full cost recovery, which involves assessing and reclaiming the full cost of providing a community with water and wastewater services (see text box, page 33). Elements typically encompassed by full cost accounting include the production, distribution, collection and treatment of drinking water and wastewater, as well as the costs of operations and administration, research and development, capital works and decommissioning.[27] Other activities, which may have an important impact on system behaviour, such as watershed management or source protection activities, have not typically been included to date.

Research has the potential to accelerate and inform decisions around best options for full cost recovery so that municipalities will be able to pay for their water systems today and into the future. Options and innovations in rate structures and revenue generation models – ones workable in Canadian settings – are needed to incorporate the full suite of costs incurred, as well as financing options to support large capital investments.

Like the physical and operational elements of water management systems, financing approaches must also be sufficiently resilient and adaptable enough that they can deal with potential changes that can dramatically alter costs for a city, including changes in regulations or policy. These changes, while often supported with short-term capital support programs, can greatly increase operations and maintenance expenditures for a community over the long term. The financial implications of such changes require an understanding of how they affect cost models and how flexibility in rate setting, innovative implementation or financing can minimize consumer impact.

For many municipalities, aging infrastructure, growing water quality concerns and the impending impacts of climate change will make for a challenging transition towards full-cost recovery for services, but it will be a necessary tool to enable communities to plan and invest in maintaining and enhancing water systems.

HALIFAX INTEGRATED RESOURCE PLAN – COVERING COSTS OF AN INTEGRATED UTILITY[28]

Halifax Water is responsible for water, wastewater and stormwater services throughout Halifax Regional Municipality (HRM). As a regulated utility, Halifax Water must cover its capital and operating costs and adhere to cost causation principles as well as the rule of intergenerational equity. Like most municipalities in Canada, Halifax must also renew aging infrastructure and bring it into compliance with new federal wastewater regulations while keeping pace with growth in HRM.

In order to accomplish these goals, Halifax Water recently completed an Integrated Resource Plan that provides a framework for sustainable capital investment over the next 30 years of approximately $2.6 billion, net present value. They also completed a Cost of Service Study (COSS) for wastewater and stormwater services that had previously been unregulated.

A guiding principle was that the cost of service aligns costs with those who derive the benefits.

The resulting rate structure includes the following features:

- **Water rates have base [covering fixed costs] and consumption [capturing variable costs] charge components**
- **Wastewater rates have base [covering fixed costs] and discharge [capturing variable costs] charge components**
- **Current stormwater rates are based on runoff**
- **Stormwater charges correlate with impervious surface area of customer property**
- **Growth pays for growth**

Taken together, these changes have put Halifax Water on a sustainable path to finance, operate, maintain and improve its water infrastructure.

NATIONAL PRIORITY #3

Identify the possibilities and implications of biosolids and wastewater resource recovery and reuse.

Biosolids and wastewater resource recovery and reuse can be a key component of a comprehensive and sustainable water management strategy. It is an area of interest for many Canadian municipalities, particularly in light of increasingly stringent wastewater discharge requirements. However, it is also an area where concerns and uncertainties about possible health issues, or the applicability of new technologies to various Canadian contexts, the applicability of new technologies to various Canadian contexts are important considerations in decision making. The CLG identified a need to better understand and contextualize the various advantages and disadvantages of wastewater recovery and reuse options to move practice forward.

Questions about the potential human or environmental health implications of contaminants in recovered products, such as land-application of biosolids, represent an important consideration when evaluating resource recovery or reuse options. Clear presentation of the implications of scientific evidence will help inform decisions on the best fit for different communities.

In addition to addressing potential health concerns, much of the identification of "fit" for resource recovery options comes down to identifying solutions that work based on local conditions such as economic viability, availability of land base, or particular industry needs that can be met by the management strategy (see text box, this page). Identifying issues in this context helps identify which knowledge and research questions can be of most use to decision makers.

EXAMPLES OF RESOURCE RECOVERY PROGRAMS IN CANADA

In Halton Region, Ontario, biosolids from seven wastewater treatment plants are applied directly to agricultural land as a fertilizer. In 2009, the region developed a comprehensive Master Plan to evaluate alternative technologies and biosolids management options that extends to the year 2031. In 2011, this program was the recipient of the Exemplary Biosolids Management Award (in the category of public acceptance activities) from the Water Environment Association of Ontario.[29]

The Gold Bar Wastewater Treatment plant in Edmonton, Alberta, is operated by EPCOR. As one of Canada's largest Class IV wastewater treatment plants, Gold Bar produces more than 100,000 million litres of treated effluent annually. Approximately five per cent of the effluent is treated and diverted to an industrial facility where it is used for process water. Gold Bar also recovers biosolids for fertilizer and biogas for heating.[30]

Research is needed to enhance the decision making power of communities to better assess when resource recovery and reuse options make the most sense for them. There is a desire for a credible assessment of what is known and not known regarding the potential benefits and risks of techniques for biosolids management or wastewater and other recovery/reuse technologies.

NATIONAL PRIORITY #4:

Determine what is practical and achievable in making municipal water systems more resilient to storms and extreme weather.

Muncipalities must develop resiliency for both anticipated and unexpected changes in conditions so that they can adapt as well as thrive. Challenges may result from a number of socio-economic or regulatory changes, but perhaps chief among concerns are the impacts that climate change will have on municipal systems.

Proactive local governments have begun to integrate climate change adaptation into city planning and policy making. These forward-looking municipalities recognize that they have a responsibility – as well as the capacity – to address climate change through bylaws, land use planning, waste management, economic development and transportation infrastructure. This shift in thinking is increasing the demand for knowledge about innovative approaches and technologies in the area of water management. For water systems, that involves identifying innovative approaches to increasing resiliency and ability to adapt, while recognizing the realities of working within systems that have significant investments in existing assets.

There is also a need to better communicate exactly what adaptation strategies entail in terms of scope, time frame, cost, and what is reasonable to expect from operation of systems in the face of more frequent, extreme events. Municipal water management was historically focused on building robust and capital-intensive systems to address safety and performance within well-defined, expected ranges of conditions. The uncertainties in future conditions that accompany climate change are driving municipalities to look for new paradigms that will increase their resiliency in dealing with significant future weather events.

INNOVATIVE STORMWATER MANAGEMENT RESEARCH[31]

Ongoing changes in land use and climate have shown that conventional stormwater management (SWM) systems in urban watersheds are no longer adequate to deal with increased runoff and flooding events. To increase understanding of innovative approaches to SWM in an urban context, CWN-funded researcher, Dr. Hans Schreier, led a project that creates innovative solutions, communicates research on these solutions, highlights research gaps, and shares information about which innovations are effective across Canada for different types of urban watersheds.

This team examined a wide range of innovative approaches to stormwater management in Canada in order to provide planners, developers and municipal engineers with information on a variety of effective practices at three levels: property, neighbourhood and watershed.

Innovation in stormwater management will enable municipalities to be more resilient in dealing with the "new normal" conditions caused by climate change. Understanding what innovations can achieve, and just how much to expect of system performance in the face of future challenges, will be an important discussion over the next few years.

conclusion

Water connects all facets of life and communities, therefore managing it well is critical to the larger goal of building resilient, sustainable and liveable communities. Water is woven throughout many important issues to communities and thus requires an integrated, holistic approach to decisions about its management.

The Consortium's approach reflects a recognition that the overall challenges facing municipal water management in Canada are similar: financing our systems, addressing changing conditions, and establishing an understanding of the full implications of the choices we make. However, the Consortium also recognizes that the individual strategies selected for the thousands of municipalities across the country will be developed in a way that fits the unique set of conditions in each case.

As the CLG approached the question of how research and knowledge can best help us move forward, it considered the overall context for Canadian municipal water decisions to be addressed by those interested in a more integrated approach. This includes better understanding the full suite of interconnected risks, options and costs needed to manage them simultaneously.

By identifying priorities for research and knowledge sharing in 2014, the CLG is not only providing focus for ongoing work by the Consortium itself, but is helping to guide national discussion on what municipalities need, want, and can address, to collectively move forward. These are early but important first steps to support the development of an integrated framework, one that includes the relevant risks, recovery of costs, an informed discussion on resource recovery opportunities, and system resiliency while considering changing weather patterns.

Canada is uniquely positioned to be a global leader in water management. With stewardship of a significant portion of the world's freshwater supply, and a demonstrated expertise in water management, municipalities can build on existing success stories and the shifting water landscape to develop more integrated approaches that provide models and solutions that are globally relevant. While there is no single path to success in water management, and the path will look different for each jurisdiction and each community, there is much to be gained by framing approaches to common problems, pooling expertise, and working together to address key questions.

references

[1] PPP Canada Inc. (2014) "About P3s". http://www.p3canada.ca/en/

[2] Gibson, Ryan (2011). "A Primer on Collaborative Multi-Level Governance." Project Report.
Canadian Regional Development: A Critical Review of Theory, Practice and Potential.
http://cdnregdev.files.wordpress.com/2011/10/primercollaborativemultilevelgovernance-gibson.pdf

[3] Environment Canada (2011). "2011 Municipal Water Use Report – Municipal Water Use 2009 Statistics." February 2, 2012.
http://www.ec.gc.ca/doc/publications/eau-water/COM1454/survey1-eng.htm

[4] Metro Vancouver (2014). "Water Treatment and Supply." http://www.metrovancouver.org/services/water/Pages/default.aspx

[5] Municipal Water System Management in Canada. Canadian Water Network, 2014.

[6] Federation of Canadian Municipalities (2012). "Canadian Infrastructure Report Card." Volume 1, Municipal Roads and Water Systems. http://www.fcm.ca/Documents/reports/Canadian_Infrastructure_Report_Card_EN.pdf

[7] Renew Canada (2014). "Heavy Hitters: Big-Ticket Infrastructure Projects Shaping Canada's Future, Volume 10, number 12014."

[8] Ministry of Public Infrastructure Renewal (2005). "Watertight: The Case for Change in Ontario's Water and Wastewater Sector."
Report of the Water Strategy Expert Panel, Toronto: Publications Ontario, 2005.
http://www.probeinternational.org/EVfiles/Watertight-panel_report_EN.pdf

[9] Grant Murphy (2011). "Stormwater Rate By-law and Utility Implementation Final-Addendum 2 to DTS 10-120."
City of Kitchener, June 7, 2010

[10] Diane Dupont (2014). "Know Your Customer: Canadian Households and Water." (In) S. Renzetti (2009).
"Wave of the Future: The Case for Smarter Water Pricing." C.D. Howe Institute Commentary 281, Toronto.

[11] Toronto Water (2014). "Toronto 2014 Budget." http://www.toronto.ca/legdocs/mmis/2013/ex/bgrd/backgroundfile-63904.pdf

[12] Bennet, J. (2013). "Price Works: Seasonality and Determinants of Toronto's Amazing Decline in Water Demand."
Sustainability Prosperity, December 2013.

[13] Environment Canada (2011). "Municipal Water and Wastewater Survey, 2011."
http://www.ec.gc.ca/eau-water/default.asp?lang=EN&n=ED7C2D33-1

[14] Government of Ontario (2002). "Safe Drinking Water Act. 2002."
http://www.e-laws.gov.on.ca/html/statutes/english/elaws_statutes_02s32_e.htm

[15] Black & Veatch Corporation (2012/2013). "50 Largest Cities Water/Wastewater Rate Survey."
Global Water Intelligence (2011)."Global Water Market 2011." Oxford.

[16] The Corporation of the City of London, Planning, Environmental and Engineering Services (2011).
"Water Service Area Financial Plans (O. Reg. 453/07 under SDWA, 2002)." Original Version April 26, 2010; Revised April 15, 2011
https://www.london.ca/residents/Water/water-bill/Documents/Water-Financial-Plan-April-15-2011.pdf

[17] European Commission for the Environment. "Use of Phosphorus and its resource availability." March 6, 2014.
http://ec.europa.eu/environment/natres/phosphorus.htm

references

[18] Examples of Biosolids Use in Canada: Compiled by CWN. Retrieved June 15, 2014 from:
http://www.peelregion.ca/pw/water/sewage-trtmt/solids.htm; http://www.metrovancouver.org/services/wastewater/treatment/recovery/Pages/default.aspx;
http://www.saskatoon.ca/DEPARTMENTS/Utility%20Services/Water%20and%20Wastewater%20Treatment/Wastewater%20Treatment%20Plant/Pages/NutrientRecoveryFacility.aspx;
http://www.niagararegion.ca/living/wastewater/biosolids/biosolids.aspx;
http://www.halifax.ca/harboursol/BiosolidsProcessingFacility.php;
http://www.halton.ca/cms/One.aspx?portalId=8310&pageId=19509;
http://corp.epcor.com/watersolutions/operations/edmonton/goldbar/Pages/gold-bar-wastewater-treatment-plant.aspx

[19] Federation of Canadian Municipalities (2012). "Canadian Infrastructure Report Card." Volume 1, Municipal Roads and Water Systems. http://www.fcm.ca/Documents/reports/Canadian_Infrastructure_Report_Card_EN.pdf

[20] Ministry of Public Infrastructure Renewal (2005). "Watertight: The Case for Change in Ontario's Water and Wastewater Sector." Report of the Water Strategy Expert Panel, Toronto: Publications Ontario, 2005.
http://www.probeinternational.org/EVfiles/Watertight-panel_report_EN.pdf

[21] Bates, B.C., Kundzewicz, Z.W., Wu, S. & Palutikof, J.P. (eds) 2008. "Introduction to climate change and water." IPCC Technical Paper on Water and Climate Change, p.7. http://www.ipcc.ch/pdf/technical-papers/ccw/chapter1.pdf

[22] IPCC, 2014: Summary for Policymakers. In: Climate Change 2014: Impacts, Adaptation and Vulnerability. Part A: Global and Sectoral Aspects, Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Field, C.B., V.R., Barros, D.J. Dokken, K.J., Mach, M.D., Mastrandrea, T.E., Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L White (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 1-32.

[23] Government of Canada (2014). Canadian Disaster Database, March 4, 2014. http://cdd.publicsafety.gc.ca/srchpg-eng.aspx
Alberta Flood 2013: Comparing Canada's Costliest Natural Disasters. The Huffington Post Alberta. January 3, 2014
http://www.huffingtonpost.ca/2014/01/03/canadas-costliest-natural-disasters-alberta-flood_n_4538825.html

[24] City of Calgary (2014). "Calgary's Flood Resistant Future." Report from the Expert Management Panel on River Flood Mitigation, June 2014

[25] Water Research Foundation (2013). "Risk Governance: An Implementation Guide for Water Utilities." Project #4363, June 2013.
http://www.waterrf.org/ExecutiveSummaryLibrary/4363_ProjectSummary.pdf

[26] Government of Alberta. "Drinking Water Safety Plan." http://environment.alberta.ca/apps/regulateddwq/DWSP.aspx

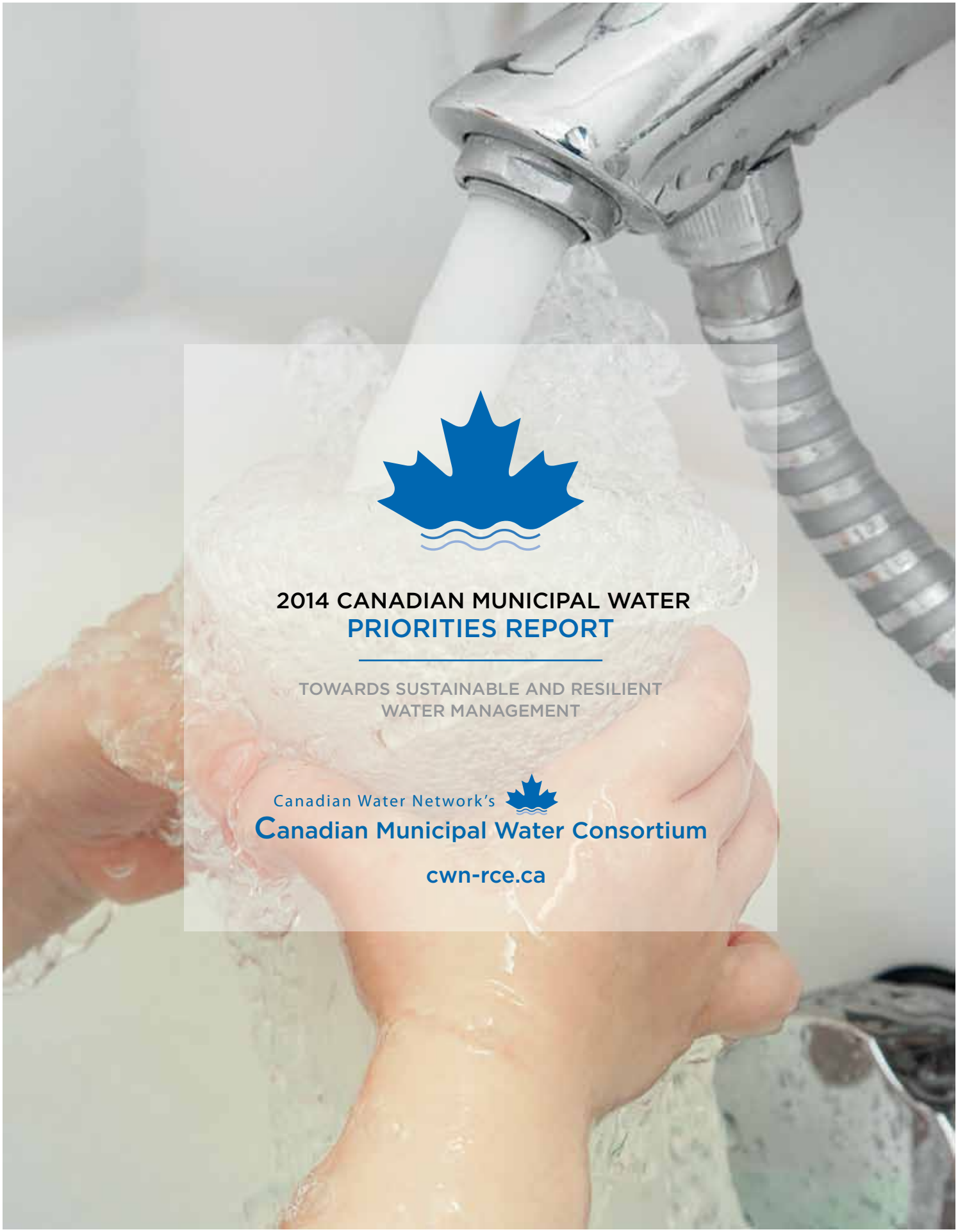
[27] Federation of Canadian Municipalities (2006). "Water and Sewer Rates: Full Cost Recovery. National Guide to Sustainable Municipal Infrastructure." March, 2006.
https://www.fcm.ca/Documents/reports/Infraguide/Water_and_Sewer_Rates_Full_Cost_Recovery_EN.pdf

[28] Halifax Water (2013). "Integrated Resource Plan (IRP)." http://www.halifax.ca/hrwc/IntegratedResourcePlan_2013.php

[29] Halton Region (2009). "Biosolids Management Master Plan." http://www.halton.ca/living_in_halton/water_wastewater/wastewater/biosolids_recycling_program/biosolids_management_master_plan/

[30] EPCOR "Gold Bar Wastewater Treatment Plant."
http://corp.epcor.com/watersolutions/operations/edmonton/goldbar/pages/gold-bar-wastewater-treatment-plant.aspx

[31] Schreier, Hans, "Innovative Stormwater Management." 2014.
http://www.cwn-rce.ca/assets/resources/pdf/CWN-EN-Stormwater-Report-FINAL.pdf



2014 CANADIAN MUNICIPAL WATER PRIORITIES REPORT

TOWARDS SUSTAINABLE AND RESILIENT WATER MANAGEMENT

Canadian Water Network's

Canadian Municipal Water Consortium

cwn-rce.ca