CITIES ADAPT TO EXTREME RAINFALL

CELEBRATING LOCAL LEADERSHIP

by Paul Kovacs, Sophie Guilbault and Dan Sandink

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Institute for Catastrophic Loss Reduction
Building resilient communities

Institut de Prévention des Sinistres Catastrophiques
Bâtir des communautés résilientes

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CELEBRATING LOCAL LEADERSHIP

Evidence that our climate is changing is now "unequivocal" according to the Intergovernmental Panel on Climate Change (IPCC), the world's leading forum for assessing and communicating current knowledge about climate change. In particular, extreme rainfall is expected to increase in frequency and severity. ICLEI, the leading forum for local governments to promote sustainability, found that the most important impacts of climate change identified by member communities around the world are i) increased storm water runoff and ii) changes in demand for storm water management. The Institute for Catastrophic Loss Reduction (ICLR) is a world-class disaster risk reduction research centre at Western University. Actions taken by ICLR include work with local governments and other stakeholders to identify best practices for managing the risk of loss and damage from sanitary and stormwater flooding. In this book, we provide 20 case studies of local leadership across Canada to address the growing challenges from waste and stormwater management associated with extreme rainfall.

A comprehensive local plan to manage extreme rainfall should include actions to enhance municipal infrastructure and also plans to involve property owners with waste and stormwater management. ICLR estimates that preventable damage to homes and infrastructure in Canada as a result of extreme rainfall presently exceeds $2 billion a year. Indeed, urban flooding has recently grown to become the leading cause of preventable damage to homes. Moreover, climate change is expected to significantly increase the frequency and severity of extreme rainfall across Canada.

Preventable damage to homes and infrastructure will continue to grow unless we adapt our current practices and confront the risks associated with extreme rainfall. Best practices for building and maintaining effective waste and stormwater infrastructure should include an evaluation of the expected intensity, duration and frequency of rainfall events based on historic local experience combined with an assessment of the change in the climate during the expected lifetime of the infrastructure.

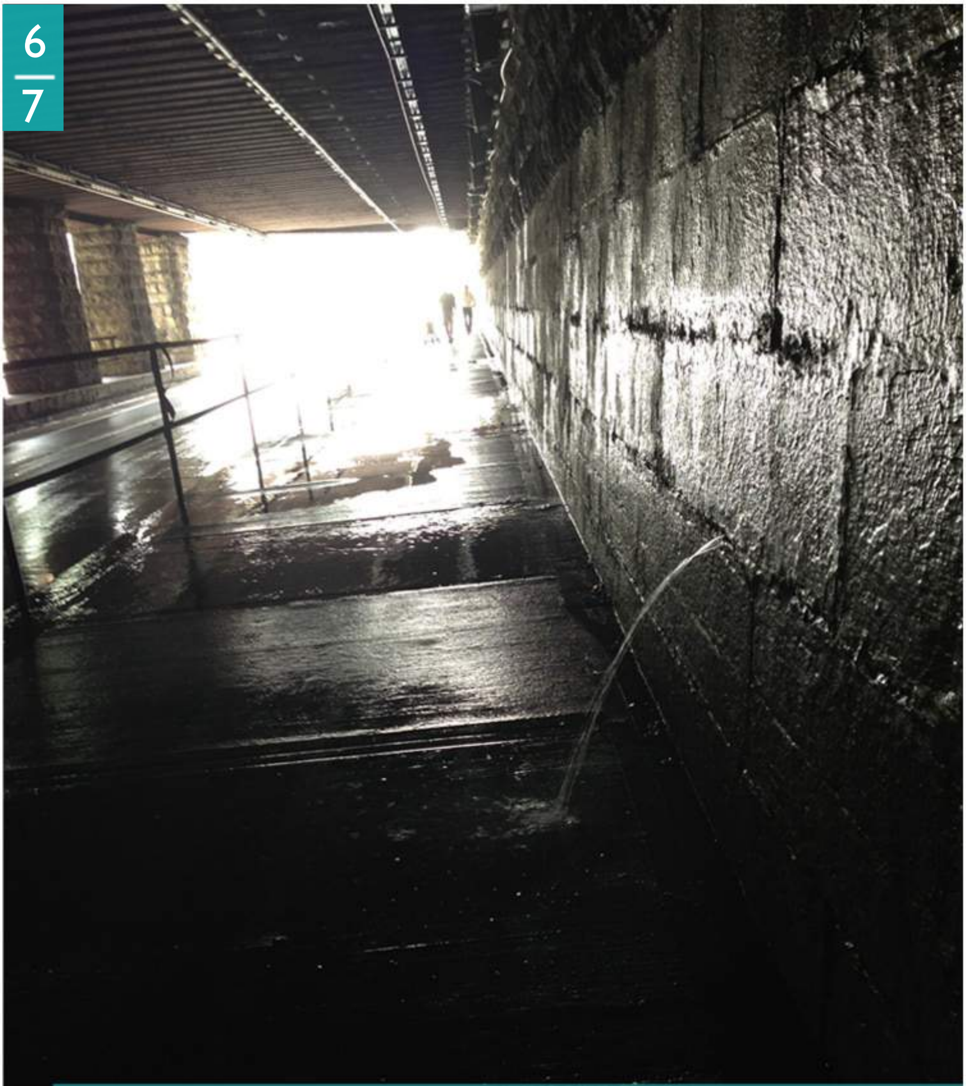
ICLR has conducted detailed climate assessments for communities like London and offers an assessment tool that local officials can apply in any community across Canada. Engineers Canada has developed the Public Infrastructure Engineering Vulnerability Committee (PIEVC) engineering protocol for local governments to guide their efforts to build and maintain waste and stormwater infrastructure in a changing climate. And the Insurance Bureau of Canada is testing MRAT (Municipal Risk Assessment Tool) in three communities across the country seeking to provide a tool for local governments to reduce the risk of basement flooding.

Figure 1: *Extreme rainfall event in Ottawa in 2006 causing sewer overflow. (Source: City of Ottawa)*

ICLR is a leader in working with local governments on strategies to involve property owners in the management of waste and storm water to reduce the risk of damage from extreme rainfall. The Institute has identified best practices for protecting homes, like the installation of backwater valves and sump pumps, landscaping and downspout disconnection to direct storm water to permeable surfaces and away from the sewer system, and regular inspection of storm laterals. Actions taken on private property are essential to manage the inflow and infiltration of rainwater into municipal wastewater systems. Legislative authority and economic considerations show that the greatest scope for local action involves the regulation of new development. Fortunately we also find many examples of financial incentives, public outreach programs and regulatory initiatives that have been successful in convincing existing homeowners to participate in actions to reduce risk.

This book provides 20 case studies of local leadership working to reduce the risk of loss and damage from extreme rainfall. Most of the identified communities have a comprehensive strategy in place but we report on only one element of their overall effort. These case studies were chosen because the actions are consistent with best local practices identified by the Institute for Catastrophic Loss Reduction and they can be applied in most other communities across the country. There is a well-established science foundation for local action, and many communities have begun to lead the way to turn scientific research into local action. Most loss and damage from extreme rainfall is preventable through local actions to manage waste and stormwater infrastructure combined with homeowner participation to protect their property. We are pleased to celebrate these examples of local leadership.


Source: ICLR



LESSONS LEARNED

Local actions to address extreme rainfall

Source: *ICLR*

Local governments are confronting one of the most important issues of our time – the alarming recent increase in damage to homes from extreme rainfall. Communities large and small across Canada are now taking action to reduce the risk of basement flooding and damage to property from sewer backup. This book describes 20 of the many successful local projects underway in communities that are adapting to better address the risks associated with extreme rainfall.

This book recognizes and acknowledges local leadership in addressing the risk of basement flooding. Mini case studies showcase successful local actions that can and should be used by communities across the country to confront the dual challenge of waste and stormwater management. The local policy decisions presented in this report are, in our opinion, scientifically sound, and provide a sustainable foundation for long-term success.

In recent years, severe rainfall has replaced fire to become the leading cause of damage to Canadian homes. Damage to homes from sewer backup and basement flooding now exceeds $2 billion a year, and has been rising at an unsustainable rate for more than 25 years. Moreover, it is inevitable that the frequency and severity of extreme rainfall events will escalate as a result of climate change, threatening to further increase the damage to homes unless we adapt.

Much of the damage to homes is preventable if local governments and homeowners apply existing knowledge to the design and maintenance of buildings and infrastructure. Fortunately, local governments, property owners and other stakeholders are starting to take action. Over the next few decades, it is expected that Canadians will experience more frequent and intense rainstorms. Nevertheless, if we adapt, it is possible that we could also experience reduced stormwater damage to homes.

Local governments need to invest in waste and stormwater management infrastructure, designed to cope with historic extreme rainfall events and also the prospect of even more intense events in the future. Vancouver is replacing all of its combined sewers to eliminate the discharge of untreated waste into waterways. Stratford has invested in stormwater systems designed to cope with a 250 year storm, well above the 100 year standard used in most communities. Welland is using PIEVC tools to design and manage its stormwater system based on rainfall intensity, frequency and duration projected under climate change.

Local governments are also working to change the behaviour of property owners. Halifax provides stormwater management guidelines to property owners, developers and other stakeholders to inform them about good practices. Kitchener and Waterloo worked together to implement a new storm water funding system, where property owners that retain an increased volume of stormwater and reduce the demands on the public sewer system are rewarded with tax credits.

Figure 2*: Boucherville won awards for installing wet and dry ponds to retain stormwater in a new development.*
(Source: ICLR)

Quebec City wrote seven times to citizens until 100 percent of the targeted homeowners disconnected their downspouts. About 50 percent of the targeted property owners in Saskatoon purchased a subsidized backwater valve to reduce the risk of wastewater in sanitary sewer pipes backing up into homes. Homeowners choosing to undertake major renovations in Surrey must replace their aging sanitary laterals. London was able to avoid costly upgrades to its sewer infrastructure by encouraging homeowners to sever their weeping tile connections from wastewater systems.

There is also a welcome focus on new developments. Boucherville won awards for installing wet and dry ponds to retain stormwater in a new development. Ottawa requires a normally open valve on the mainline sanitary sewer lateral and a normally closed valve on the stormwater connection for new homes. Markham has prohibited the construction of reverse-sloped driveways. In Edmonton, lot grading for new homes must be pre-approved.

It is possible to significantly reduce the risk of damage to homes from extreme rainfall if more communities and more homeowners take action. Considerable knowledge exists about the design and management of buildings and infrastructure to reduce the risk of damage from basement flooding and sewer backup. There is a strong consensus about the best practices to reduce the risk of damage. The current challenge is to encourage more governments and more homeowners to take action.

For example, much of the current risk of damage to homes from sewer backup could be eliminated through the installation of a backwater valve. The preventable damage to homes is greater in any recent year than the cost of purchasing a backwater valve for every home in Canada. However, most homes do not yet have a valve. Indeed, thousands of new homes continue to be built each year without a backwater valve. And communities that offer financial incentives to existing homeowners frequently discover that most property owners fail to take action.

Local governments are typically viewed by the public as responsible for ensuring that waste and stormwater does not enter and damage private property. In effect, local governments are seen to 'own' this issue. But many of the actions required to address this risk must take place on private property. A recurring theme in this report is the challenge for local governments to serve the public good through a comprehensive strategy that likely includes regulation of private actions.

In this report, we document some of the ways local governments seek to influence private behaviour. For example, Ottawa regulates the construction of new homes to ensure that builders install backwater valves. Kitchener and Waterloo have stormwater fees based on usage. London provides incentives for at-risk homeowners to disconnect weeping tiles. Halifax provides public information about the options available to interested stakeholders.

Finally, we observe that the trigger for action by most governments across Canada involved responding to damage from an extreme rainfall event. Nevertheless some communities have been proactive, seeking to take early action before large losses strike. For example, Collingwood has mandated the installation of backwater valves in new homes and Surrey requires the replacement of storm laterals when substantial renovations are planned.

Considerable effort is required to regain control over the risk of damage to homes from extreme rainfall, nevertheless the direction we must follow is becoming clear. All stakeholders are encouraged to share these and other stories of successful efforts by local governments, celebrating the actions of progressive communities that have begun to show the way forward.

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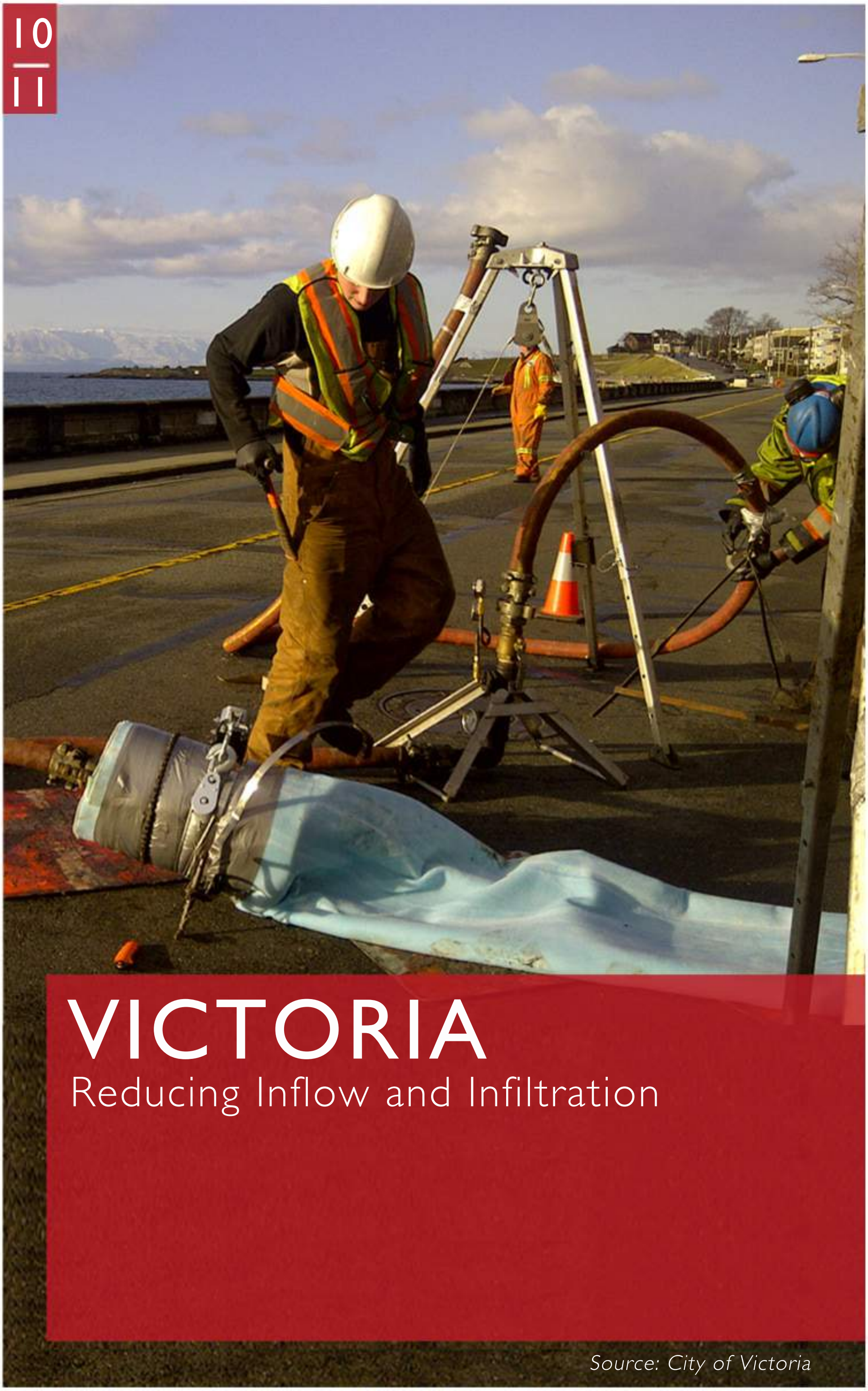


VICTORIA

Reducing Inflow and Infiltration

Source: City of Victoria

THE SCIENCE

Extreme rainfall events temporarily increase demands on stormwater systems and increase the volume of rainwater flowing into streams and rivers, but, in theory, should have a relatively small impact on flows through independent sanitary pipes to treatment facilities. However, many municipalities experience alarming growth in flows through sanitary sewers, increasing the costs of wastewater treatment and increasing the risk of flooding. There are a number of actions local governments can take to control and reduce the inflow and infiltration of excess water into sanitary sewer systems. Reduced volumes of rainwater in sanitary sewers provide savings to the community because they can reduce the need to spend on increased sanitary system capacity and wastewater treatment costs. More importantly, less rainwater in sanitary systems reduces the risk of sanitary sewer backup damage to homes.

The 2012 Canadian Infrastructure Report Card noted that 40 to 50 percent of participating local governments have no data on the state of their buried infrastructure. The study estimated that perhaps 20 percent of Canada's wastewater and stormwater infrastructure was in "fair" to "very poor" condition. Local governments likely need more than $55 billion to replace these failing systems, beyond the significant funds also needed to modernize infrastructure for drinking water, roads and address other pressing needs.

The risk of preventable damage due to aging sewers and wastewater infrastructure is often most acute in older neighbourhoods across Canada. Some storm and wastewater systems are being required to serve for decades beyond their original design, and to cope with a significant increase in demand. Canadians experience extensive damage each year from sanitary waste backing up into homes, and environmental damage as untreated sanitary waste is discharged into streams and lakes. These losses, triggered by extreme rainfall, are largely preventable.

THE TRIGGER

In 2009 the Capital Regional District's Liquid Waste Management Plan mandated that each municipality in the region should not be exposed to peak wet weather sanitary sewer flows that exceed four times average dry weather flows. Flows in the City of Victoria were known to be above this target. The City needed to establish and implement a plan to better control the inflow and infiltration of rainwater into the sanitary sewer system.

The James Bay area within the City of Victoria was largely developed in the late 1800s. Much of the sewer infrastructure in the area consists of vitrified clay pipes with butt-joints for sewer mains and laterals. Aging infrastructure is highly vulnerable to inflow and infiltration of stormwater during heavy rainfall events. Extreme rain events can bring a sudden surge in the volume of water passing through the sewers and can result in the backup of sanitary waste into homes and the discharge of untreated sewer water into the environment.

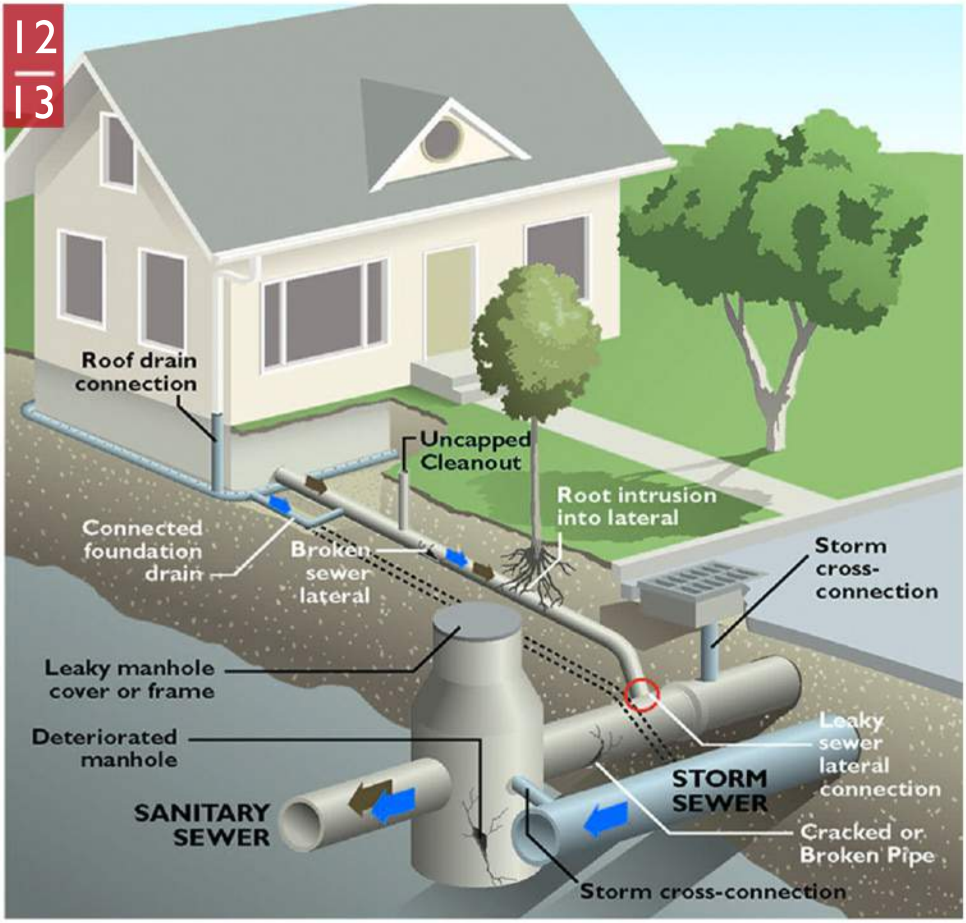


Figure 3: *Different sources of Inflow and Infiltration (Source: B.C. Capital Regional District)*

THE APPROACH

During the planning phase, the project focused on determining how stormwater was entering sanitary sewer pipes in the James Bay area. This involved video inspections of the sewer system, smoke and dye tests, and the collection of flow monitoring data. Through this phase, the James Bay area was divided into smaller sections and isolated sources of inflow and infiltration were identified in each section.

During the subsequent design phase, four different approaches to reduce inflow and infiltration were tested, with a focus on the use of trenchless technologies. This included mainline rehabilitation using pipe bursting and cured-in-place pipe lining, lateral rehabilitation using pipe bursting and cured-in-place lining, manhole rehabilitation using a coating system and internal chimney seals, and stormwater inflow redirection through the elimination of cross connections.

During the evaluation phase, flow monitoring was conducted to measure the reduction of stormwater in sanitary sewer pipes once the rehabilitation work was completed. Rehabilitation was conducted in three of four sub-catchment areas so the fourth basin would provide a benchmark for evaluating progress.

THE OUTCOME

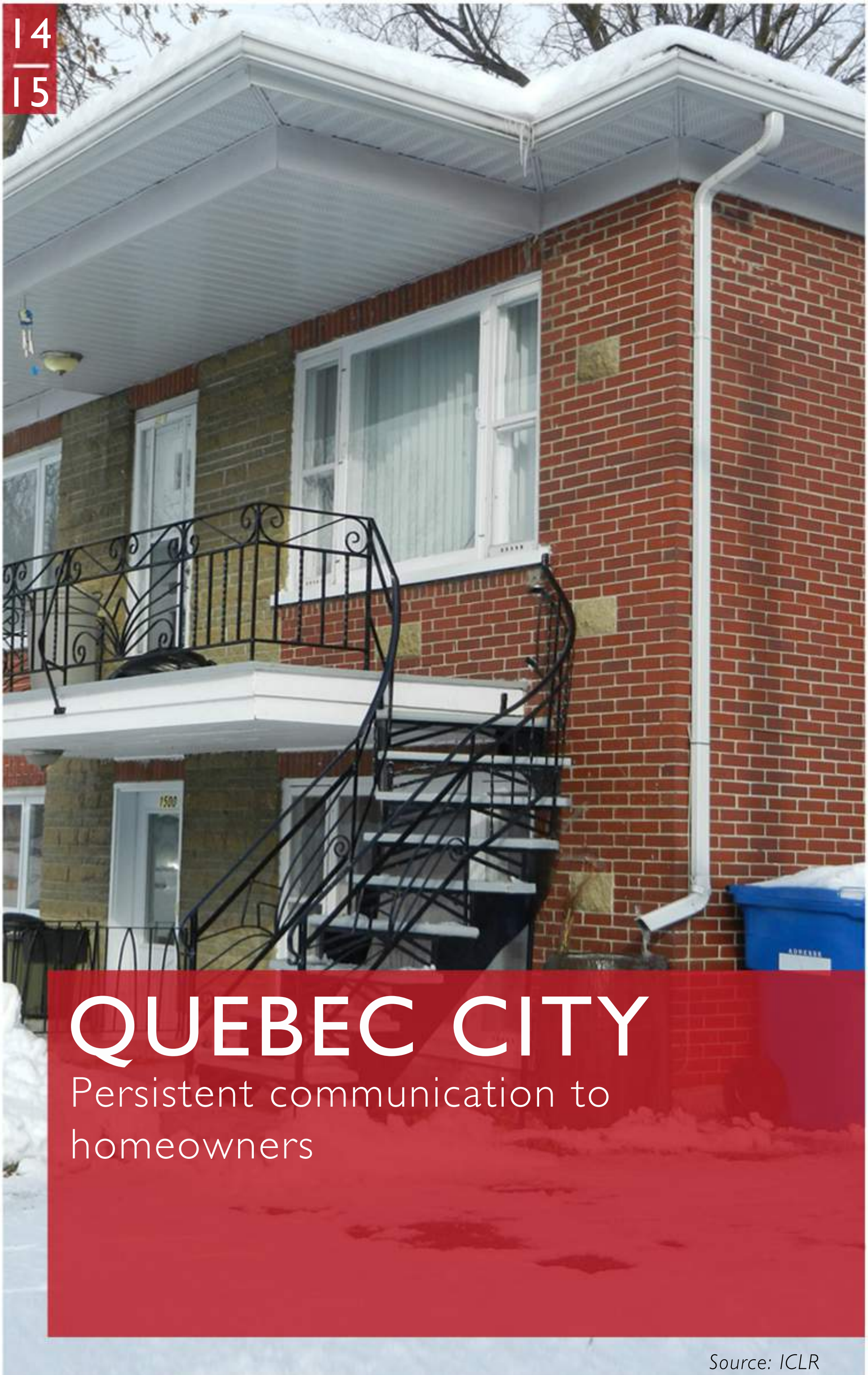
Victoria's study in James Bay revealed that mainline and lateral sewer rehabilitation contributed to a 60 percent reduction in stormwater inflow and infiltration. Moreover, the study also found that manhole rehabilitation and stormwater inflow reduction were not effective in reducing inflow and infiltration when conducted as individual measures with no attention to sewer main and laterals.

The City of Victoria was unlucky with the timing of its study since very few rainfall events happened during the time allocated for data collection. However, the study was successful in that it now provides Victoria with a blueprint for future inflow and infiltration reduction programs in the City. Other objectives were related to the elimination or reduction of sanitary sewer overflows, the improvement of public safety by lowering the risk of sewer collapse, the reduction of future sewage treatment costs and public education. Investments in local research and testing like Victoria's study in James Bay provides important knowledge to support future actions by the City to address long-term issues.

A WORD FROM VICTORIA

The study conducted by the City of Victoria helped the engineering department to establish a long-term plan to best manage their current infrastructure and decide in which cases they should adopt renewal or rehabilitation practices. According to Adam Steele, Sewer and Stormwater Quality Technologist Underground Utilities for the City of Victoria, the study gave the team more confidence in the effectiveness of specific methods and helped them decide which technologies were the most appropriate under specific circumstances. "It also helped to identify sufficient flow monitoring timelines pre- and post-renewal/rehabilitation to quantify the success of our I&I reduction program," said Mr. Steele.

When asked what advice he would give to other municipalities that would like to conduct a similar study, Mr. Steele said, "As new technologies emerge, being able to evaluate them through an exercise like this is useful to help justify rehabilitation and renewal expenditures." He also recommended a minimum of one year for data collection during the study period to cover a range of rain storm intensities and durations. Having an appropriate area with similarly sized catchments and similar inflow and intrusion rates through the different catchments is important in comparing the effectiveness of the technologies used.



QUEBEC CITY

Persistent communication to homeowners

Source: ICLR

THE SCIENCE

Property owners can and should be significant participants in efforts to reduce the risk of damage to homes from severe weather. Many practices that homeowners should follow, like disconnecting downspouts, are inexpensive and relatively easy to implement. Nevertheless it remains a considerable challenge to involve property owners in retrofit programs. Often, efforts by local governments to involve property owners are constrained by legal issues, like limits to the power of municipal officials to compel action on private property.

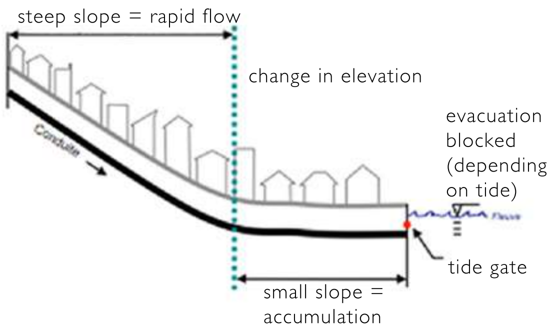
Local government officials consistently express concerns about the challenges associated with effective communication with property owners and other stakeholders. What information should be shared? What is the best timing? Who should write on behalf of the City? Some actions to protect homes against the risk of damage from extreme rainfall are technical and require professional implementation. Some actions are costly in terms of the equipment required and time involved. Some actions provide direct benefits to an individual homeowner while others provide benefits shared across a neighbourhood. Best practices to influence behaviour remain an approach with increasing support from local governments willing to share their experience.

THE TRIGGER

Maizerets is a neighbourhood enclaved in Québec City's Limoilou district. Developed mostly at the beginning of the last century, it is a neighbourhood served by a combined sewer system. The topography of the area has some parts of the neighbourhood located on higher ground and some in low-lying areas, resulting in stormwater accumulation, causing basement flooding. The neighbourhood is also located on the banks of the St. Lawrence River where a tide gate has been installed. Under normal conditions, the tide gate prevents water from backing up into the system from the St. Lawrence River. However, it does increase the risk of flooding during extreme rainfall events.

THE APPROACH

Faced with frequent basement flooding, the City conducted several studies to identify the elements contributing to the problem. It found that 373 out of 623 pitched roof houses had gutters connected to the foundation drain, which meant that roof rainwater was directly entering the combined sewer system. This connection went against municipal regulations and was unnecessarily overloading the system when it rained. The City launched a program in 2005 to fund downspout disconnections for the 373 households.



Section of Maizerets Neighbourhood

Figure 4: *The map and section presented above highlight the vulnerability of the Maizerets neighbourhood to sewer backup. Since the neighbourhood is located at the bottom of a steep slope, the water tends to accumulate in the low-lying area. A tide gate located on the bank of the St. Lawrence River also contributes to the neighbourhood's vulnerability. This device is an opening through which water can flow freely when the tide flows in one direction but which closes automatically and prevents the water from flowing in the opposite direction. In the Maizerets neighbourhood, the tide gate prevents stormwater from being directed to the river during high tide.*
(Source: Quebec City)

THE OUTCOME

Since all of the downspouts in the neighbourhood were on private property, Quebec City needed to encourage property owners to participate. The first letter from the City provided an explanation as to why disconnection was important for the neighbourhood and offered to cover the full cost of disconnection. One quarter of homeowners agreed to participate.

Seeking higher compliance, the City decided to make the program mandatory. The City wrote again to targeted homeowners explaining the importance of the program, that the City would cover the costs of disconnection, offered a free rain barrel and noted that compliance was mandatory. Almost 60 percent of the outstanding homeowners agreed to participate when the program became mandatory.

The City wrote five more times to reluctant homeowners stressing the value of disconnection to the neighbourhood and warning that a $300 fine may be imposed for non-compliance. Ultimately 100 percent of the targeted homeowners participated in the program by early 2008, about three years after the program was launched.

Securing 100 percent compliance required a persistent public awareness campaign that ultimately required seven letters and two brochures. Further, this campaign utilized increasingly senior officials and a shift from incentives to coercive measures. In addition to the downspout disconnection program, other mitigation measures were also undertaken by the City that incorporated stormwater retention systems in public parks and parking lots.

Quebec City invested $100,000 in the downspout disconnection project and $25 million for the construction of a retention tank and renovations to the sewage system. The City estimated that the measures to encourage disconnection by homeowners allowed the City to build a smaller retention tank, saving about $500,000. Flow regulators were also installed in parks and parking lots around the neighbourhood. Replacing the combined system with a separated system would have required a significant investment that the City was not able to make. However, the City increased the capacity of the system and approved a new standard commonly used elsewhere in the City.

By increasing citizens' awareness, enforcing regulations and investing in the repair or construction of new infrastructure, the City was able to significantly reduce the risk of basement flooding in Maizerets.

A WORD FROM QUEBEC CITY

Manuel Parent, Urban Infrastructure Engineer for Quebec City stressed the importance of explaining to homeowners how connected downspouts can increase the risks of sewer backups and why this connection goes against municipal legislation. He further stated that City representatives should make sure that necessary retrofits and costs are explained, and ideally present the program as a turn-key project funded by the City. Communication with homeowners should be from senior officials and ideally no more than three letters should be sent.

If he had to go through the process again, Mr. Parent said he would "use the first letter as a non-compliance notice explaining to homeowners that their downspout connections go against municipal legislation and that they have 30 days to conform or a $300 fine could be imposed. The second letter would include an additional 30 day deadline and inform that a $300 fine will be imposed after that point. Finally, the third letter would inform homeowners that they have to pay the fine unless they immediately register in the disconnection program. It is important to start by promoting citizens' participation instead of presenting the program as a constraint," said Mr. Parent.

OTTAWA

Mandatory backwater valves on storm and sanitary laterals

Source: City of Ottawa

THE SCIENCE

Backwater valves are recognized for their effectiveness in reducing the risk of damage from sewers backing up. A backwater valve, however, is not a guarantee that the risk of loss and damage will be eliminated. Some homes that experience damage from basement flooding have a backwater valve in place. In particular, if a backwater valve is not properly maintained, water and sanitary waste can back up into a home during an extreme rainfall event. Homeowners need to be educated about proper maintenance of the valves if the mechanisms are to be effective.

Backwater valves are just one tool in a complex scheme of storm and wastewater management. An assessment by the City of Ottawa seeking to understand why a number of homes in the City with backwater valves experienced basement flood damage identified these valves as a second line of defense. The study by Ottawa emphasized the importance of properly designed and maintained municipal storm and wastewater systems as the primary means to protect homes from damage due to extreme rainfall.

Research and evidence consistently recognize backwater valves as a powerful mechanism for reducing basement flooding, but it is important to understand how they can be most effective and what their role is within the broader system of storm and wastewater management.

THE TRIGGER

In July 2009, Ottawa experienced a severe rainfall event that resulted in the identification of approximately 1,500 basement flooding incidents in the west end of the City. Out of these known incidents, almost eight percent happened in homes where a backwater valve was installed on the storm sewer lateral. The number of homes with backwater valves experiencing sewer backup was unexpected and suggested the need for additional information about why the valves failed to prevent basement flooding.

A comprehensive review was undertaken by the City to understand what caused water to enter homes protected by a backwater valve, to investigate City standards with regard to current industry technology and practices, and to see what other municipalities were doing to prevent sewer backups. Once this review was completed, the City of Ottawa came up with a five-step plan to optimize the potential of backwater valves and reduce the occurrence of basement flooding in the future.

THE APPROACH

The plan developed by the City covered various aspects related to increasing the level of protection against sewer backups. The first recommendation was to keep improving the municipal sewer system in order to reduce the reliance on backwater valves as defense against damage to homes from wastewater backing up during extreme rainfall events. The underground sewer system

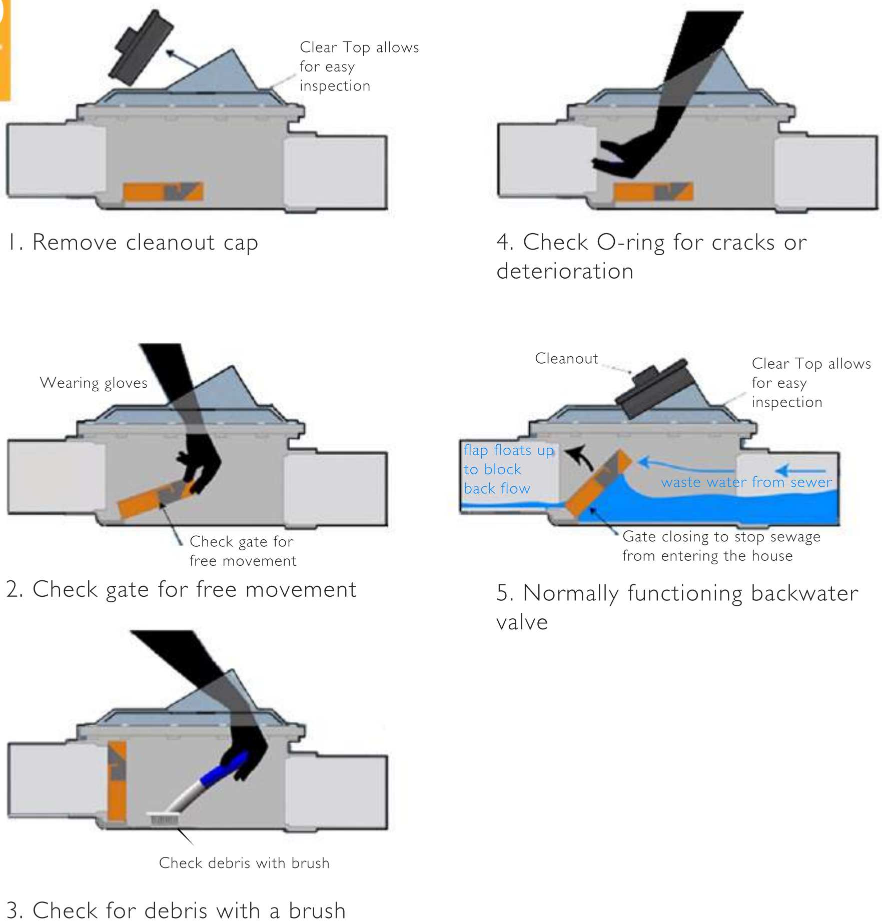


Figure 5 : *The illustration above outlines different steps that need to be taken to ensure the proper maintenance of a backwater valve.*
(Source: ICLR)

and overland stormwater management system were identified as the primary mechanisms for preventing damage to homes as a result of extreme rainfall events. Nevertheless, backwater valves were identified as an essential element of a comprehensive risk reduction strategy.

The review also identified the need to increase homeowners' awareness about the importance of backwater valve maintenance. The City determined that the main mode of failure of the backwater valves was likely through the valve cover, as one third of the backwater valves covers inspected were not screwed down tightly, resulting in failure of the valve. Ottawa determined that many homeowners were not aware of the appropriate maintenance and care required to secure the greatest protection from backwater valves.

Finally, an important recommendation of the review was to expand the installation of backwater valves to have better protection against sanitary sewer backup by making them mandatory for new homes on both storm sewer and sanitary sewer laterals.

THE OUTCOME

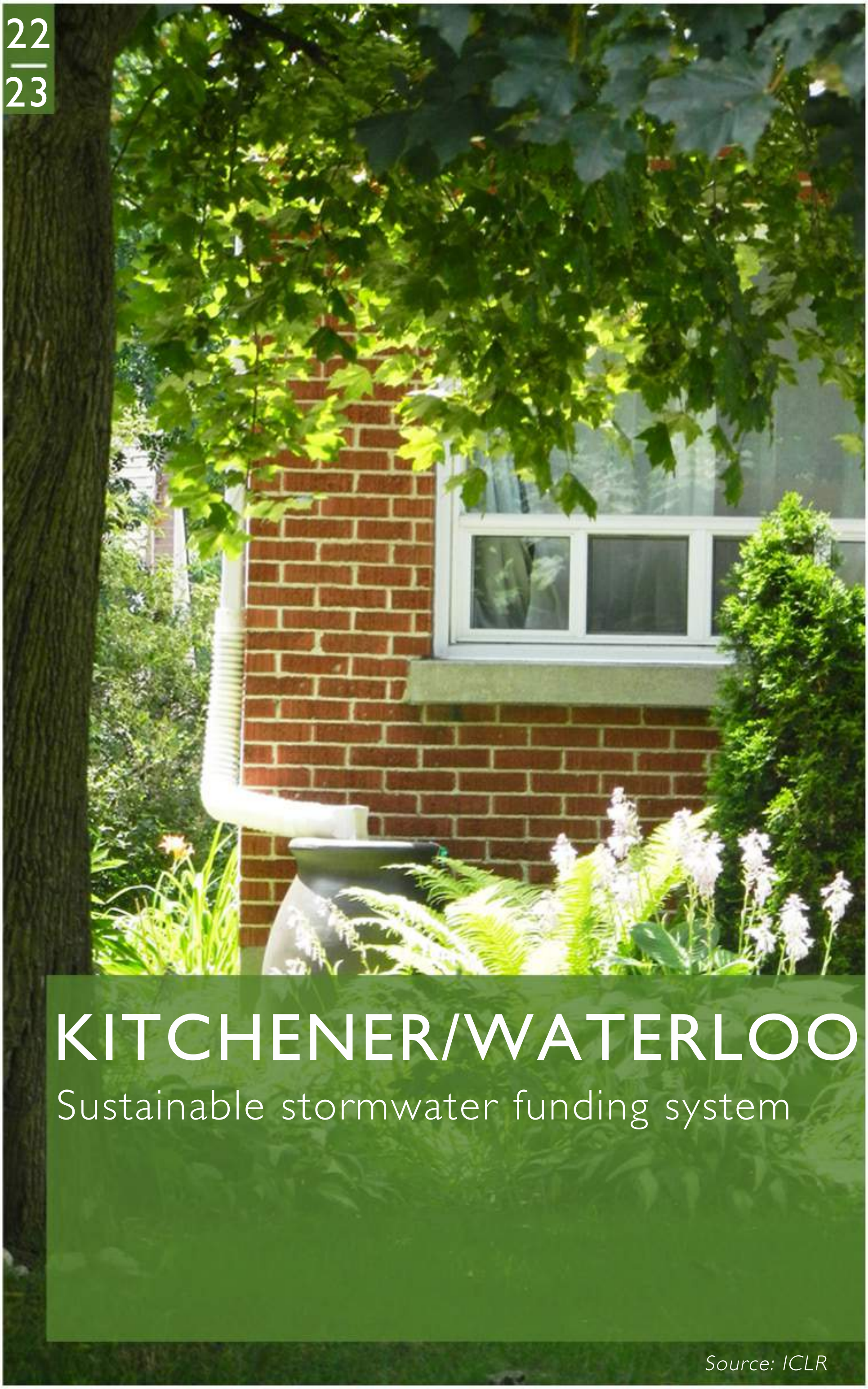
In 2009, Ottawa introduced a by-law requiring installation of a backwater valve on all new sanitary sewer connections. This applied to all properties, including residential and commercial, if there is a basement with new lateral connections to the sewer system. This expands on earlier requirements in the City where the installation of a sewage backflow prevention device was already mandatory on new foundation drain systems connected to a City storm or combined sewer system.

The recommendation presented by the City was developed to improve protection within areas that have a separated sewer system in place. It was established that installing backwater valves on sanitary sewer service laterals as well as on storm connections in new homes would not have a big impact on costs to the homebuilder. Investing in the installation of a backwater valve in new home construction is also much more economical when compared to retrofitting as installations in new homes were estimated at $250, compared to an average of $1,400 for retrofits. The requirement has been well received in the community and there has been no opposition from the building industry.

A Residential Protective Plumbing Program was implemented in Ottawa in 2005 as part of the Sewer Backup Protection By-law. It supported the installation of more than 900 backwater valves. The current program continues to focus on high-risk areas and offers a subsidy of between 50 and 100 percent in areas that experienced basement flooding.

A WORD FROM OTTAWA

When asked what advice he would give to other municipalities considering subsidy programs for basement flood risk reduction, Eric Tousignant, Senior Water Resources Engineer for the City of Ottawa, highlighted the importance of adequate public education when implementing these types of programs. He stated that "when this program started out, people were not aware of it or didn't understand it. Some residents also refused to buy into the program because they wanted the City to be responsible and accountable for the work. It took some time before property owners understood that the subsidy program was implemented to provide a second line of defence after adequate infrastructure servicing to help residents in high risk areas."



KITCHENER/WATERLOO

Sustainable stormwater funding system

Source: ICLR

THE SCIENCE

Canadian municipalities are responsible for the construction and maintenance of their stormwater management infrastructure. Municipalities across the country are struggling with aging infrastructure unable to cope with existing stresses and loads. For example, the Federation of Canadian Municipalities recently reported that more than $50 billion is needed to replace or repair municipal storm and wastewater infrastructure. Many wastewater and stormwater systems are approaching the end of their service life and often are unable to protect homes from extreme rainfall damage. Numerous other agencies, including the Canadian Water and Wastewater Association and the Canadian Water Network, have reported that local governments across Canada are facing significant infrastructure deficits, and much of the core infrastructure on which current cities rely is outdated and under-maintained. The cities of Kitchener and Waterloo, however, have introduced a novel way to address infrastructure deficits related to stormwater management infrastructure.

THE TRIGGER

In order to find a sustainable way to fund stormwater infrastructure, the Cities of Kitchener and Waterloo decided to re-evaluate their stormwater funding system. The first step to this process was to launch a detailed review of their funding models for stormwater infrastructure, which was started in 2004. The review brought several concerns to their attention. Similar to many other Canadian cities, stormwater management infrastructure in Kitchener and Waterloo was aging, maintenance costs were increasing, and growing urbanization and climate change were pushing the system over its limits. Kitchener and Waterloo decided to rethink their approach to stormwater management to come up with a more sustainable way to fund stormwater management infrastructure. The result was the development of a funding mechanism that would provide revenue for infrastructure while giving property owners a more direct interest in awareness of the quality of their infrastructure system and its impact on the environment.

Kitchener and Waterloo jointly conducted a feasibility study that encompassed a five-year comprehensive public consultation and review. The cities decided to replace their tax-based funding model with a user pay system.

One of the most important drivers for changing the funding approach was ensuring that users would pay for stormwater management services in a way that reflected their use of these services. Essentially, those who contributed more runoff from their property into public stormwater management systems would be charged more for stormwater management services. When Kitchener and Waterloo decided to implement the user pay approach, they first had to figure out how to determine how much each property was contributing to the run-off.

Figure 6 : *The Victoria Park Lake Improvement project includes a new sediment forebay. It is designed as an initial storage area to trap and settle out sediment and heavy pollutants before they reach the main basin.*
(Source: ICLR)

THE APPROACH

The City of Kitchener decided to calculate the fee based on the amount of impervious area on each property. The City sampled 500 properties, measured the total impervious area and statistically correlated that information to building footprints. Kitchener established 13 funding tiers for the new stormwater charge ranging from $47 a year for the smallest property to more than $23,000 a year for the largest non-residential property. Under the previous tax-based funding model, residential properties were paying for about three-quarters of the stormwater maintenance costs. This amount dropped to 55 percent under the user-pay approach. The remaining funds and overall increase in funds were generated from industrial/commercial/ institutional stormwater fees. Overall, this new approach generated a $4 million increase to the annual capital and operating budget for the City of Kitchener. With this budget, they were able to fund the construction of new infrastructure.

Waterloo's approach used a tiered structure. Under this structure, the fee is also based on the amount of runoff that enters the stormwater management system from a property. The runoff level for each property was estimated by a land-use classification and property size. In Waterloo, the user-pay approach was implemented progressively over the course of four years, ending in 2014.

THE OUTCOME

Prior to the implementation of the user-pay approach, Kitchener and Waterloo identified an annual deficit in spending of $4.7 million. This deficit led to consequences such as flooding and erosion. The new rate structure established by both cities made it possible to have a dedicated and stable funding source to finance both the rehabilitation and improvement of stormwater infrastructure. Officially implemented in March 2012 for Kitchener and January 2013 for Waterloo, the user-pay approach has proven to be sustainable on multiple levels. Not only does it encourage sustainable practices from property owners, but it can also eventually help the municipalities to invest in capital improvements in areas where stormwater infrastructure is non-existent or needs to be replaced. As an example, the City of Kitchener was able to fund the Victoria Park Lake Improvements project.

When the Cities of Kitchener and Waterloo decided to switch to a user-pay approach for stormwater management, they also introduced a stormwater credit program. With a rate structure and the utility model, it became feasible to provide financial incentives for properties that have implemented onsite stormwater controls to reduce runoff from impervious areas. In both Kitchener and Waterloo, stormwater credit programs have been created for both the residential and non-residential sectors. For non-residential property owners installation of various features, such as stormwater management ponds, oil grit separators, rooftop storage, underground storage, parking lot storage, filter strips, paved area sweeping program, salt management plans, and so on, can result in a lowering of the stormwater management fees charged to stormwater users. On the educational level, businesses, schools and landlords can qualify for educational credits by implementing training programs to increase employee awareness of stormwater management or by distributing educational material.

A WORD FROM KITCHENER/WATERLOO

When considering a user-pay program for stormwater management, Todd Chapman, Manager of Programs, Water Services for the City of Waterloo recommended that municipalities implement some kind of stormwater credit or rebate program for property owners. In Waterloo, around 750 applications for the rebate program have been made to the City since its implementation at the beginning of 2013 and Kitchener has received 4,500 applications less than a year after making applications available to the public. Mr. Chapman also mentioned that several residents have contacted his team to get more information on various stormwater retention techniques.

SURREY

Mandatory replacement of sewer laterals

source: *ICLR*

THE SCIENCE

Wet weather sanitary sewer overflows and sewer backups are generally caused by excessive amounts of rainwater inflow and groundwater infiltration entering the sanitary sewer system. Excessive inflow can occur when roof drain leaders, foundation drains and drainage catch basins are incorrectly connected to sanitary sewers instead of storm sewers. Further, cracks and loose joints in storm sewer laterals can lead to exfiltration into the sanitary system.

A particular challenge for local governments involves confronting problems with sewer connections and laterals on private property that have the potential to cause damage that may occur elsewhere in the community. Losses resulting from excessive inflow and infiltration are frequently misidentified by the public to be exclusively the result of a failure in municipal infrastructure when in reality, they often come from problems that should be addressed by private property owners.

Inflow and infiltration in sewer systems can cause many problems. Excessive water flow can severely limit the capacity of existing sewer systems to serve expanded populations, generate sewer backups, flood basements, impose health risks, increase the operation and maintenance costs of treatment and pumping facilities, and lower groundwater levels leading to detrimental effects on water resources. In certain cases, sewer laterals may also deteriorate to the point where they can no longer perform their intended function for the property owner.

THE TRIGGER

The City of Surrey is a relatively young community that has not experienced much damage to homes from sewer backup and basement flooding. Nevertheless, the City is proactive in monitoring the performance of its sanitary and stormwater management systems and has identified and taken action to address an emerging, longer-term problem with private sewer connections.

Surrey's sanitary system is separated into several catchment areas. These catchment areas are monitored through flow monitoring devices to determine the extent of inflow and infiltration for each area across the City. The severity of the inflow and infiltration is then ranked and rehabilitation work is assigned accordingly.

Over the years, local authorities in Surrey have come to learn that 30 to 70 percent of inflow and infiltration originates from private laterals. Owners are responsible for repairing or replacing their sewer connection so no rainwater or groundwater enters the system, yet a significant and growing volume of rainwater has been entering the sanitary sewer system through private connections. The City of Surrey took early action to confront this problem with a by-law to ensure better maintenance of private laterals (sanitary and storm).

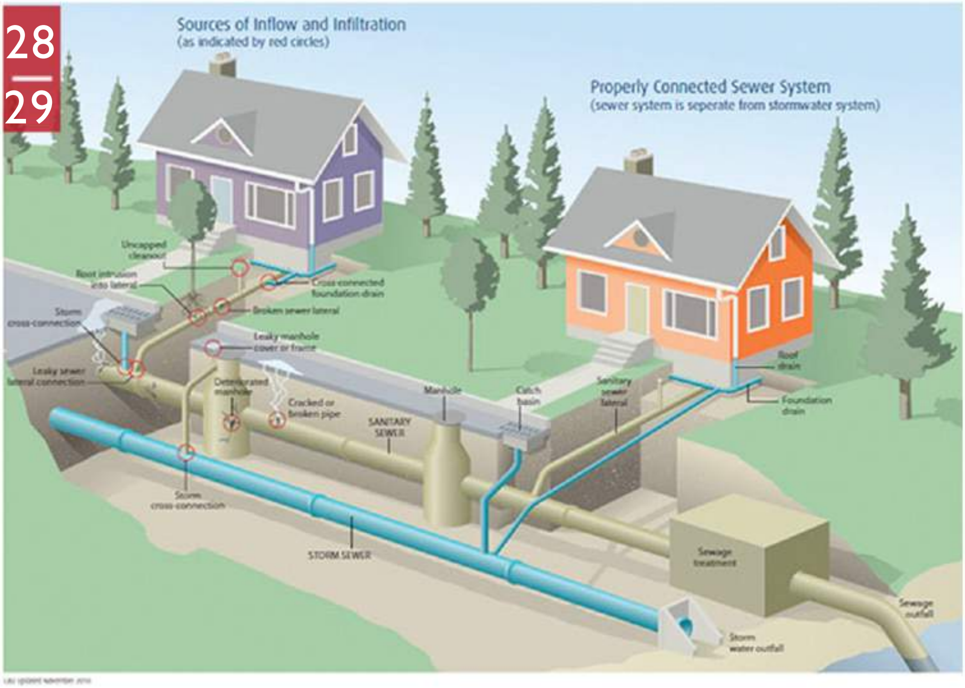


Figure 7 : *Illustration used by the City of Surrey to outline potential sources of inflow and infiltration (highlighted by the red circles) and how a properly connected sewer system should look.*
(Source: City of Surrey)

THE APPROACH

Several triggers can lead to the mandatory replacement of sewer laterals in Surrey. If the service connection or the building sanitary sewer is more than 30 years old, replacement or new service is required when a property owner submits an application for a building permit with construction value greater than $100,000 or where a parcel of land is being redeveloped.

If a building's sanitary sewer lateral is less than 30 years old, then an application for a building permit for construction value greater than $100,000 must include a video inspection of the service connection. This video inspection is also required when a parcel is being redeveloped. The City will review the inspection videos and determine if the connection is adequate or has excessive damage. The owner must repair or replace the connection if needed.

In addition, all no-corrode, asbestos, cement, or clay service pipes have to be replaced, regardless of their age. Also any shared service connections and building sanitary sewers have to be replaced when an application for a service connection accompanies a building permit for construction with a value greater than $100,000 or where a parcel is being redeveloped.

Central to the approach in Surrey is the focus on properties choosing to undergo significant renovation or redevelopment. The assessment of laterals has been included in the building permit management process, and improvement in private sewer connections becomes one element of a larger renewal process. The general view is that private property owners are not aware of the health of their sewer connections, and a period when property owners choose to make a significant investment in renewing their homes is an ideal time to assess the state of their sewer laterals.

THE OUTCOME

In Surrey, most development has occurred over the past 30 years so the City has not experienced many circumstances when sewer laterals required replacement. The mandatory sewer connection replacement program provides a mechanism to address an issue of poor sewer connections on private property that is expected to grow in importance over time. Creating the by-law was a relatively simple task and no one has challenged it since its implementation.

The City is looking to revise the mandatory sewer lateral replacement by-law. Surrey seeks to focus on property owners that choose to do significant renovations but would like to provide an exemption for property owners required to conduct major unplanned renovations. This may be the result of a catastrophic fire or other extreme event.

A WORD FROM SURREY

When asked what advice he would give to other cities that would like to implement a similar by-law, Jeff Arason, Manager, Utilities for the City of Surrey, responded that "it is very easy to demonstrate that pipes are at the end of their service life but I think that in future years there will be more and more pressure on municipalities to replace these connections. However, I believe there needs to be some consideration for those that have unplanned replacements of their homes and that cities should be flexible in that regard." Mr. Arason also mentioned that requiring all homeowners to change their sewer laterals, which would equate to approximately 90,000 sewer laterals in Surrey, would be practically impossible, but using building permits as a way to enforce the by-law has proven to be very efficient.

TORONTO

Mandatory downspout disconnection

Source: ICLR

THE SCIENCE

The risk that extreme rainfall events will overwhelm storm and wastewater systems is increased where downspouts discharge directly into sewers. A large volume of water can be collected from rooftops during an extreme rain event and if this water is directed into the storm, sanitary or combined sewer system, sewers can quickly become overwhelmed, increasing the risk that water and wastewater is driven into homes, or that untreated wastewater will pollute local surface water. The increased risk of damage to homes from basement flooding not only affects houses with connected downspouts, but can also affect neighbouring properties. Accordingly, the benefits of downspout disconnection can be perceived both at the lot level and neighbourhood level.

A smaller volume of storm water in the sewer system reduces the risk of basement flooding caused by sewer backup and improves the quality of the water that is discharged from storm sewer systems into local streams and rivers. Roof runoff contains deposited atmospheric pollutants, particles or roofing materials and concentrations of other pollutants that can have negative environmental impacts on local lakes and streams. When downspouts are disconnected and drain over lawns and gardens, the rainwater is filtered through plant roots improving water quality and benefiting the environment.

THE TRIGGER

Over the past few decades, the City of Toronto has experienced a number of extreme rainfall events resulting in extensive damage to homes from basement flooding. There have been several major loss events affecting the City including extreme rainfall events in 2000, 2005 and 2013. Damage to homes has been evident in older parts of the City with combined storm and sanitary sewer systems, but most of the largest losses occurred in relatively new neighbourhoods with modern, separated storm and sanitary systems.

Actions to address the risk of damage from sewer backup and other water perils are a priority issue for the City. Toronto has developed a comprehensive program focusing on local infrastructure needs and actions seeking to involve property owners in taking steps to protect their homes. The long-term program includes specific action plans for each flood vulnerable neighbourhood throughout the City, a significant investment in sewer infrastructure renewal, financial incentives to encourage high-risk homeowners to install backwater valves and disconnect foundation drainage from the City's sewer system, and a major public outreach campaign. Toronto has consistently demonstrated a long-term commitment to aggressively confront the risk of damage to homes from sewer backup and extreme rainfall.

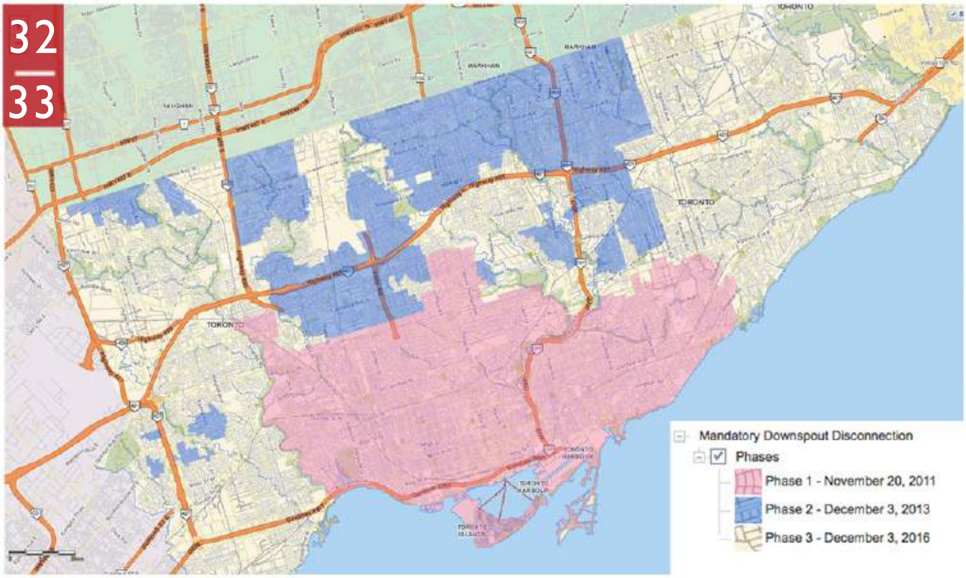


Figure 8 : *The mandatory downspout disconnection program will come into effect across the City in three phases as shown on the map. These phases are organized by priority, disconnecting the areas with combined sewer systems first.*
(Source: City of Toronto)

THE APPROACH

For new homes, Toronto's municipal code prohibits the connection of downspouts to sanitary, combined or storm sewer systems. Therefore, under normal circumstances, property owners and home builders cannot connect downspouts to sewers, and should instead drain eavestrough stormwater at grade away from buildings and adjacent properties. For existing homes a City-wide Voluntary Downspout Disconnection program was implemented in 1998 to decrease stormwater loads in the sewer system. The program targeted homes where downspouts were legally connected to either the combined or separate sanitary sewer system at the time of construction. Toronto offered to disconnect the downspouts at no cost to property owners.

In 2003, Toronto's Wet Weather Flow Management Master Plan identified downspout disconnection as one of the most effective and readily available source control options available to the City to reduce demands on the capacity of sewer systems.

The Voluntary Downspout Disconnection program initially focussed on two high risk neighbourhoods serviced by combined sewer systems. By 2006, a total of

26,000 downspouts had been disconnected, at an average rate of 2,300 downspouts disconnected each year, with $1.5 million in annual funding. In 2007, the City Council approved a by-law to move from a voluntary program to a mandatory disconnection requirement starting in 2011, with all areas of the city to be covered by 2016. Every homeowner in Toronto is required to disconnect their downspouts unless they secure an exemption because the disconnection would create a hazardous condition.

THE OUTCOME

Transitioning from a voluntary to a mandatory program brought a number of challenges for the City. Toronto needed to develop the necessary computer systems, communications, application, processes and reporting tools to process applications for exemptions. The City also needed to communicate with the public and educate homeowners, Councillors and internal stakeholders about their underground plumbing system and how it operates.

Toronto does not provide financial incentives for the current mandatory downspout disconnection program unless property owners can prove financial assistance is needed. The City offers a reimbursement of the costs of labour and materials up to a maximum of $500 for eligible low-income seniors or low income persons with a disability. Toronto provides tips on its website about what should be considered before disconnecting, how property owners can perform their own disconnections and advice for hiring a contractor to perform the work. When the City's Mandatory Downspout Disconnection program was implemented, there was some push-back from property owners in areas serviced by separated sewer systems that did not feel disconnection should be a requirement for them.

A WORD FROM TORONTO

When asked for advice he would give to other municipalities that would like to implement a similar program, Michael Caruso, supervisor of the Downspout Disconnection Program for Toronto Water, recommended that "there should be an easy process for property owners that cannot comply with the by-law to apply for an exemption. In Toronto's experience, it was also important to provide sufficient staffing resources to handle calls and emails about the program, requests for assistance, inspection and the review of exemption applications," said Mr. Caruso. "Further, municipalities considering a similar program should keep in mind that low income property owners might need financial assistance and that seniors may need additional help to complete applications."

SASKATOON

Incentive for installing backwater valves

Source: ICLR

THE SCIENCE

Backwater valves are a powerful and cost-effective mechanism to reduce the risk of damage to homes from basement flooding, however most homes do not have a valve installed. Local governments across Canada are applying programs to inform and encourage homeowners about how to reduce the risk of damage to homes from basement flooding. Most local programs include a focus on encouraging the installation of a backwater valve as a critical element of property owner participation in protecting a home from sewer backup damage as a result of extreme rainfall.

Most communities, however, have been disappointed by the small number of homeowners that install a backwater valve despite financial incentives offered by the local government. There is agreement within the expert community on the importance and protective value of backwater valves, but there is not yet agreement concerning the best way to convince homeowners to take action. Saskatoon has been successful in achieving a high participation rate. The City targeted its program to homeowners with an increased risk of sewer backup.

A professional plumber can significantly reduce the risk of basement flood damage to a specific home through the installation of protective devices like backwater valves and foundation drain disconnection. Each home is unique, including the circumstances of its location, so a professional can best determine the best protection for a particular dwelling. Saskatoon actively worked with plumbing contractors in the implementation of the City's backwater valve installation program, and this partnership is another factor contributing to the success of the program.

THE TRIGGER

Sakatoon's Flood Protection Program was introduced following extreme rainfall events in 2005, 2007 and 2010. Unacceptable and largely preventable water damage to homes led the City to develop the program. One element of the program included financial incentives encouraging homeowners to take action to protect their dwellings from the risk of sewer backup damage by installing backwater valves. Homeowners who wish to qualify must also redirect weeping tile flows away from the floor drain and into a sump pit where the water may be pumped outside. In addition, they need to safely drain the water expelled by the sump pump away from the property and onto a suitable lane, ditch, street, or easement. The City decided to focus its initial efforts on the identification of properties with a higher risk of sewer backup damage, and targeted incentives to these homeowners.

Partnerships between Saskatoon and local plumbing and restoration professionals is consistent with research by ICLR and others identifying the importance of the unique nature of each home. Experts can identify the ideal strategy to reduce the risk of damage to a particular home from sewer backup and other perils associated with extreme rainfall.

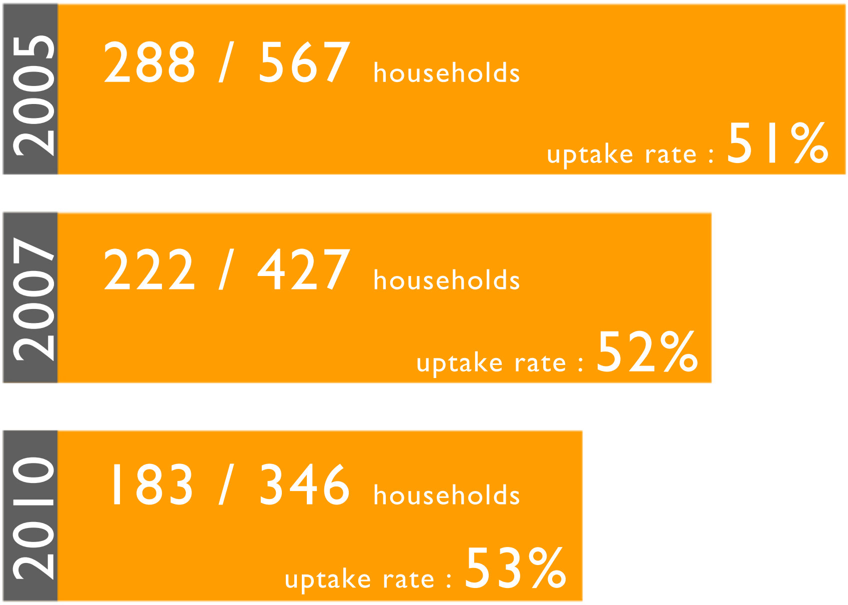


Figure 9 : *The table above illustrates the uptake rate of Saskatoon's Flood Protection Program after each flooding event. Each time, the City was able to experience an uptake rate higher than 50 percent for the installation of backwater valves.*
(Source: ICLR)

THE APPROACH

Two different analyses were conducted to identify which properties were at risk in the City. First, the location of flooded basements was mapped. This map allowed the city to evaluate roughly which properties were located in more vulnerable areas and were likely to flood in the future. After completing this first assessment, a hydraulic model of the area was created to provide the City with more precise information on which houses were at higher risk of sewer backups and basement flooding. A challenge for Saskatoon was the identification of dwellings that had previously experienced damage. Many homeowners do not report flood damage to the City, and privacy laws prevent insurance companies from sharing their confidential information about specific policyholders, so it can be difficult for local governments to identify the extent of the problem.

Saskatoon next needed to craft a strategy for encouraging at-risk homeowners to take action. The City chose to focus on financial incentives to pay for retrofits that would reduce the risk of sewer backup damage. The City was aware that most communities with programs experienced low rates of take up. The City also approached 120 plumbing contractors to determine their capacity, interest and willingness to install risk reduction measures.

THE OUTCOME

Saskatoon's Flood Protection Program has consistently led to sewer backup damage reduction investments by about half of qualifying homeowners, a very high uptake rate for this kind of program. The mapping and hydraulic modeling was used to identify higher-risk homeowners that would qualify for the Program. The City offered these residents up to $2,500 (increased to $3,000 in 2010) to install backwater valves on their sanitary sewer lateral. Homeowners were given the choice of paying the contractor and recovering funds from Saskatoon, or having the City pay the contractor directly.

About 50 percent of targeted homeowners participated in the program. The uptake rate for the program was higher than programs offered in other communities because, in part, Saskatoon offered the Flood Protection Program immediately after flooding events in 2005, 2007 and 2010. When damage had just happened homeowners where found to be more willing to invest in protection. Moreover, the City found 85 percent of those who had backwater valves had no further flood issues.

A WORD FROM SASKATOON

When asked what advice he would give to other cities that would like to implement a similar program, Galen Heinrichs, Water and Sewer Engineering Manager for the City of Saskatoon, mentioned that his team was happy with their decision to limit the program to people most likely to need it. The program was initially managed through a consultant but the City of Saskatoon realized that this kind of program was best managed internally. "Administratively, it's pretty intensive and it takes quite a bit of personnel and several hours to manage the program but I believe it is better to run it internally because there are too many things that are tied into the process."

MONCTON
Backwater valve incentive program

Source: City of Moncton

THE SCIENCE

Backwater valves permit the flow of wastewater away from a home to the municipal sanitary sewer system. During an extreme rainfall event, the valve will close automatically if sewage or water approaches the home through the sanitary or storm lateral. A backwater valve is one of the most effective tools available to reduce the risk of damage to homes from stormwater and sanitary waste. Most homes in Canada, however, do not have a backwater valve.

Backwater valves are particularly cost effective when installed in a new home. This can be encouraged by local by-laws and provincial building codes. Backwater valves are also powerful tools to protect more than eight million existing homes connected to the sanitary or combined sewer system, although the cost of installation is higher than during initial construction. Many communities offer financial incentives to encourage property owners to install backwater valves and other protective devices. The outcome, however, has been disappointing in many communities. Frequently the majority of homeowners do not participate in these programs. The incentive program in Moncton was successful in reaching about half of eligible homes, a higher take up rate than most communities. In part Moncton's success was the result of a rigorous communication effort.

THE TRIGGER

Similar to many Canadian communities, extreme rainfall and basement flooding occurs regularly in Moncton. Significant basement flood damage in 2008 in the Pearlview West area led to a City pilot project of financial incentives for homeowners to install backwater valves and other measures to reduce the risk of basement flooding.

The initial success of the pilot project combined with damage across the City the following year from sub-tropical storm Danny led to a comprehensive effort by Moncton to address the risk of loss and damage from basement flooding.

THE APPROACH

Backwater valves were offered to 100 homeowners in Pearlview West. Approximately 50 percent of the eligible homes agreed to participate in the program. This is a high uptake rate relative to most other communities. No basement flooding occurrences have since been reported in these homes.

The pilot program included a number of other measures to assist homeowners in the reduction of basement flooding risks. This included active public education about backwater valves, weeping tiles and sump pumps. Requirements for lot grading and window well covers were also adopted. The pilot was successful in determining actions Moncton could use in city-wide efforts to reduce the risk of basement flood damage. In particular, the City focused on the opportunity for financial incentives to be a mechanism for Moncton to secure the participation of residents in the implementation of actions to reduce the risk of basement flooding, such as installing backwater valves on private property.

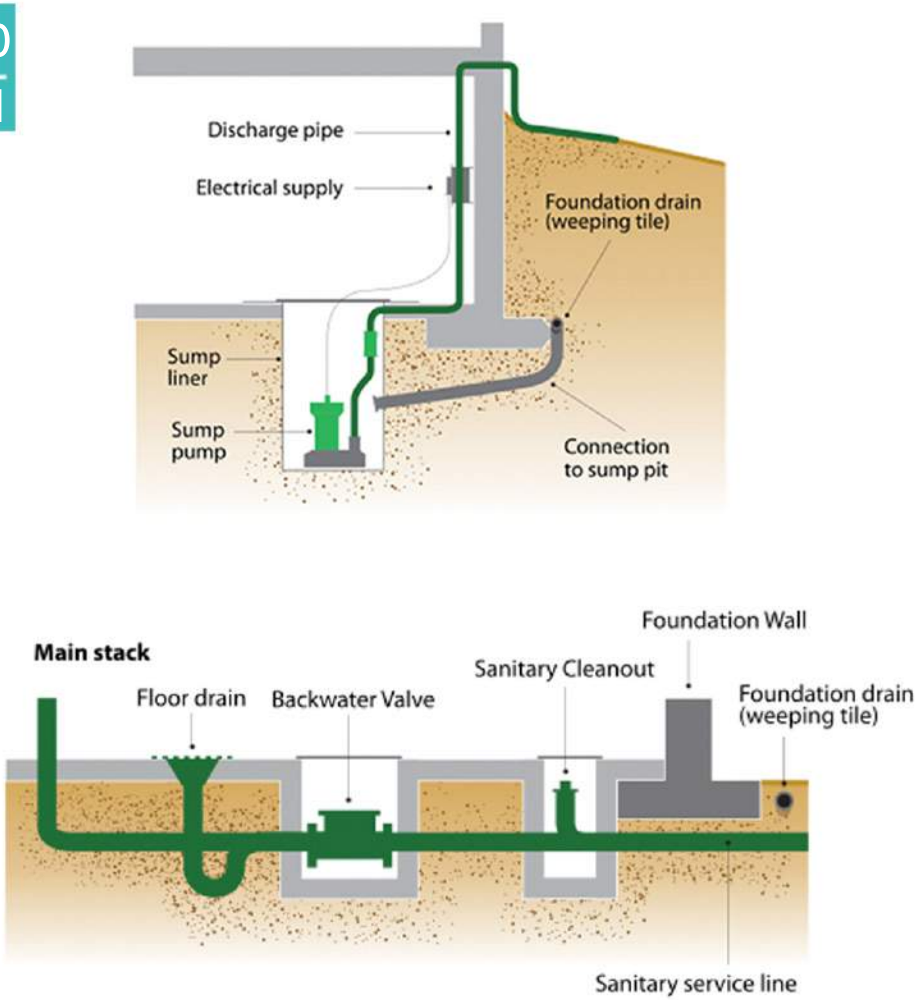


Figure 10 : *Actions that can be taken by property owners to reduce the risk of water damage. From top to bottom: sump pump installation and backwater valve installation. (Source: Homeowner's Guide to Flood Protection, City of Moncton)*

THE OUTCOME

Following the success of the pilot program in Pearlview West and the extensive damage to homes the following year from Danny, various initiatives were undertaken to promote and encourage the use of backwater valves in the City. In 2009, a by-law was implemented to require the installation of normally open backwater valves in sanitary laterals for new homes. In 2010, Moncton established a $250 rebate for backwater valve installation on household sanitary and combined laterals. The rebate was later increased to $500, which represents half of the estimated cost of installing a backwater valve in Moncton, to increase the number of homeowners that use the program. The program was expanded beyond a normally open backwater valve on the sanitary lateral to also provide a $150 rebate for installation of a normally closed backwater valve on the storm sewer connection.

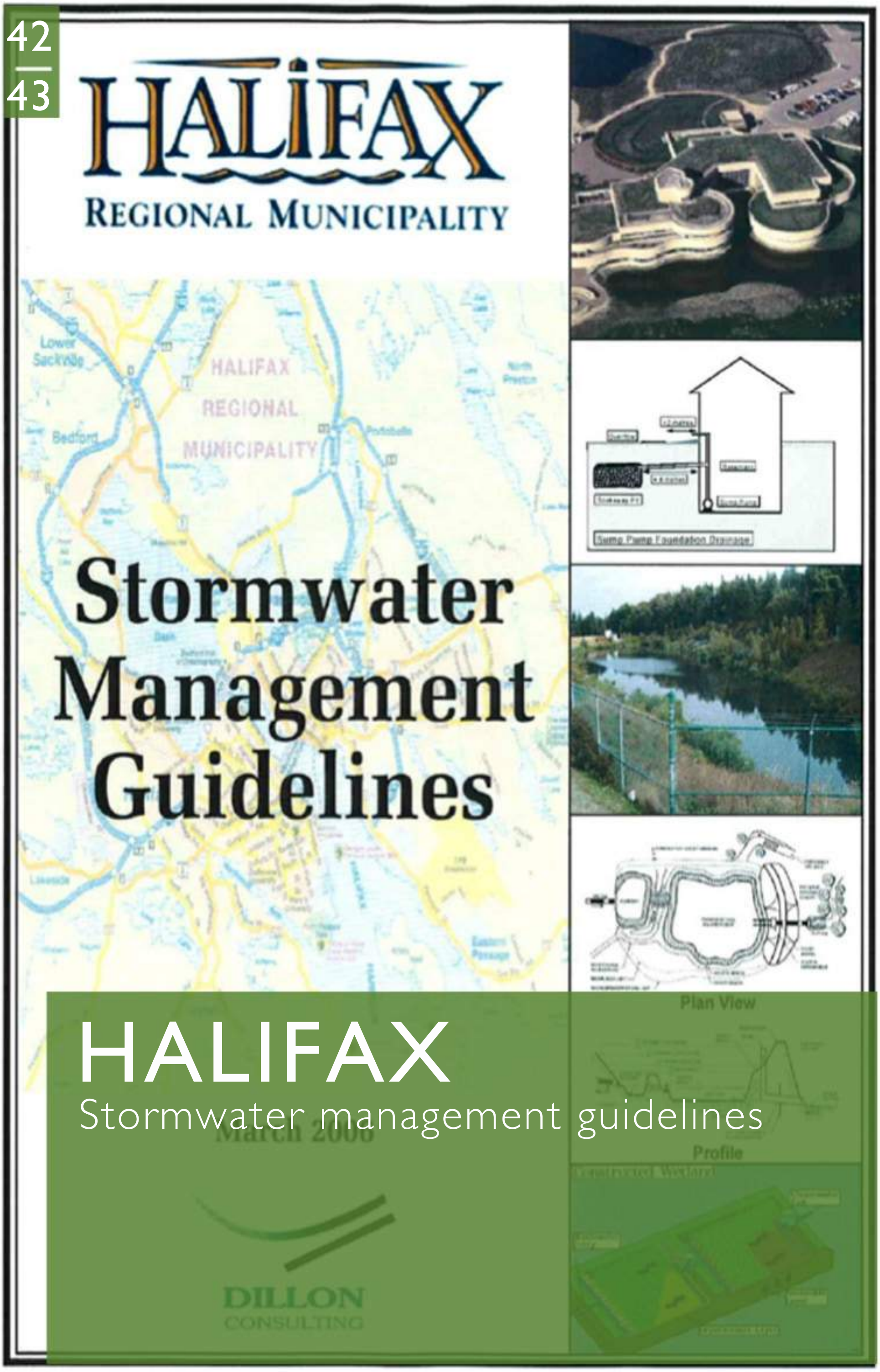
Moncton also developed literature -- The Homeowner's Guide to Flood Protection -- to educate the public about the best methods to reduce the frequency and severity of basement flooding. The materials explain why basements flood, how municipal drainage systems work and provides a list of actions that can be conducted by property owners to reduce the risk of water damage. This includes information about lot grading, downspout disconnection, and the installation of backwater valves and sump pumps. The broad objective of the City was to empower homeowners with the information needed to participate in protecting their property from damage during extreme rainfall events.

In addition to the rebates provided for the installation of backwater valves, Moncton City Council launched a new program that was directed to homeowners who had been denied sewer backup coverage by their insurance provider. If it was found that homeowners were ineligible for insurance coverage for sewer backup damage, residents may qualify for the installation of a backwater valve at no cost.

Moncton also embarked on a number of projects working directly with the insurance industry to demonstrate the City's commitment to confronting the risk of basement flooding. This included partnership with ICLR's Showcase Homes program and work with the Insurance Bureau of Canada toward development of its Municipal Risk Assessment Tool (MRAT) for combating urban flooding.

A WORD FROM MONCTON

When asked what advice she would give to municipalities that would be interested in implementing a similar incentive program, Sherry Sparks, Director of Building Inspection for the City of Moncton, spoke about the importance of effective communication with the public. "In Moncton, information about the incentive and grant program was included in all water bills with a link to the program's website. This same link was also included in staff members' electronic signatures. In addition, the City used media to reach out to the community, including twitter, radio and television interviews, and local bilingual newspapers."



HALIFAX
Stormwater management guidelines

Source: Dillon Consulting Limited

THE TRIGGER

In 2000, Halifax's Regional Council recommended that the Municipality conduct a Water Resources Management Study to determine when and how new development should happen in Halifax Regional Municipality. This study also addressed "the importance the community places on the health of water systems and health issues such as preserving water quality and avoiding flood risk and damage." The report recommended that Halifax develop guidelines to protect the environment from adverse impacts of urban stormwater runoff.

THE APPROACH

The goal was to set general design criteria for stormwater quantity, quality, erosion and base flow control in new residential, industrial, commercial and institutional developments in Halifax. By presenting several Best Management Practices (BMPs), Halifax's objectives were to minimize the adverse effects of stormwater on and off development sites, to preserve a site's natural features and to develop a new stormwater system that could closely reproduce pre-development drainage and infiltration conditions. The guidelines were an additional tool towards appropriate stormwater management facilities. The Region found that design principles that are oriented toward the preservation of natural features on sites were a good way to reduce the lifecycle cost for stormwater management and minimize the need for costly capital improvements.

THE OUTCOME

The guidelines identifiy good stormwater management practices for developments that could provide the required environmental protection, function appropriately over time, were safe, were easy to operate and maintain, and had public acceptance. The guidelines were designed to be used by professionals from various sectors such as planning, design, review, operation and maintenance of stormwater facilities. The document provides BMPs that can be used individually or in combination to improve water quality while reducing flood risk. The guidelines do not act as a substitute for any pre-established standards, but rather as an additional tool to better manage stormwater. They provide details on stormwater management methods that can achieve adequate quantity and quality targets while achieving economic sustainability.

In order to identify which stormwater management practices were most appropriate for Halifax Region, the study reviewed the latest technical literature and past experiences in planning, design and construction of stormwater management facilities. Halifax then identified four broad categories of preferred alternatives: source controls, conveyance controls, end of pipe controls and miscellaneous controls.

Design criteria were set for the Region for both water quantity and quality. The objective behind quantity control is to manage flood hazards by preventing or reducing damages associated with extreme storm events. In terms of

BMP Alternatives	Applicability	Advantage	Disadvantage	Effectiveness	Operation/ Maintenance
source control					
Disconnection of Roof Leaders	• Mostly for detached or semi-detached homes • Suitable outlet and soil conditions required • Requires cooperation of owners in existing homes • By-law and/or public education required	• Decreased runoff quantity to receiving system • Increased infiltration • Runoff detainment • Potential for some water quality benefit	• Potential for home owner inconvenience (e.g. ponding water, clogging of pond outlet/soakway pit if implemented) • Difficult to implement in existing developments or in poor soil conditions	• Effective in reducing peak flow and volume of runoff in storm and combined sewers • If combined with ponding or soakway, it will impact homeowner's use of land	• Roof leader filter cleaning and replacement and trash removal • Where constructed with soakway pits or ponding areas, it requires regular inspection
Disconnection of Foundation Drains	• Requires a potential outlet-often not available unless a clearwater sewer • Requires cooperation of owners in existing homes • Provide sump pump to discharge to surface	• Decreased runoff quantity to receiving system • Increased infiltration	• May require sump pump • Difficult to implement in existing developments • If enforced may caused unwanted discharge to sanitary sewer	• Effective in reducing peak flow and volume of runoff in storm and combined sewers • Sump pumps not effective if high water tables exists	• Soakway pits and sump pump require regular maintenance
Porous Pavement	• New technology • Requires testing before applying	• Decreased runoff quantity to receiving system • Increased infiltration • Traffic noise reduction	• Potential for groundwater contamination • Potential for clogging	• Depends on maintenance to keep pores clean	• Require regular inspection and cleaning

Figure 11: *The table presented above shows some of the BMPs recommended in the Stormwater Management Guidelines. Each BMP is presented with its applicability, advantage, disadvantage, effectiveness and operation/maintenance to help users choose which method could be the most appropriate for their needs.*
(Source: Dillon Consulting Limited)

water quality, the main objective was to ensure that water quality pre- and post-development be similar.

The introduction of BMPs in the Municipality was done to minimize adverse stormwater effects on and off development sites. Although there are no practices that could suit every development, Halifax identified that the most efficient site design would happen when BMPs are selected in the following order: Water Quality Control, Runoff Peak Attenuation for Flood and Erosion Control, and Groundwater Recharge and Base Flow Maintenance.

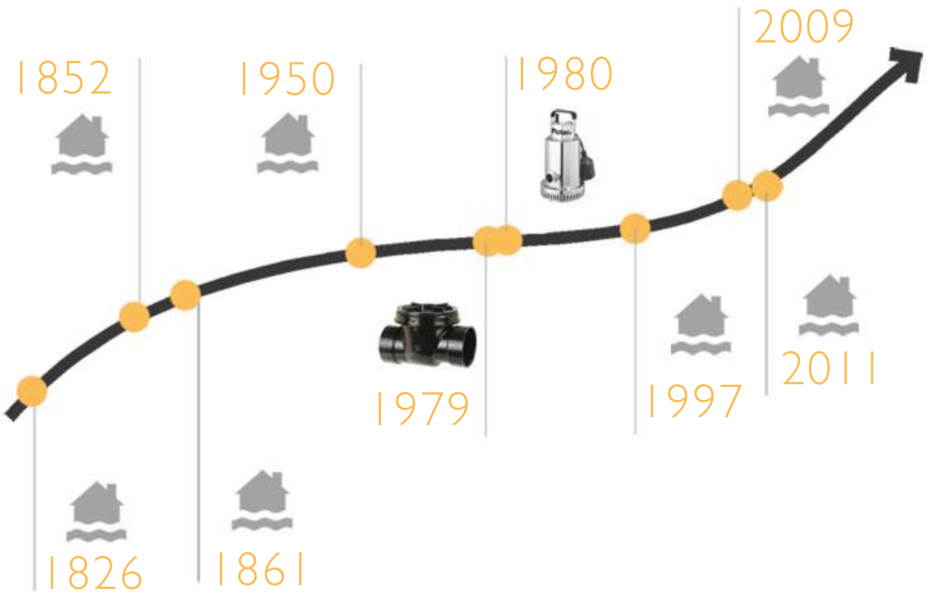
The guidelines provide examples of best practices but also a four-step selection process to ensure that appropriate practices are chosen for a particular site. The first step of the design process is to establish the objectives of the practices and identify corresponding design criteria for the site. During the second step, the user chooses the most suitable practices for the site with the help of a screening tool that has been developed to compare the capabilities and limitations of each practice. The user then develops a refined list of alternatives derived from the initial assessment that would take into account the capability to remove pollutants, space requirements, environmental considerations and health and safety issues. The final step reviews and analyzes the list developed to make a final selection.

As soon as the Stormwater Management Guidelines were completed, the document was made available online to be used as a reference tool for developers, planners, designers and contractors.

A WORD FROM HALIFAX

When asked what advice he would give to other municipalities that are considering implementing stormwater management guidelines, Cameron Deacoff, Environmental Performance Officer for Halifax Regional Municipality Energy & Environment, responded that it is essential to be clear about your objectives and their scope. It is also important to fully assess the available approaches to determine which one is the most appropriate to meet a specific objective. Also, to make sure that the guidelines are appropriate for a specific municipality, Mr. Deacoff recommended thoroughly reviewing the basic assumptions and conditions affecting this locality. "Are your flood plain maps up to date? Do rainfall models (i.e. IDF curves) adequately account for expected changes in precipitation patterns?"

Finally, Mr. Deacoff highlighted the importance of reaching out to other members of the community. "Consult with professionals in your area for expert guidance [and] with members of your community to identify their concerns and their priorities. [Also], consider working with non-profit organizations in your area. They may be able to help to engage your residents and/or other stakeholders in a number of ways, including but not limited to surveys, direct-to-owner programs, workshops and demonstration projects."



WINNIPEG

Early adaptation of backwater valve by-laws and incentives

Source: ICLR

THE SCIENCE

Backwater valves are recommended or required by many municipalities across Canada as a measure to reduce the risk of sewers backing up into homes during extreme rainfall events. Sewer backup can happen in any home, new or old, when municipal sewer systems receive more water than they can handle. This additional volume of water can create a surcharge, pushing water and untreated waste backwards through private sewer laterals and eventually causing sewage to back up in homes through basement floor drains, toilets and sinks.

When a proper backwater valve is in place, it can considerably reduce the risk of damage to homes from sewer backup. In Canada, municipalities have developed a variety of mechanisms to encourage the installation of backwater valves. This includes education and subsidy programs for existing homeowners. By-laws and code enforcement are some approaches used to influence new home construction. There is a wide consensus among local government experts across Canada that backwater valves are a valuable protection mechanism for all homes connected to a sanitary sewer system.

Data provided by insurance companies indicates that damage to homes from sewer backup has been growing for three or four decades, including an alarming increase over the last five to 10 years. In recent years damage to homes from sewer backup and other water damage has exceeded $2 billion a year. Most communities taking action to encourage the use of backwater valves are responding to a major local loss event, so many actions have been implemented relatively recently. Some communities, like Winnipeg, took initial action in the 1970s, and continue to evolve and renew their programs to prevent damage to homes from basement flooding.

THE TRIGGER

The City of Winnipeg is located in a former glacial lake with a remarkably low-lying flood plain over a flat topography. Sewers and other buried infrastructure are particularly vulnerable to damage from flooding because they are located below ground at very low elevation.

Moreover, sanitary sewers and stormwater systems are vulnerable to water inflow and infiltration from also extreme rainfall events. The City has experienced many extreme rainfall events in the past that have overwhelmed the capacity of the storm and wastewater management systems.

These extreme rainfall events have convinced local authorities early on to think more aggressively about possible mitigation measures to protect homes from basement flooding. In particular a backwater valve by-law was developed in 1979, followed by a sump pump by-law in 1980.

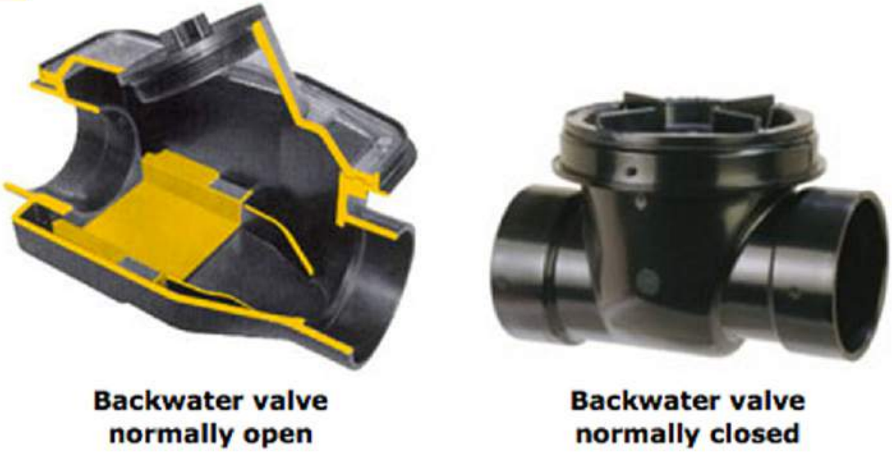


Figure 12: *Depending on the plumbing in a house, homeowners may need one or more backwater valves of either the normally open or normally closed type to properly protect their basement from flooding. The City of Winnipeg recommends that homeowners consult with a plumbing contractor licensed by the City for an assessment of the cost involved in installing any of these two eligible devices.*
(Source: City of Winnipeg)

THE APPROACH

Winnipeg was one of the first municipalities in Canada to create a by-law requiring the installation of backwater valves in all new homes. Since 1979, houses have to be built with an in-line backwater valve on the sanitary sewer connection. Approximately 28 percent of houses across the City have installed a backwater valve and 15 percent have installed a sump pit system since the implementation of the by-laws.

The core area of Winnipeg was built prior to 1979. Recently the City has implemented a subsidy program to encourage the installation of backwater valves and sump pumps in older homes. Winnipeg will pay 60 percent of the invoiced costs for the installation of an in-line backwater valve, up to a maximum of $1,000. The City will also pay 60 percent of the invoiced cost of a sump pit drainage system up to a maximum of $2,000. The province of Manitoba and the City of Winnipeg share equally in the cost of funding the program. All homes in Winnipeg qualify for the program regardless of their flood history.

THE OUTCOME

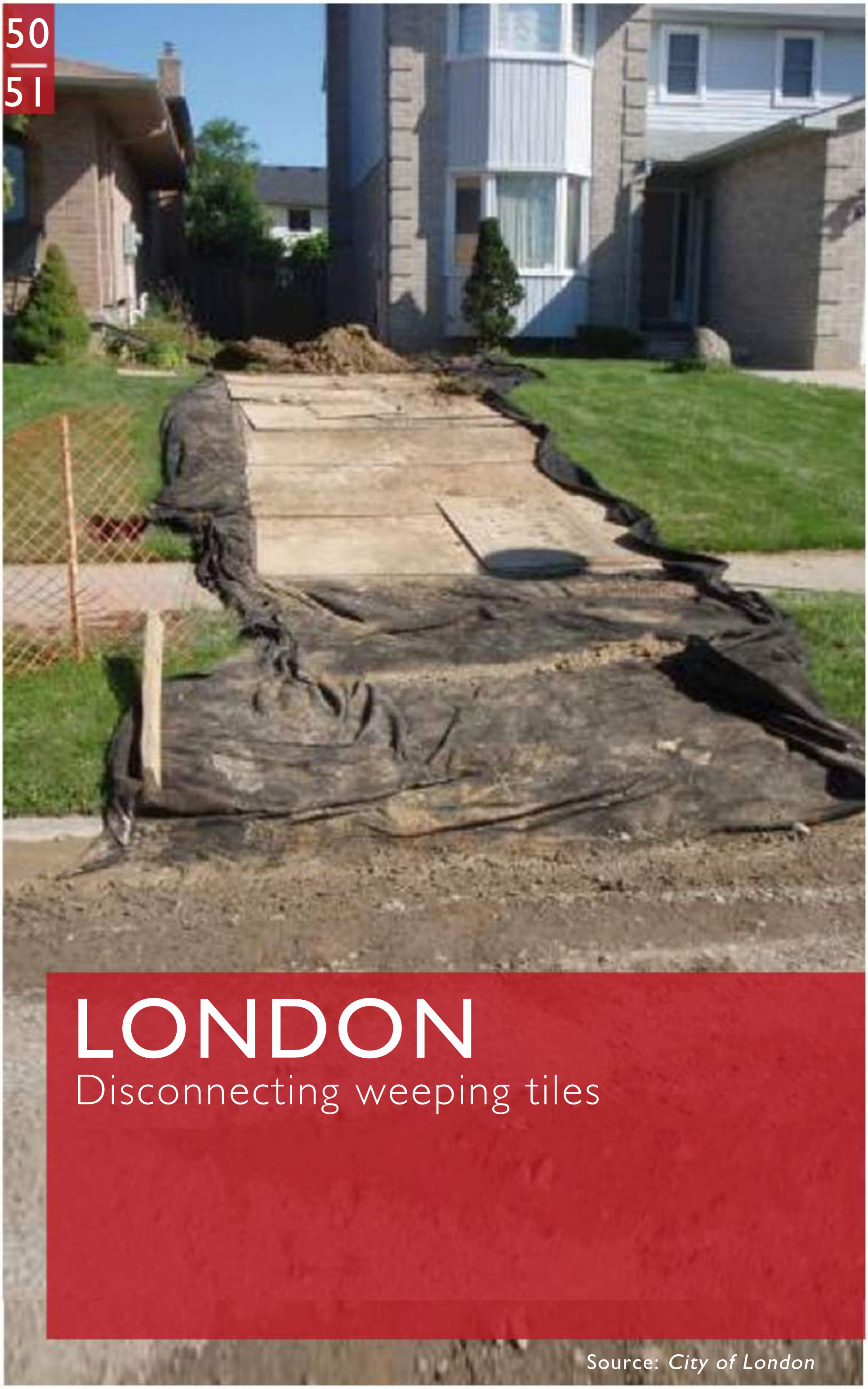
Early implementation of backwater valve and sump pit by-laws made it possible to protect a relatively large part of the City of Winnipeg against basement flooding. Over time, the number of homes with protection has continued to grow. In particular it has been possible to ensure that the risk of basement flooding is low in new developments for more than 35 years.

It was important to extend Winnipeg's efforts into the historic core of the City. Winnipeg has made significant commitments to renewal of sewer infrastructure, and this is now supported by the Basement Flood Relief Subsidy Program. Over the past three years, the program has generated an additional 1,532 backwater valve and 2,275 sump pit approved applications, a significant increase in the number of protected homes in the City. Securing cost sharing with the Province of Manitoba was an important element to the early success of the subsidy program.

A WORD FROM WINNIPEG

When asked about his thoughts on the by-laws and the flood damage reduction subsidy program developed by Winnipeg, Charles Boulet, Senior Project Engineer for the City of Winnipeg responded that he would completely support the implementation of similar programs in other cities since it represents an effective means to prevent basement flooding. One of the biggest challenges that Winnipeg faced when implementing the subsidy program was to ask the province for a fifty percent cost-sharing. "We received a commitment from them for the last three years and we are going to ask for three more," said Mr. Boulet.

Through his career, Mr. Boulet noticed that homeowners are not always aware of whether or not they have a backwater valve or sump pump, where it is located and how it needs to be maintained. In order to better educate the public, the City of Winnipeg has been hosting presentations directed to homeowners through a local Home and Garden Show where they explain to the public how to find and maintain a sump pump and backwater valve. They also send flyers to homeowners on a regular basis as well as information on backwater valves.



LONDON

Disconnecting weeping tiles

Source: *City of London*

THE SCIENCE

Wet weather sanitary sewer overflows and sewer backups are often the result of excessive inflow and infiltration overwhelming sanitary sewers. The risk of excessive inflow increases when roof drain leads, foundation drains and drainage catch basins are connected to sanitary sewers. For several decades, most communities have prohibited the connection of weeping tiles in new homes to the sanitary sewer system, but this practice was common in the past and remains present in many homes.

THE TRIGGER

Over the past decade or two, the City of London has experienced a number of extreme rain events that resulted in extensive basement flood damage to homes. Some neighbourhoods have experienced recurring flooding. In the City of London, connection of weeping tiles to sanitary sewers was a common practice for homes built prior to 1985. Some neighbourhoods, like Sherwood Forest, were mostly developed in the late 1970s and early 1980s and now experience chronic basement flooding because the sanitary sewers become overwhelmed with foundation drainage water during heavy rainfall events.

Sherwood Forest's vulnerability to basement flooding is enhanced by clay soil conditions resulting in poor rainwater absorption. Lot grading in this area has also settled over time and homes are close to each other reducing the neighbourhood's drainage capacity due to a relatively high percentage of impervious surface area.

THE APPROACH

The City of London assessed source control and infrastructure alternatives to reduce the risk of damage from basement flooding in Sherwood Forest. Research commissioned by the City found that a $2 million investment in source control would achieve greater protection than a $10 million investment in protective infrastructure.

The City launched a source control pilot project to disconnect weeping tiles from the municipal sanitary sewer system. "On top of the cost savings, it was simply a better option," says Kyle Chambers, Wastewater and Drainage Engineer for the City of London. "By adopting this approach, the City did not have to worry about the sizing of new infrastructure. Disconnecting weeping tiles also represented a sustainable option since it contributed to reduced sewage pumping and treatment costs at municipal facilities."

The City of London implemented a sump pump program more than 20 years ago. The level of grant funding was initially set at 50 percent of the eligible cost, and increased in 2009 to 75 percent. Even with this increase, the program has experienced a very low uptake rate, highlighting the need for further mitigation actions. The City decided to work directly with homeowners in Sherwood Forest to reduce inflow at the source by disconnecting household weeping tiles from private sanitary sewer connections.

The pilot project for Sherwood Forest

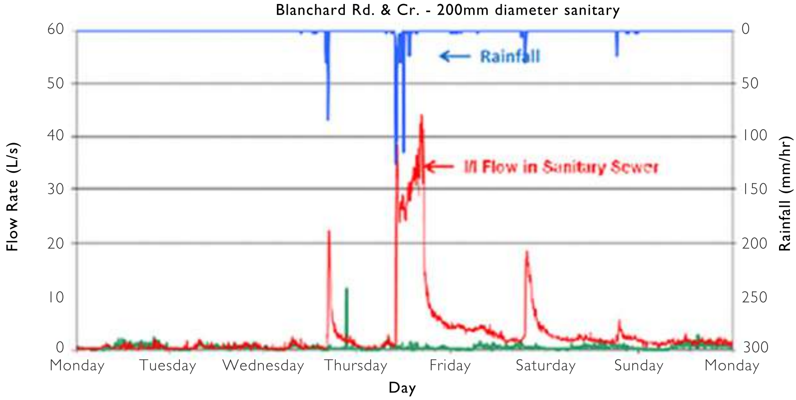


Figure 13: *In this graph, the blue line represents the amount of rain received in mm/hour, the red line represents the flow inside the sanitary sewer in L/s and the green line represents a week's worth of flow in the sanitary sewer with no rainfall in L/s in the Blanchard Crescent Area. This graph highlights the fact that there is a direct correlation between the amount of rain received (approximately 80mm during the rainfall event) and high flow in the sanitary sewer, evidence of Inflow and Infiltration.*
(Source: City of London)

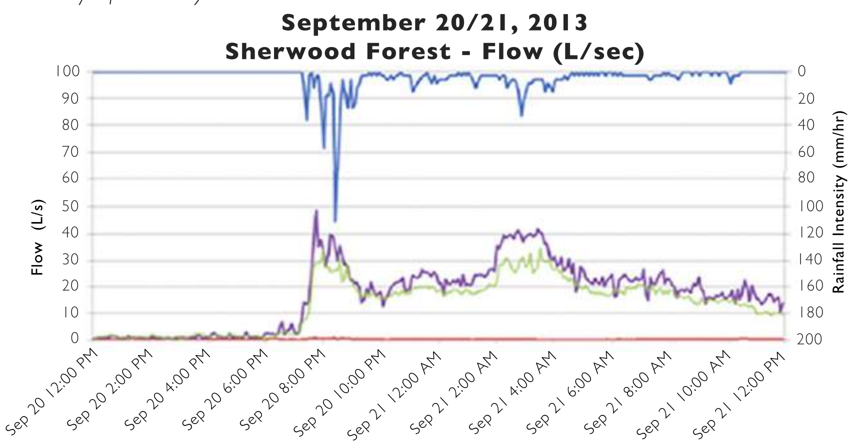


Figure 14: *On September 21 2013, after the pilot project resulted in the disconnection of 50% of the weeping tiles on Blanchard Crescent, a rainfall of approximately 99mm occurred in the neighbourhood. Flow monitoring (red line for Blanchard Crescent) during the storm revealed that weeping tile disconnection has resulted in a surprising reduction of extraneous flow in the sanitary sewer system. The difference in flows is also highlighted by the comparison with Ardsley Crescent (purple line) and Aldersbrook Road (green line) where no disconnection was in place.*
(Source: City of London)

targeted 65 homes. Through computer modeling, the City was able to determine that it was necessary to disconnect weeping tiles for at least 50 percent of the homes to ensure that enough excess foundation drainage water was removed from the sanitary system to reduce sanitary sewer backup risk for the neighbourhood. Several methods were used to reach out to households to encourage participation in the program. Public meetings were organized and homeowners were contacted by mail and phone. Once homeowners signed up, the City met with each of them to explain the pilot project in more detail, and assessed each basement to determine retrofit feasibility. In order to get a high uptake rate, the City covered all the costs associated with the retrofit and provided an additional $1,000 payment for future maintenance.

THE OUTCOME

32 of the 65 households participated in the full pilot program, while five more houses installed a private storm sewer lateral. The Weeping Tile Disconnection Pilot Project presented the City with several challenges. First, it required working directly with homeowners on private property and inside homes. This brought a number of legal challenges for the City, including the need for police record checks for all contractors and their staff, additional requirements for liability insurance, and comprehensive insurance coverage for all employees. Coordination with the City's Building Division was also necessary to obtain building permits for each house.

Working directly with homeowners also implied that several individual agreements needed to be signed prior to each retrofit, and that contractors were able to work under a flexible schedule.

Since the weeping tiles were disconnected there has been a dramatic decrease in the flow of water within the sanitary sewer system during extreme rainfall events.

Moreover, there has been no sewer back up damage in participating homes, despite the occurrence of extreme rainfall events.

A WORD FROM LONDON

When asked for his thoughts on the Weeping Tile Disconnection Pilot Project, Mr. Chambers said that he believed it was a great program for homeowners willing to buy into the solution. As anticipated, scheduling was a challenge as it was difficult to coordinate the work with homeowners' work schedules. However, they proved to be flexible and accommodating, and most adapted their schedules to coordinate with City workers. Mr. Chambers mentioned that if he had to go through the process again, he would probably have spent more time explaining the project to homeowners. "When doing the work, some people asked us to repair the sidewalk or repave parts of their streets. I think it is very important to be clear and set realistic expectations about what we are doing and not doing from the beginning", said Mr. Chambers. Overall, homeowners that took part in the project were very cooperative and pleased with the work that had been done. Monitoring done by the City showed that the project was a success, with a significant reduction of excess flow in the sanitary sewer system. The City will be able to draw more conclusions out of this pilot study after the next significant rain event in the neighbourhood.

WELLAND

Updated IDF curves to anticipate climate change

Source: *City of Welland*

THE SCIENCE

Southern Ontario is expected to experience an increase in the frequency and severity of extreme weather as a result of climate change. Climate change presents a challenge that may be most evident in the design, operations and maintenance of public infrastructure that seeks to provide service to the public over a lengthy period of time. For example, sanitary sewer pipes and stormwater management infrastructure typically remain in place for 50 to 100 years or more.

Across most of Canada, a significant increase is expected in the severity of extreme rainfall events under changing climate conditions. Local governments across Canada recognize that stormwater management systems must not only demonstrate their capacity to successfully cope with historic extreme events, but the design and construction of new systems need to anticipate the expected increase in future rainfall events. Climate change is an important priority for local governments, particularly with respect to the design, maintenance and operation of stormwater systems and extreme rainfall.

THE TRIGGER

In 2005, the Canadian Council of Professional Engineers created the Public Infrastructure Engineering Vulnerability Committee (PIEVC) to develop a tool to better design and manage the potential impact of climate change on public infrastructure. Welland applied the tool to identify the components of the City's wastewater and surface drainage collection system at risk of failure, damage or deterioration from extreme climatic events.

Stormwater management in Welland at the time was based on Intensity Duration Frequency (IDF) rainfall curves established in 1963 using data from Buffalo, NY from the 1930s, 1940s and 1950s that needed to be updated. The City also used a two-year design standard for buried stormwater management infrastructure, which needed to be reviewed. Faced with ongoing sewer separation and aging infrastructure, Welland wanted to ensure that new assets were designed to an adequate standard that would prevent obsolescence in the face of climate change. Also, the City experienced basement flooding and sewer overflows in the past, a risk that needed to be addressed. Furthermore, Welland was looking to review its standards for new development projects that would lead to additional loads on the sewer system in place.

THE APPROACH

Welland first identified the infrastructure components to be evaluated. Applicable design codes and policies, criteria, best practices and procedures were then identified for each of the infrastructure components when the information was available. The City then established a set of climate parameters describing climatic and meteorological phenomena relevant to the City of Welland and a general probability of occurrence of each climate phenomena, both historically and in the future. Once these components were identified

Duration	Comparison of Current and Projected Rainfall Intensities to 1963 Values							
	1963	2000	2020			2050		
			average	90th percentile	maximum	average	90th percentile	maximum
10 minutes	100%	82%	91%	98%	115%	94%	104%	122%
15 minutes	100%	82%	91%	97%	113%	94%	103%	119%
30 minutes	100%	88%	96%	105%	121%	100%	111%	124%
1 hour	100%	97%	110%	108%	117%	82%	112%	112%
4 hours	100%	99%	n/a	n/a	n/a	n/a	n/a	n/a
6 hours	100%	109%	110%	111%	118%	80%	112%	116%
10 hours	100%	143%	n/a	n/a	n/a	n/a	n/a	n/a

Duration	Comparison of Current and Projected Rainfall Intensities to 2000 Values						
	2000	2020			2050		
		average	90th percentile	maximum	average	90th percentile	maximum
5 minutes	100%	112%	122%	144%	117%	130%	154%
10 minutes	100%	110%	119%	139%	114%	126%	148%
15 minutes	100%	111%	118%	137%	114%	125%	146%
30 minutes	100%	110%	119%	137%	113%	126%	141%
1 hour	100%	110%	119%	139%	114%	128%	143%
2 hours	100%	110%	120%	139%	114%	128%	143%
6 hours	100%	110%	123%	145%	116%	129%	150%
12 hours	100%	103%	113%	134%	106%	120%	136%
24 hours	100%	110%	118%	138%	110%	124%	142%

Figure 15 *: The tables above compare 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 for the two year design rainfall event, which is the current municipal standard used for stormwater system design. The comparison shows consistent increases for all durations for all scenarios.*
(Source: AMEC)

and the nature and levels of risk were established, a vulnerability assessment based on two future time frames - 2020 and 2050 - was developed. With this information in mind, the study assessed the adaptive capacity of the infrastructure in place and developed specific recommendations on adaptive measures.

THE OUTCOME

High priority vulnerabilities for the wastewater collection system were those associated with performance responses, like combined sewer overflows, which can generate environmental contamination and risks to public health and safety. It was determined that increased rainfall and the associated increase in sewer flow were acting as triggers for these vulnerabilities. For this reason, it was recommended that Welland work with all levels of government to establish a consistent funding program for the sewer separation and maintenance program. It was also recommended that the City conduct further studies in specific areas such as the relationship between increased rainfall and inflow and infiltration rates in the collection systems. An assessment of the applicability of green infrastructure, as an additional tool to increase resiliency in adapting to climate change, was also recommended.

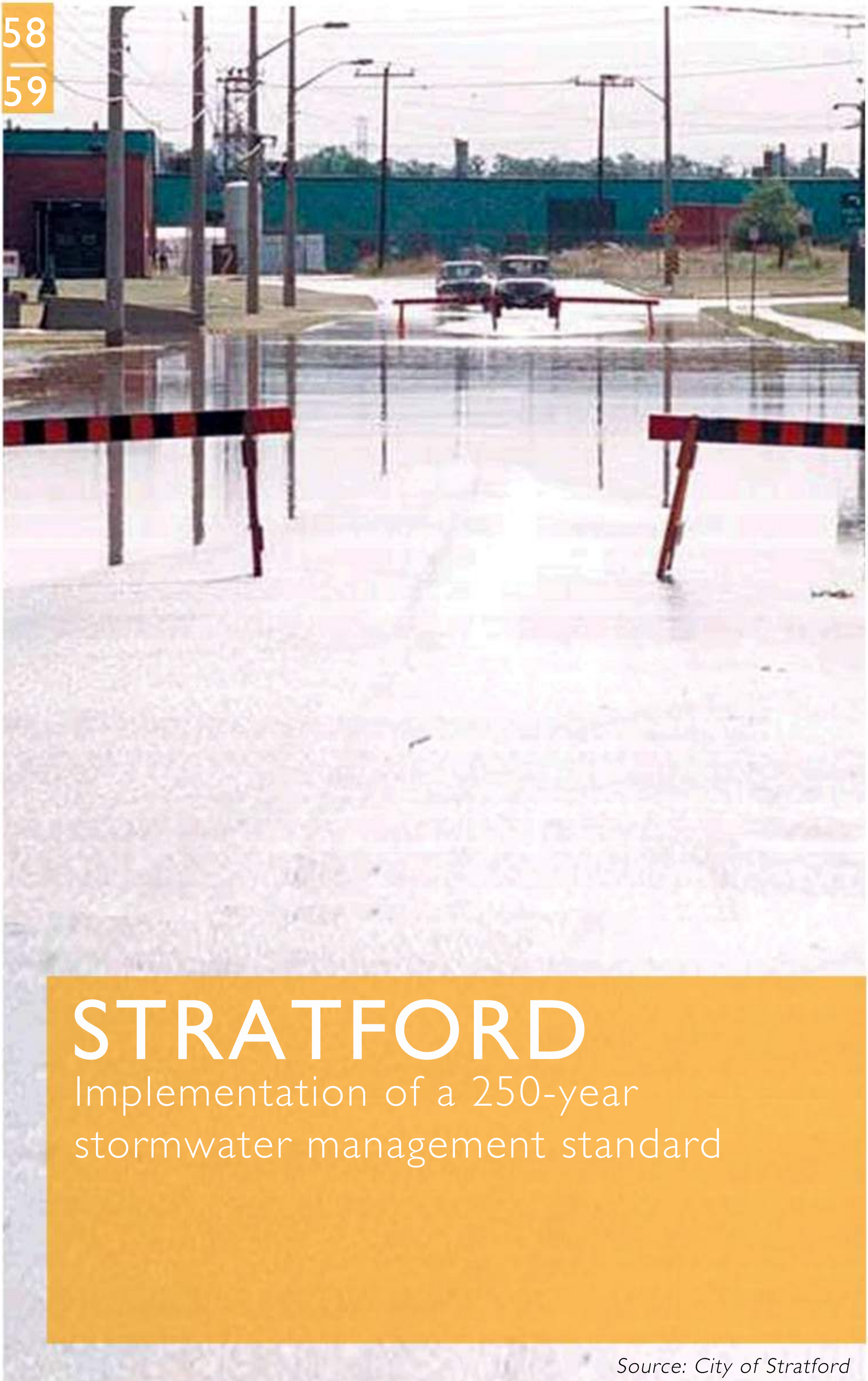
Welland is a two-tier municipality, which means that the Region looks after the wastewater treatment plant and pump stations. For the Region's wastewater treatment plant, the vulnerabilities identified as being of the highest priority were related to screening, grit removal and flow splitters. The operational life of these systems would be reduced with an expectation of more intense rainfall events, which would lead to maintenance and replacement costs.

One of the goals of the vulnerability assessment was to update the City of Welland's IDF curves to anticipate predicted changes in precipitation with climate change. With the tools available at the time of this study, it was estimated that the 1963 IDF curves provided conservative results for more frequent storms and it was therefore recommended to keep working with these curves.

After the publication of the PIEVC report, the City of Welland moved forward with the lower cost, high-priority recommendations, including further analysis of its IDF curve. At the moment, the City and the Region are also working on the preparation of a City Wide Sanitary Sewer Model and subsequent Pollution Control Plan update.

A WORD FROM WELLAND

To successfully complete the Vulnerability Assessment of Public Infrastructure to Climate Change, Marvin Ingebrigtsen, Technical Analyst, Infrastructure Programs for the City of Welland, recommended that cities first come up with good asset data and good storm event records to ensure the review of the infrastructure reaction is accurate. He added that "it is very useful to have senior staff including operators and Public Works and Operations foremen that can provide insight into how the infrastructure system reacts to climate variables, usually storm events." To conclude, Mr. Ingebrigtsen suggested that cities interested in implementing a similar project first gather specific data on how their infrastructure reacted to extreme events in the past. Once the final recommendations are made, he recommended following up on recommendations as soon as the report is finalized while the information is still fresh in peoples' minds.



STRATFORD

Implementation of a 250-year stormwater management standard

Source: City of Stratford

THE SCIENCE

Most developments in Canada built after the 1970s are protected from flooding caused by extreme rainfall events in two ways: An underground stormwater management system that conveys water from relatively frequent events (i.e. the minor system), and an overland flow system to protect homes from very severe rainfall events (i.e. the major system). In most communities, the major system of overland stormwater management is designed and managed to cope with stormwater flows likely to occur once every 100 years. Even more severe events are possible, but are rare.

New subdivisions are built with both a major and a minor stormwater system. The minor system consists of a pipe network, plus gutters and inlets which provide a conveyance system to rapidly move storm runoff away from roads. The major system typically conveys volumes of water expected for a one in 100 year rainfall event that would exceed the capacity of the minor system. The major system mostly relies on overland drainage conveyance elements.

More common events, like a 20-year storm or a 50-year storm, may be disruptive to transportation or other aspects of daily life due to flows and ponding in streets, but they should not result in damage to well maintained homes and public infrastructure. Rainstorms that overwhelm sanitary and stormwater systems should be rare events, and they should seldom result in damage to homes and infrastructure in communities with major and minor systems. Unfortunately there have been many extreme rainfall events over the past five to 10 years that have resulted in extensive damage to homes and infrastructure.

Moreover, there has been an increase in the frequency and severity of extreme rainfall events. This is projected to increase over the next few decades as a result of climate change. By 2100, the storm of the century design standard of the past may occur five to 10 times a century.

THE TRIGGER

In 2002, an extreme rainfall event overwhelmed Stratford's stormwater management system. The storm resulted in major damages and significant costs for the City. There was extensive basement flooding in hundreds of homes.

This unprecedented flood event also resulted in a class action lawsuit against the City. The mediated settlement provided compensation totalling $7.7 million to more than 800 homeowners. The flooding was a trigger to develop a new stormwater management plan for Stratford. Prior to the 2002 flood, a sanitary sewer master plan was initiated to analyze the sanitary collection system, identify problems and suggest potential solutions. The plan evaluated existing and future developments and arrived at a conclusion that $35 million should be invested in priority projects and $16.5 million for other strategic projects. In addition, the Sanitary Sewer Master Plan recommended to conduct a stormwater study that resulted in the creation of a City Wide Storm System Master Plan.

Figure 16 : Stormwater management pond built in Stratford to accommodate surcharging of local systems.
(Source: City of Stratford)

THE APPROACH

The City Wide Storm System Master Plan was completed in October 2004 and presented a comprehensive action plan for Stratford to develop and implement the required changes and improvements to the storm system infrastructure to meet current and future needs. It evaluated the performance of the existing storm system, reviewed and updated city drainage policies and created a city-wide computer model. Additional activities were also carried out such as the review of the city's drainage policies and standards, the development of a system improvement strategy, the implementation of a sewer flow monitoring program and a drainage system inventory. Assessments of storm sewer capacities, major drainage system flow and ponding areas was also conducted.

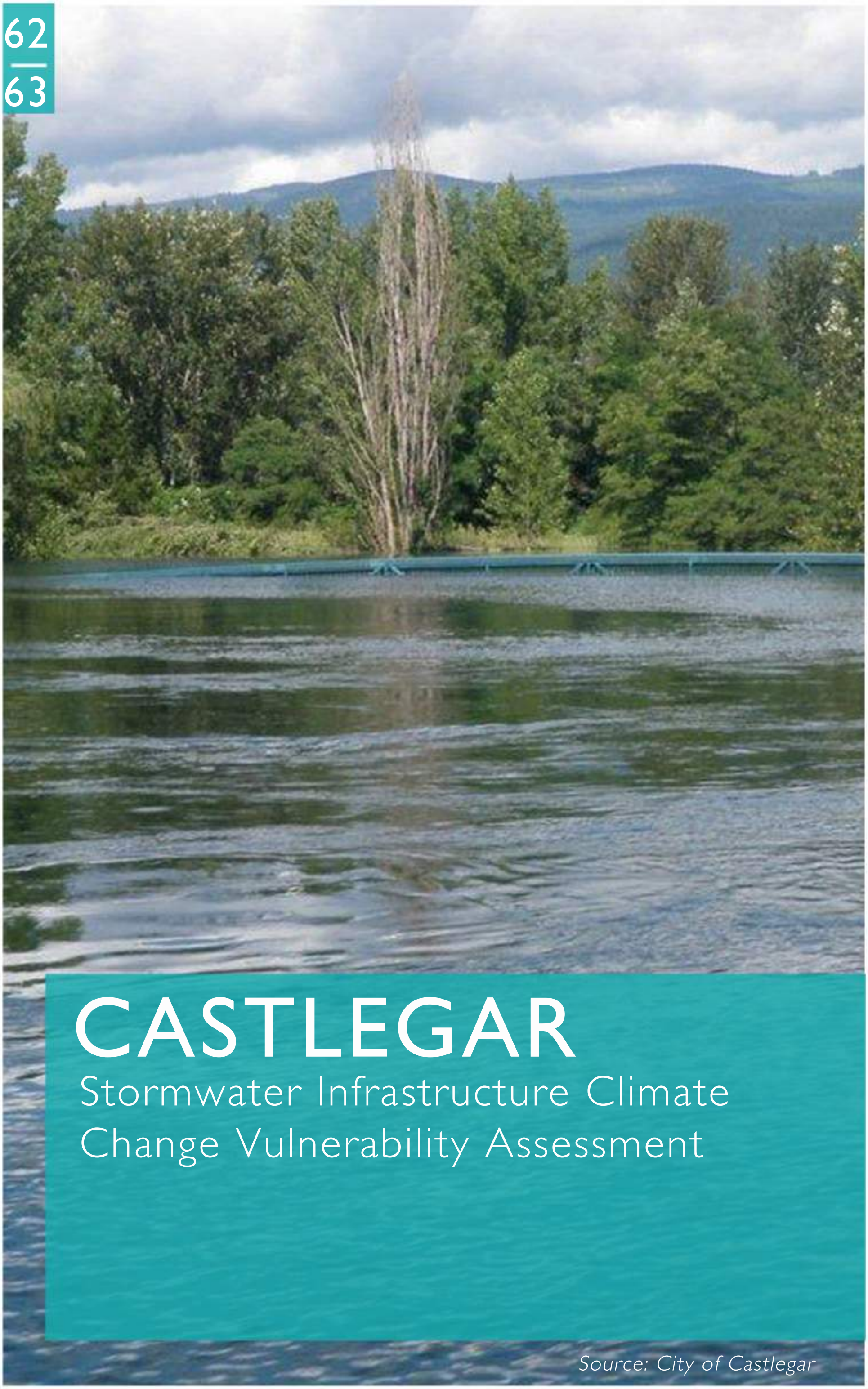
Through the development of the Storm System Master Plan, a Court Drain Subwatershed study was conducted in 2002 and resulted in the introduction of a 250 year storm standard for the City of Stratford. This proposed new standard would lead the City to upgrade its infrastructure to accommodate the rate of runoff that would occur in a one in 250 year rainfall event. As previously discussed, a one in 100 year return period is a widely accepted standard used across Canada in the design of stormwater management systems. However, Stratford decided that looking at the past was no longer sufficient and that a 250 year storm standard would be more appropriate to prepare for future storms. The implementation of a 250 year design standard implied that the City had to change the design of its storm system so it could support a 15 percent increase in peak flows.

THE OUTCOME

The City of Stratford has spent $70 million to retrofit its stormwater management infrastructure to comply with the new 250 year design standard. Infrastructure such as stormwater management ponds, overland flow routes and oversized trunk storm sewers were built to accommodate surcharging of local systems. Stratford also established two incentive programs: one to replace old sanitary laterals in order to reduce inflow and infiltration into the sanitary system and another to assist with installing sump pumps for storm laterals to reduce the risk of surcharging storm mains.

A WORD FROM STRATFORD

According to Ron Shaw, Stratford's Chief Administrative Officer, "It became evident shortly after the flood that the problem was not only related to the sanitary system and that a more global approach was needed to prevent similar events from happening in the future." The City of Stratford undertook major sanitary and storm sewer upgrades after the storm and is now considered a leader in basement flood prevention. As most Canadian Municipalities tend to plan for 'the flood of the century', Stratford has decided to improve its management of basement flooding risk by establishing a safer flood standard.



CASTLEGAR

Stormwater Infrastructure Climate Change Vulnerability Assessment

Source: City of Castlegar

THE SCIENCE

Traditionally, local government best practices have used historic local weather data as the guide for the design and maintenance of waste and stormwater infrastructure. Lengthy delays by Environment Canada to update intensity, duration and frequency (IDF) rainfall records, combined with growing evidence of change in extreme rainfall patterns, indicate that traditional approaches to waste and stormwater infrastructure management are slow to evolve.

The expectation that waste and stormwater infrastructure may be in place for 50 to 100 years or more further increases the importance that both historic and future climate considerations are addressed. Climate models have emerged in recent years as a new tool available to local governments to manage the impact of extreme rainfall on waste and stormwater infrastructure.

Climate projections combined with historical data are now available to help municipal governments anticipate local extreme rainfall risks. Tools have been developed, including Engineers Canada's PIEVC assessment protocol, assessing how extreme rainfall risks can be accommodated in stormwater management design, maintenance and operations. Municipal infrastructure that can cope with, say, a 15 to 20 percent increase in the volume of waste and stormwater flows may add one percent to the initial cost of construction while avoiding the risk that waste and stormwater infrastructure becomes prematurely obsolete and needs to be replaced in 20 or 30 years because it is unable to cope with the predicable increase in flows.

A small additional initial investment in waste and stormwater to use available information about the expected change in the climate will also reduce the local government's exposure to liability for damage to homes from sewers backing up.

THE TRIGGER

In 2009, the City of Castlegar became part of a case study evaluation of various types of infrastructure in different climate settings throughout the country. The Columbia Basin Trust provided funding to apply Engineers Canada's Public Infrastructure Engineering Vulnerability Committee (PIEVC) Engineering Protocol for Climate Change Infrastructure Vulnerability Assessment. The study focused on the impact of climate change on the city's stormwater infrastructure.

Local officials and other stakeholders were concerned that watersheds surrounding Castlegar were changing and that these changes could eventually affect the reliability of local stormwater infrastructure. Under the PIEVC protocol, a vulnerability risk assessment of Castelgar's stormwater infrastructure was developed to identify the components most vulnerable to future climate events. Three years after specific recommendations emerged from this study, the City of Castlegar faced a spring marked by heavy rainfall events that caused widespread flooding and heavy erosion throughout the City. The recommendations made through the PIEVC assessment provided timely advice to support implementation of a number of actions to rehabilitate the most vulnerable stormwater infrastructure.

Figure 17: *Following the publication of the study and the extreme rainfall events in 2009, Castlegar installed storm sewers in areas that were washed out.*
(Source: City of Castlegar)

THE APPROACH

The protocol used for the study was divided into five distinct steps: project definition, data gathering and sufficiency, risk assessment, engineering analysis, and recommendations. For the first step, the team developed system boundaries for an adequate assessment of infrastructure vulnerabilities. In order to achieve this, the City first considered stormwater infrastructure in a broader context by looking at catchment and various drainage areas, physical infrastructure and operations, maintenance and resource requirements for stormwater management. The City then decided to focus the study on the infrastructure draining five upland catchments since they were the most likely to be impacted by climate change.

A team from the Pacific Climate Impact Consortium was brought into the project to help assess the local probabilities of climate change, including changes in the intensity, duration and frequency of extreme rainfall events. For the City of Castlegar, climate models projected more rain and less snow, with an increased risk of extreme rainfall events that could result in more frequent and larger flow events in streams and stormwater management systems.

THE OUTCOME

The study conducted under the PIEVC protocol indicated that the City of Castlegar is vulnerable to climate change. Over the course of the study, 11 climate change events were applied to 35 infrastructure elements and 313 interactions were considered to have a cause-and-effect relationship necessitating further assessment. This assessment revealed that 34 of the 35 stormwater infrastructure elements studied were at medium or high risk, including 10 at high risk.

The study recommended that the City review the 10 high risk infrastructure elements, develop an action plan to address these issues and explore funding opportunities that might be available at the provincial level to quickly fix these elements. In order to address the 10 high risks elements, actions such as the development of a mitigation strategy to prevent erosion for a creek, resizing certain culverts and storm sewer trunks and improving sections of a stream channel to carry expected peak flow were deemed necessary.

When Castlegar faced heavy rain events in the spring of 2012, the City conducted infrastructure workshops with the City's Public Works Department in order to explain which infrastructure elements were identified as the most vulnerable and to have a discussion about which other elements might have been identified as vulnerable by the workers. "Some of the projects we decided to work on were related to the study and some others were things we noticed by looking closer in the field by looking at specific elements and wondering how much of a risk they were. This process brought up things we never questioned before and encouraged us to do more preventative work," said Chris Barlow, Director of Transportation and Civic Works for the City of Castlegar.

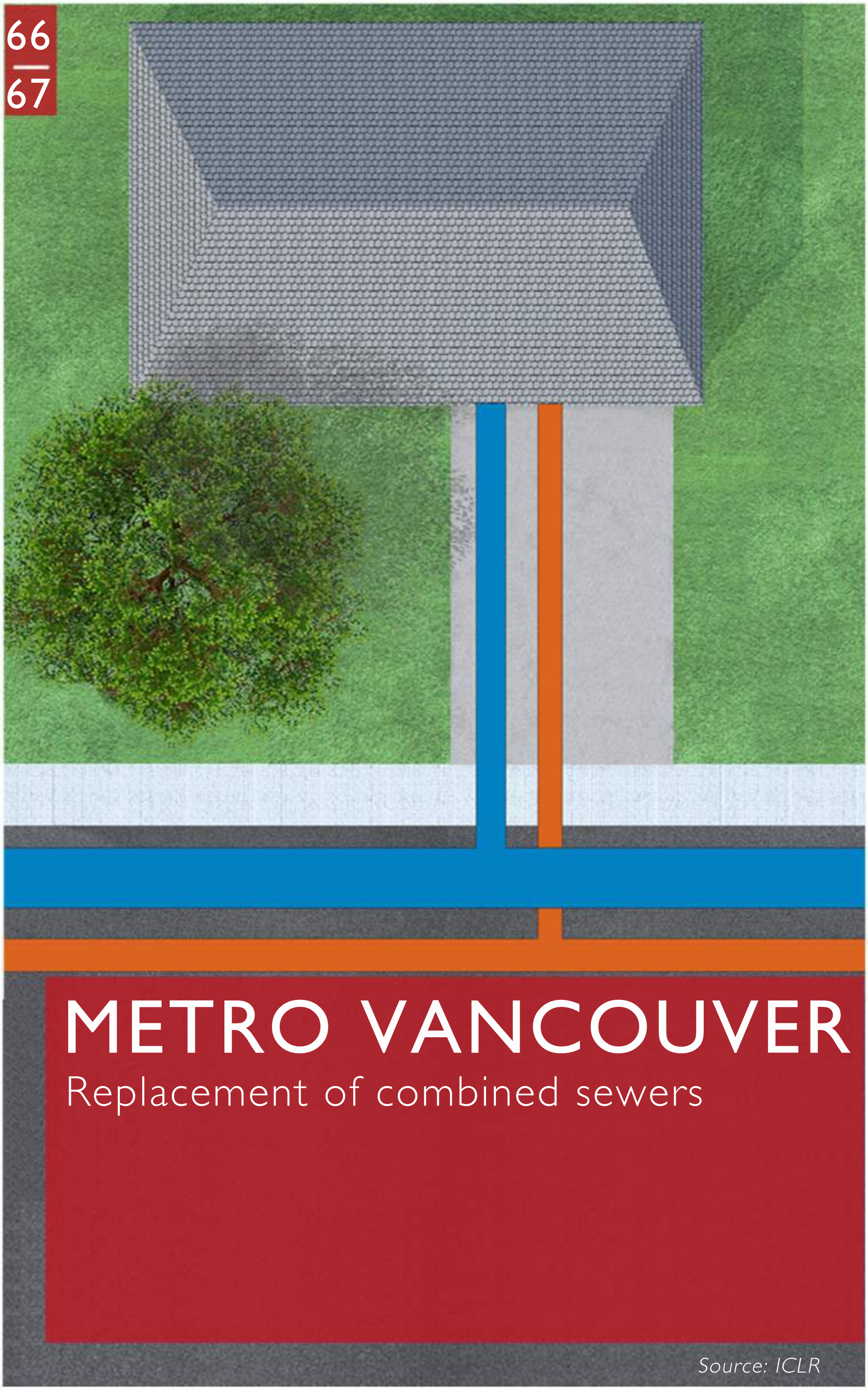
The study also brought a change in the way the City was monitoring extreme rainfall events. As an example, it was identified in the PIEVC report that inlets and outlets were an issue.

Altough there was no budget available to conduct rehabilitation work, the City started to monitor weather forecasts more closely and sent a crew to check inlets and outlets every time a heavy rain event occurred. Since 2012, several large stormwater infrastructure projects were also completed such as the installation of storm sewers in areas that were washed out during previous storm events and the addition of curb gutters.

The Stormwater Infrastructure Climate Change Vulnerability Assessment also contributed to the development of a comprehensive climate change adaptation strategy for the City of Castlegar. In addition, it became part of a learning network established by the Columbia Basin Trust to support other Basin communities with climate change adaptation.

A WORD FROM CASTLEGAR

When asked for his thoughts on the Stormwater Infrastructure Climate Change Vulnerability Assessment, Mr. Barlow mentioned that one of the aspects that made this project successful was the involvement of multiple stakeholders. "When we first looked at vulnerabilities, we brought in our Public Works Department. They are the front line guys and the ones that are the most aware of what is really happening in the field. Bringing these people into this training helped a lot." Mr. Barlow also mentioned the importance of including elected officials early on in the process since funding is always necessary for the successful completion of infrastructure rehabilitation projects.



METRO VANCOUVER

Replacement of combined sewers

Source: ICLR

THE SCIENCE

The sanitary waste system takes wastewater discharged from toilets, sinks and other household plumbing through municipal sewer pipes to a treatment facility. An independent stormwater system transports rainwater underground in sewer pipes or above ground flow in ditches, sending this water into local surface water after some treatment. Independent (i.e. separated) waste and stormwater sewer systems have been municipal best practice for new developments for the past five or six decades. However, before current practices were adopted, the approach in Canada had been to service homes with a combined sewer system to carry both sanitary waste and stormwater.

Combined systems continue to serve many homes across Canada, particularly in older neighbourhoods. Combined sewers are designed to discharge untreated sewage into local receiving waterbodies during intense precipitation events.

Some local governments replace combined sewers when they approach the end of their service life, choosing to install independent sanitary and storm water systems. Nevertheless, many homes in Canada are presently serviced by combined sewers.

THE TRIGGER

Metro Vancouver is seeking to eliminate the discharge of untreated sanitary waste during extreme rainfall events. The primary objective of the member municipalities of Metro Vancouver is to eliminate the discharge of pollutants, although a secondary impact of the approach chosen may be a reduction in the risk of damage to homes connected to combined sewers from the backup of sanitary wastewater.

The federal Fisheries Act prohibits the discharge of stormwater runoff that would negatively impact fish and their habitat. In order to understand and prevent changes in stormwater runoff quantity and quality, Metro Vancouver, its member municipalities, and provincial and federal environmental agencies combined their efforts in the formation of the Stormwater Interagency Liaison Group in 2002 under the provincially approved Liquid Waste Management Plan. This organization's main objective was to facilitate the co-ordination and sharing of common research related to stormwater management.

THE APPROACH

In 2002, several environmental goals for the province were set under the Liquid Waste Management Plan. Since the largest impact of climate change in this area is expected to be increased frequency and severity of intense rainfall events. It was considered crucial for the Metro Vancouver area to improve stormwater management. Starting in 2002, Metro Vancouver initiated sewer studies analyzing long term rainfall records and climate change scenarios.

One of the goals of the Plan is the elimination of wet weather combined sewer overflows. In order to reach that goal, all combined sewer systems in Metro Vancouver will be replaced with

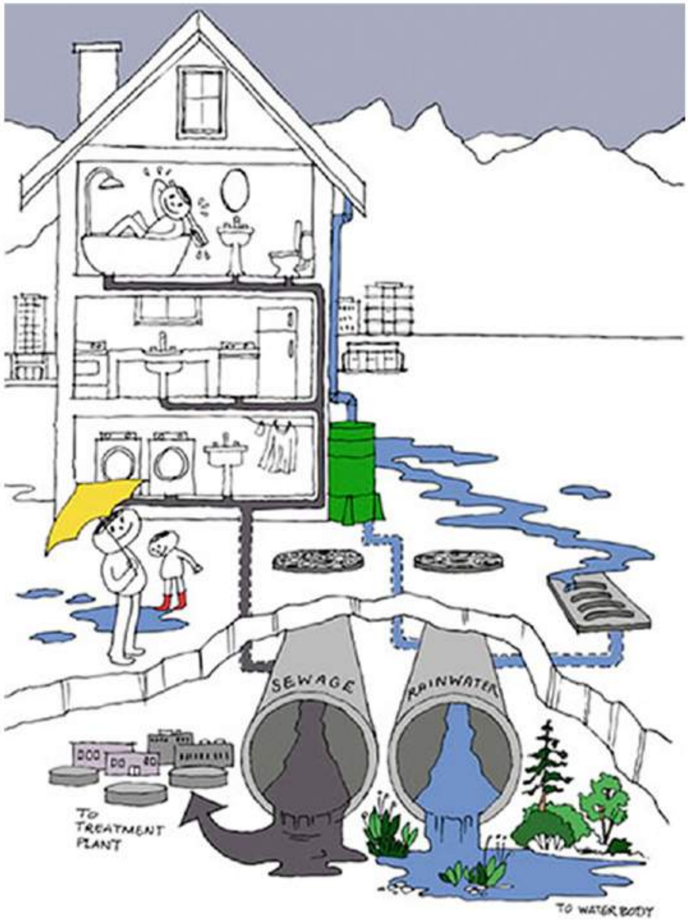


Figure 18: *In a separated sewer system, stormwater is collected through storm drains and is conveyed through different pipes than household sewage. A separated sewer system eliminates combined sewer overflow (CSOs), prevents flooding by increasing capacity and allows stormwater to be used as a resource.*
(Source: City of Vancouver)

separated sewer systems.

Metro Vancouver has relatively young cities that experienced considerable growth in recent decades. Most of this expansion has been supported by modern sewer infrastructure. Some older neighbourhoods have legacy combined sewer systems but combined sewers are less common in Greater Vancouver than in many other large, older cities in North America.

THE OUTCOME

In the Metro Vancouver area, the three municipalities with the highest percentage of combined sewers are Vancouver, Burnaby and New Westminster. Other communities were developed more recently and were predominantly built with separate sewer systems. Vancouver, Burnaby and New Westminister have launched multi-year sewer separation programs, with regular reporting to the public in neighbourhoods where the work is completed, and a schedule for future work. Most combined sewers are to be replaced by 2050, with the last replaced by 2075.

The major challenge to emerge involves addressing sewer laterals on private property. The main purpose of the sewer separation program is the long-term elimination of wet weather combined sewer overflows into the ocean and Fraser River. To also reduce the risk of sewer backup, some work on private properties would need to be done. Sewer backups are generally caused by excessive amounts of rainwater inflow and groundwater infiltration entering the sanitary sewer, or by blockages caused by tree roots or debris in private sewer laterals. Excessive infiltration can occur when foundation drains and roof downspouts are incorrectly connected to sanitary sewers, or when the condition of the sewer lateral is poor, allowing excessive groundwater to flow into the sanitary sewer.

Metro Vancouver commissioned research to explore whether it would be feasible to implement a regulatory private sewer lateral certificate program in Metro Vancouver. The study reported that using the time-of-sale of a home or a property transfer as a triggering circumstance for requiring the rehabilitation of private sewer laterals could be a feasible option for long-term management of inflow and infiltration from private properties. That option would imply a commitment from external key professionals in the building, plumbing, real estate and property transfer industries. Sewer lateral maintenance and rehabilitation tend to be far out of the average property owner's regular consciousness and, according to the report, "success is most likely to result from a staged timeline for implementation, to build understanding of the issues, acceptance of responsibilities, and move towards a general acceptance of the need for regular private sewer lateral maintenance over the long term." It would be the role of Metro Vancouver municipalities to enforce these recommendations through various programs or by-laws.

A WORD FROM VANCOUVER

As explained by Robert Hicks, Senior Engineer, Liquid Waste Services Department for Metro Vancouver, "Private sewer laterals seldom receive any maintenance or inspection after their initial construction and most property owners do not know the condition of their sewer connections." The private portion of a sewer system is more difficult for municipalities to tackle because of complex jurisdiction issues. In Metro Vancouver, several jurisdictions, like the City of Surrey and Vancouver, have implemented sewer lateral replacement programs to minimize the long-term impact of inflow and infiltration.

COLLINGWOOD

Mandatory backwater valves in all new homes

Source: ICLR

THE SCIENCE

Extreme rainfall events have resulted in widespread basement flood damage across Canada. Damage has been evident in older neighbourhoods but surprisingly also in newer homes. This includes some homes supported by relatively new infrastructure, separated sewer systems and modern best practices for home construction. In particular, data provided by insurance companies shows an alarming increase in loss and damage to homes through the backing up of water and sanitary waste through sewer laterals.

Damage to homes in Canada from sewer backup exceeds $2 billion a year. Most of the damage to homes from the backflow of sanitary sewers is preventable. A backwater valve can be installed in new homes for less than $250 and automatically closes when wastewater flows back through the sewer system toward a home, significantly reducing the risk of damage.

Provincial building codes require the installation of a backwater valve in new homes "where a building drain or a branch may be subject to blackflow". However, thousands of new homes are built in Canada each year without a backwater valve. This is due to ambiguity about when a home may be subject to backflow. Some homebuilders and local code enforcement officials seek a prior history of basement flooding in the area as evidence of the risk, so many new homes do not have a backwater valve. Several recent large scale sewer backup events in relatively new separated sewer systems indicate that all homes connected to public underground sanitary sewer systems have the potential to experience sewer back up. Unfortunately, the wording of current provincial building codes is unclear about when to install a valve.

Several communities, like Collingwood, have taken action to address ambiguity in the building code by giving clear direction to developers and builders that all new homes connected to the sanitary sewer system are at risk of backflow so a backwater valve is required. This may involve revision of a local by-law or clarification of enforcement practices.

THE TRIGGER

Collingwood's Director of Building Services and Chief Building Official participated in an ICLR study on how municipal officials interpreted the building code provision concerning backwater valves in new houses. The research led the Director to review the evidence of increasing risk of basement flooding during extreme rainfall events, and to consult with local homebuilders about the risk of backflow. This resulted in a public statement by the Director on January 10, 2013 that all new homes in Collingwood connected to the sewer system require a backwater valve.

A number of communities across Canada have begun to mandate the installation of backwater valves in all new homes. Typically this change was introduced following an extreme rainfall event. Action in Collingwood, however, involved a proactive adaptation of local practices in anticipation of the growing risk of loss and damage.

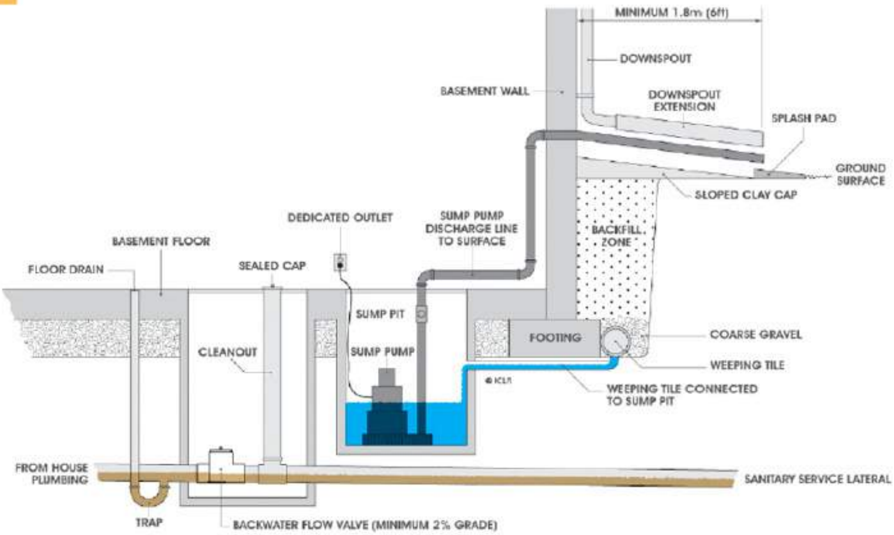


Figure 19 : *Installation of a backwater valve (Source: ICLR)*

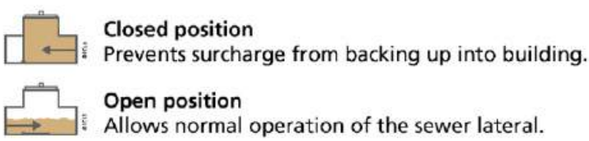


Figure 20 : *Backwater valves in open and closed position (Source: ICLR)*

Discussions between ICLR and building code officials across the country have found significant variation in local interpretation of the building code requirement for the installation of backwater valves in new homes. The findings of consultations with local code enforcement officials were identified by Collingwood as influential in their decision to require backwater valves in all new homes.

THE APPROACH

Town officials in Collingwood confirmed with local developers and builders that there is some risk of backflow in all homes connected to the sewer system, including new homes. Accordingly, the Town decided that interpretation of the building code would require the installation of a backwater valve in all new homes. Moreover, Collingwood chose to avoid the potentially complex task of developing a by-law, an approach that has been used in some other communities seeking to ensure the benefits of backwater valves. Rather, Collingwood issued a public statement about its interpretation of the current building code. On January 10, 2013, Bill Plewes drafted a letter indicating that the Town requires backwater valves in all new home construction effective February 1, 2013. The Chief Building official noted in his letter that "there is enough historical data collected in Collingwood to require backwater valves be installed in every new dwelling that has fixture(s) below adjoining street level."

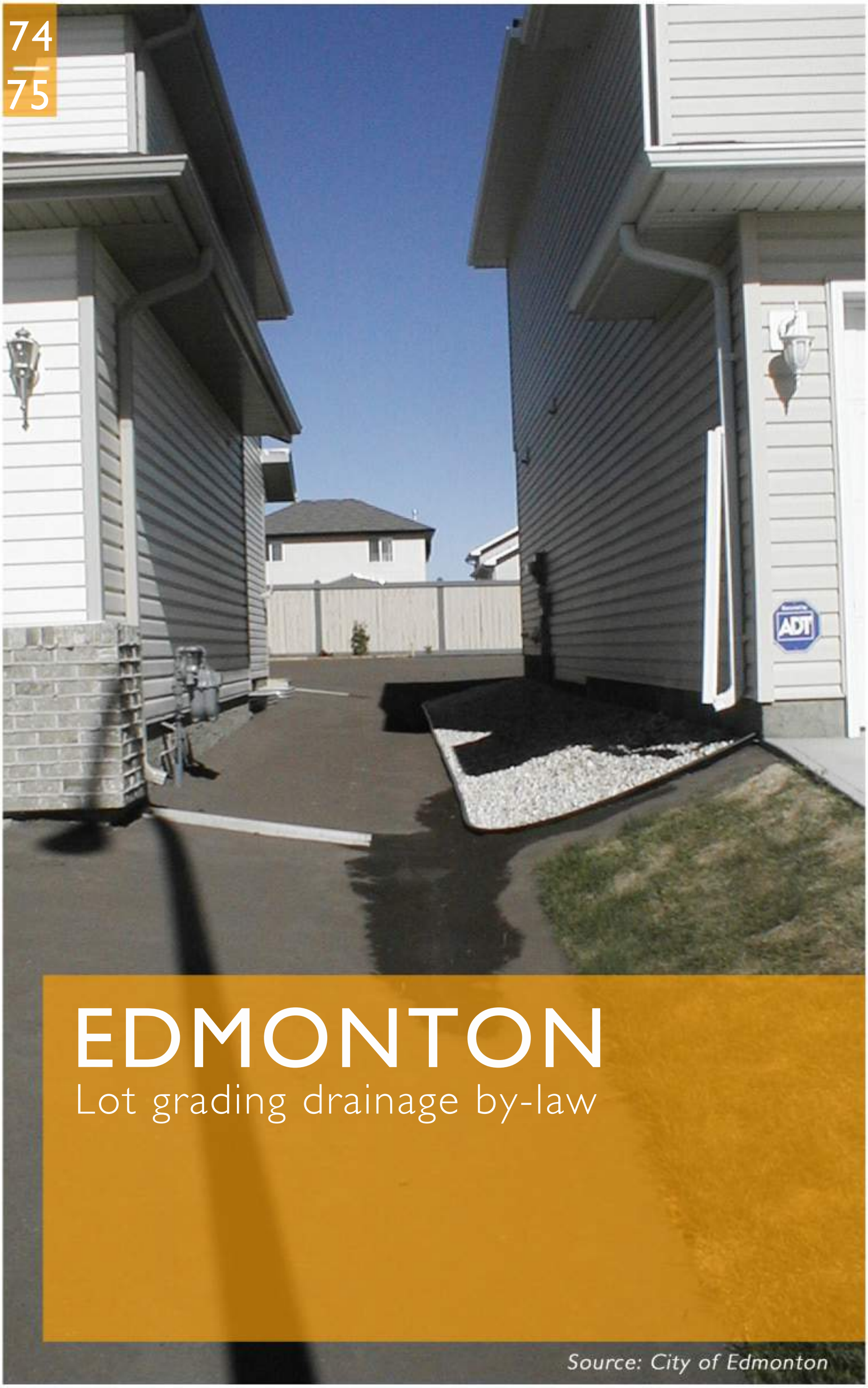
THE TRIGGER

Collingwood issued a public letter indicating that the Town would require the installation of backwater valves in all new home construction. This decision was well received by developers. Some developers are using the backwater valve as a selling feature, noting that most of the existing homes in the region do not have a backwater valve but these safety features are present in new homes. There was no push back from home builders in Collingwood since backwater valves are easy to install and inexpensive. Some contractors even mention that a backwater valve is one of the best investments they can put in a new home. A small investment in safety can significantly reduce the risk of damage to homes and may even lower the cost of insurance.

Town officials indicated that a useful area for future work would focus on actions to encourage the installation of backwater valves in existing homes. In particular the Town may explore the idea of a by-law for property owners that conduct a major renovation to mandate installation of a backwater valve.

A WORD FROM COLLINGWOOD

Collingwood's approach is presently focused on actions to reduce the risk of basement flooding in new homes from the backing up of sanitary sewers during extreme rainfall events. When interviewed on the subject, Bill Plewes, Collingwood's Director of Building Services and Chief Building Official, said "We found it very easy to make the installation of backwater valves mandatory. Interpreting the code in a way that requires developers to install backwater valves in new homes allowed the Town to avoid the complicated task of developing a municipal by-law to require this important measure."



EDMONTON

Lot grading drainage by-law

Source: City of Edmonton

THE SCIENCE

Lot grading is a powerful mechanism for managing the risk of damage to buildings from extreme rainfall. Where possible, water should be directed safely away from buildings through appropriate grading to reduce the risk of damage from inflow and flooding associated with overland flows and seepage. Moreover, if water is permitted to accumulate near buildings, it can overwhelm drainage systems and sewers, increasing the risk of sewer backup damage to the building and neighbourhood, and water damage from flooded basements, especially when foundation drainage is connected to sewer systems.

Land that slopes toward buildings increases risk of flood damage, while the risk is reduced if the land slopes away. Water should be directed toward permeable surfaces, like grass covered swales, lawns, rain gardens, and appropriate stormwater management infrastructure. The lot grading must not increase flood risk for neighbouring properties.

Moreover, appropriate lot grading created during the construction of a new residential development needs to be maintained to remain effective. Over time, land will settle and may reduce the protection initially in place. Also property owners may inadvertently alter the lot grading protection for their homes through landscaping and gardening projects. Responsibility for ensuring the effectiveness of lot grading shifts over time from homebuilders and landscape specialists during initial construction to the property owner.

THE TRIGGER

Edmonton is widely recognized for its leadership in the identification and implementation of local actions to reduce the risk of damage to homes from basement flooding. Many elements of Edmonton's comprehensive flood reduction strategy have been in place for more than three decades, like a requirement that all new homes install a backwater valve (1989).

The City of Edmonton has also been a pioneer in testing actions to address lot grading. This evolved from a strong relationship with local developers and home builders seeking direction from the City about how to best address the risk of basement flooding. In the mid-1980s, surveyors, developers and builders approached the City to create an enforcement process for all developers, builders and owners for an approved surface drainage plan design. In 1988, the Municipal Planning Commission requested that a strategy be developed to enforce lot grading design plans for new developments.

THE APPROACH

The Drainage By-law was developed and implemented by the City of Edmonton to reduce flood risk in new buildings through appropriate lot grading. The by-law requires that the City Manager approve surface elevations and grades of residential lots in two stages: the rough grade and the final grade. The rough grade stage is typically the responsibility of the homebuilder. During this phase, the lot is graded approximately seven to 20 cm below

Figure 21 : *The illustrations above were used by the City of Edmonton to show proper lot-grading.*
(Source: City of Edmonton)

the proposed final grade elevations in order to generate a drainage template before the final grading and landscaping.

Once that step is completed, seven to 20 cm of topsoil is placed on the lot to create the final surface drainage pattern. An inspection has to be completed by a lot grading inspector following the completion of each phase to determine if the surface elevations are within acceptable tolerance of the design elevations on the approved Lot Grading Plan. During the inspection, inspectors make sure that driveways and sidewalks are completed, that the site is clean and free of debris and construction materials, that the grading is uniform and free of ruts, depressions or excess soils, and that the lot slopes away from foundation walls.

Every sloped surface on a lot has to effectively drain water away from foundation

foundation walls, including areas under steps and decks. To meet this requirement, a 10 percent slope has to be generated for the first 2.0 m around the building with a minimum of 20 cm drop for final landscaping. The slope standard for concrete, asphalt and other impervious surfaces is 0.75 percent. The slope standard for grass drainage swales is 1.5 percent and paved swales have to meet a minimum slope requirement of 0.75 percent. Swales are lower tracts of land designed to collect and convey surface runoff away from the building. The standards apply to new home construction and major renovations.

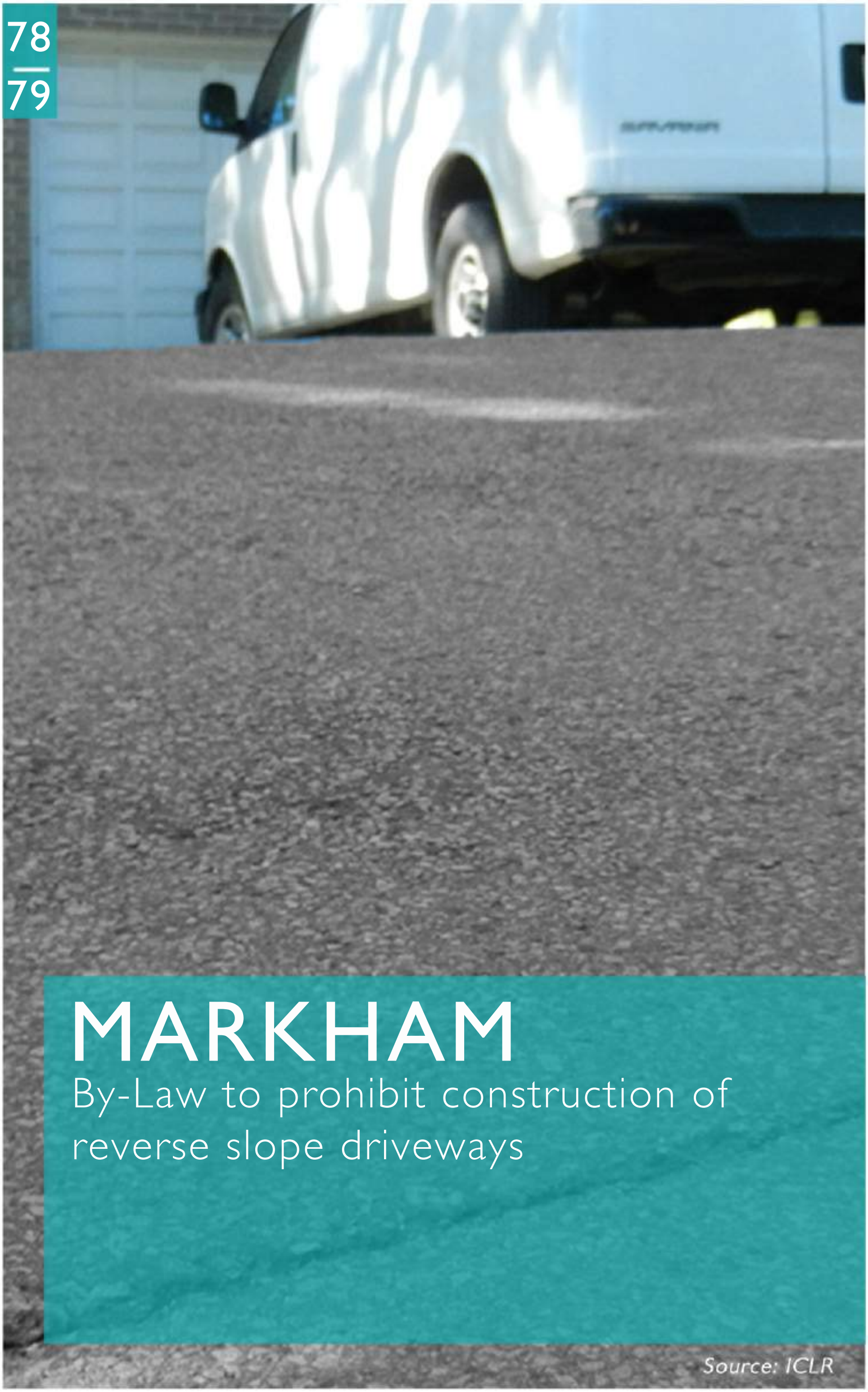
THE OUTCOME

The establishment of the lot grading by-law in Edmonton has evolved over three decades. Following requests by surveyors, developers and builders, the City of Edmonton implemented drainage and lot-grading standards under the Minimum Property Standards By-law in 1989. Edmonton's Building by-law was amended in 1993 to accommodate lot grading approval fees and from this point residents who applied for a building permit were asked to cover the charges of lot grading approval. In 1997, the Surface Drainage By-law came into effect, consolidating parts of the Minimum Property Standards and Edmonton Building by-laws. The Surface Drainage By-law was consolidated into the Drainage Bylaw on June 1, 2013.

Even though the drainage by-law only came into effect as it is today in the late 1990s, the lot grading standards stated in the by-law are enforced retroactively for all properties developed after 1989. Edmonton has been recognized for its leadership in addressing a number of stormwater management issues, including lot grading. Since the adoption of the Drainage By-law, several municipalities across Alberta have approached the City of Edmonton to mirror their lot grading requirements.

A WORD FROM EDMONTON

When asked for his thoughts on the Drainage by-law, Filipe Gonçalves, Lot Grading Inspector for the City of Edmonton, suggested that it was a great method to establish a standard for the industry and owners in order to avoid drainage issues for properties. Mr. Gonçalves stated that "…during the implementation process, we faced some resistance from property owners back in 1993 when the final grade inspection became mandatory. At the time, some property owners felt like a surprise additional cost was added when renovating or buying a new property. Now, the owners expect that cost as part of the purchase of a new property since the process has been in place for more than 20 years."



MARKHAM

By-Law to prohibit construction of reverse slope driveways

Source: ICLR

THE SCIENCE

Reverse slope driveways are present in many communities across Canada. This kind of driveway tends to be found in high-density areas where there is limited area to build external garages. However, reverse slope driveways increase the risk of basement flooding.

Reverse slope driveways have a high potential to direct overland stormwater into homes. Stormwater directed into a house through a reverse slope driveway may also increase the risk of sewer backup when the water enters the sanitary sewer system through basement floor drains. In some cases reverse slope driveways have catch basins connected into the weeping tile system or sanitary sewer lateral increasing sewer backup risks for the home and the neighbourhood. Connections into storm systems can be a problem. The resulting surcharge in the municipal sewer system may force stormwater back into catch basins, where it may flow into basements, garages and weeping tiles. Catch basins may also be blocked by debris which can reduce their draining capacity and further increase the risk of basement flooding.

THE TRIGGER

In August 2005, a major storm struck Southern Ontario. Until July 2013, this was the most expensive natural catastrophe in Ontario history costing insurance companies $718M (2013 dollars). As much as 153 mm of rain fell on the Northwest area of Toronto in less than three hours, causing extensive damages in Southern Ontario.

There was significant basement flood damage in the West Thornhill area of Markham. Damage to residences in this area, like other older neighbourhoods in the storm's path, was affected by limitations in the capacity of the surface drainage system and high infiltration overwhelming the wastewater system. Storm flows and volumes exceeded the storm and wastewater infrastructure capacities in the area. In the aftermath of the August 2005 storm, residents petitioned the City of Markham for remedial measures to prevent future problems. The public was seeking a long-term and comprehensive plan for reducing the risk of basement flood damage in Markham.

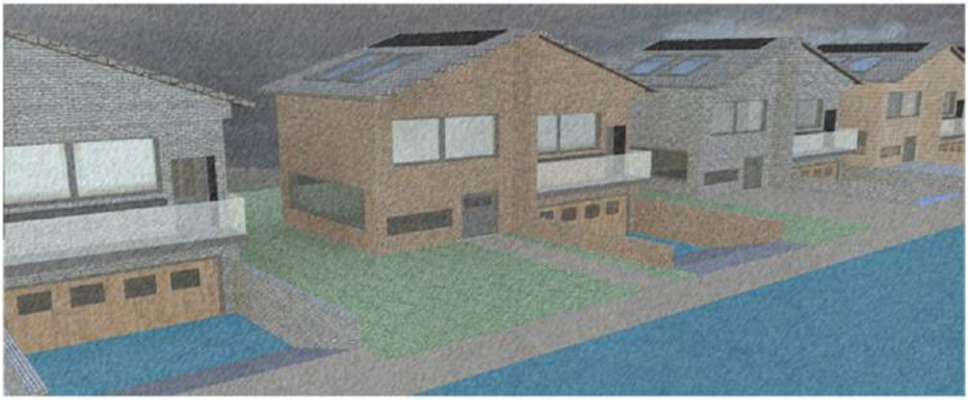


Figure 22: *Flooded driveways following an extreme rain event. (Source: ICLR)*

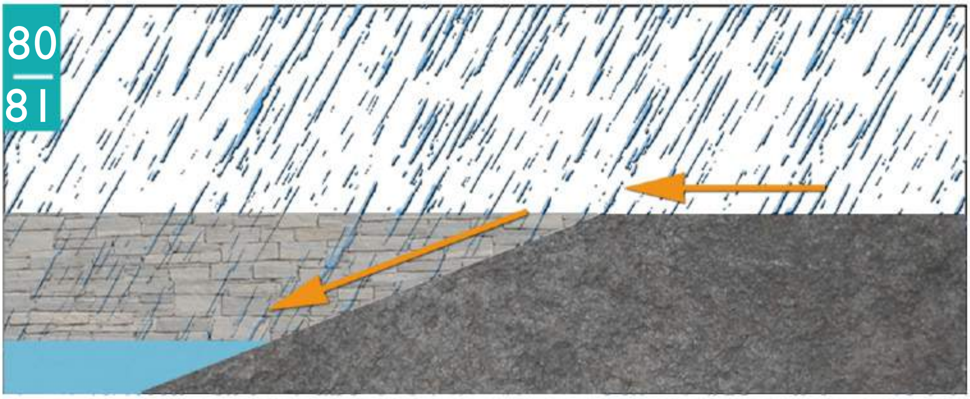


Figure 23 : *Reverse slope driveway before minor asphalt grading (Source: ICLR)*

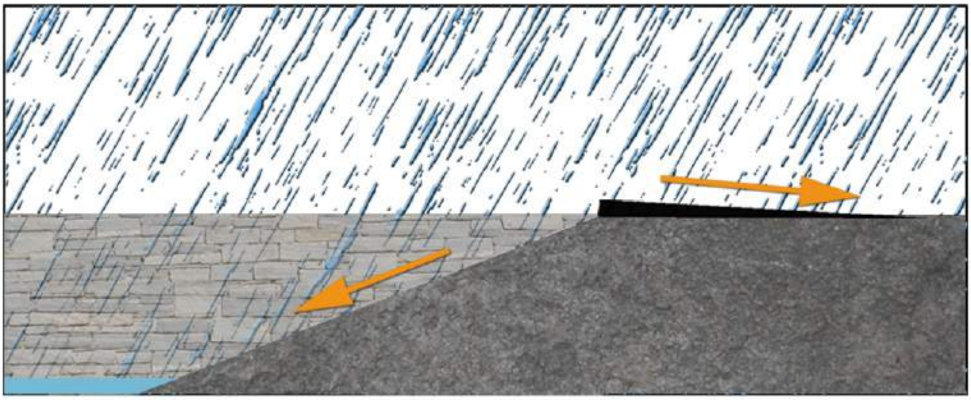


Figure 24 : *Reverse slope driveway after minor asphalt grading (Source: ICLR)*

THE APPROACH

The City of Markham initiated a Municipal Class Environmental Assessment study and hired a consulting firm to identify preferred alternatives to improve current storm system performance in West Thornhill and increase it to an appropriate level of protection. The City also initiated an internal review of wastewater system capacity to identify required upgrades and infiltration reduction opportunities.

In addition to an assessment of the City's storm sewer capacity, other measures were identified that could reduce the amount of run-off entering the sewer system. The study was to identify and assess a broad range of measures that could be undertaken by the City and by property owners. The external consultant and internal reviewers sought to provide a comprehensive assessment of alternative actions to better manage and reduce the risk of basement flooding in the City. For example, one of the measures considered for new residential dwellings was prohibiting the construction of new homes with reverse slope driveways.

THE OUTCOME

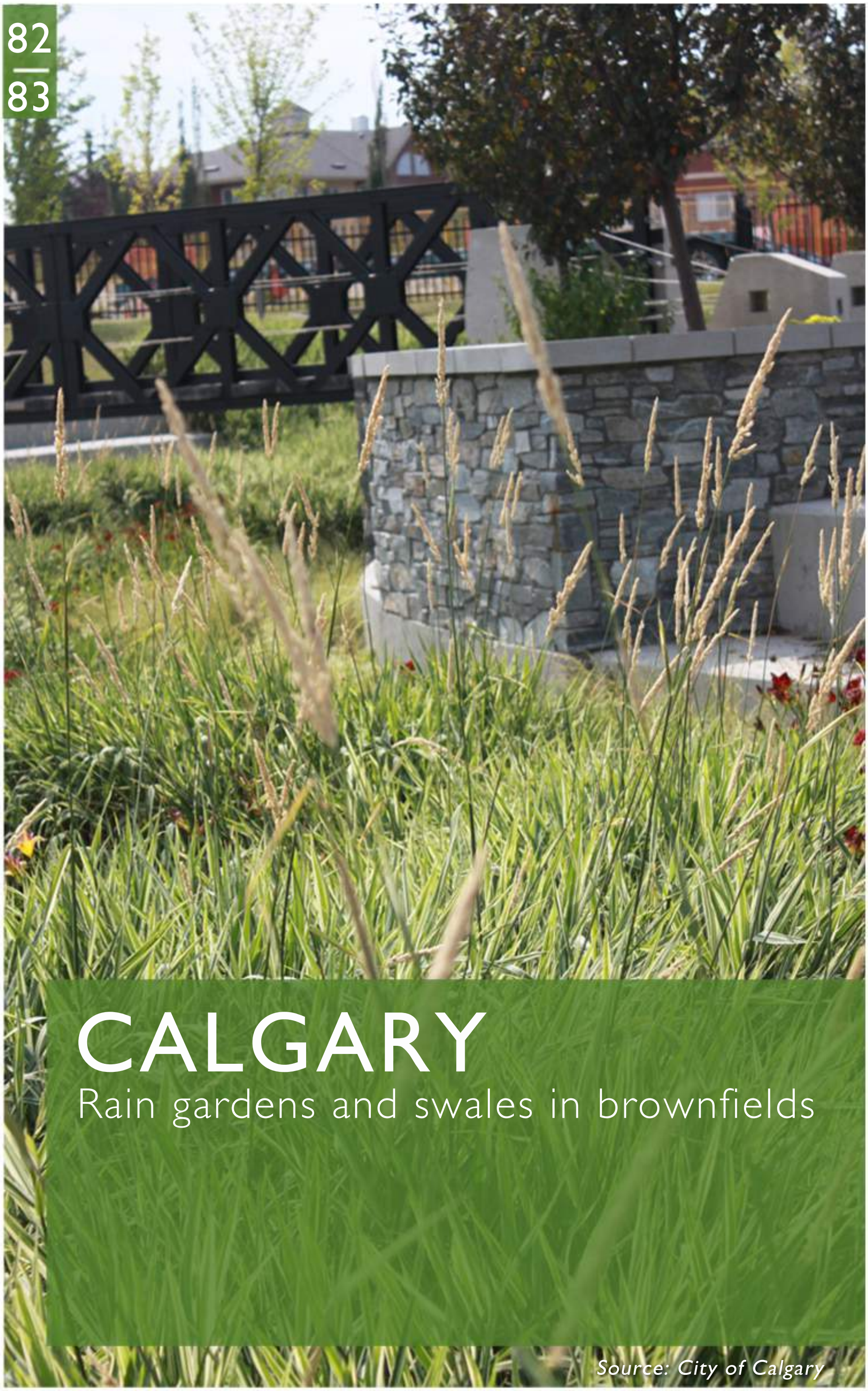
In April 2012, a by-law amendment was approved by the City of Markham prohibiting reverse slope driveways for new home construction. Where a private driveway leads to a parking garage attached to a dwelling unit, the finished floor elevation of a garage must be higher than the elevation of the public street or public lane from which access to the parking garage is provided. The by-law is enforced when developers and property owners submit their construction plans to the City.

Markham is also taking action to reduce the risk of basement flooding for existing homes with reverse slope driveways. The City is seeking to limit the depth of water on the street by adding more sewer and inlet capacity to reduce the risk of spill onto driveways. This measure has been taken in areas that have faced historical flooding problems. Markham also has a road operations group that is doing minor asphalt grading at locations where the grade is not sufficient between the road gutter and the high point in the driveway (see illustration 23 & 24).

Recently, while conducting sewer smoke testing, the City of Markham found that some reverse driveway catch basins were potentially connected to the sanitary sewer. Once connections are verified, the risk of basement flooding in these neighbourhoods will be reduced by requiring homeowners to fix the cross-connection.

A WORD FROM MARKHAM

When asked for his thoughts on the prohibition of construction of reverse sloped driveways, Robert Muir, Manager of Stormwater at the City of Markham said that "[the by-law amendment] represents a small change for a lot of gain. It is the kind of adjustment that is usually very well perceived by homeowners and developers since its first objective is to protect the homeowners themselves."



CALGARY

Rain gardens and swales in brownfields

Source: City of Calgary

THE SCIENCE

Many communities across Canada have brownfield lands with potential for development if specific environmental challenges are successfully addressed. These are often former industrial sites requiring treatment of contaminated soils before development can proceed. Stormwater management is often an important dimension of successful brownfield redevelopment, particularly for large projects.

During development of brownfield sites, and later when the lands are returned to active use, it is essential that contaminated runoff does not pollute nearby streams, lakes and rivers. Moreover, redevelopment has the potential to significantly alter the rate and volume of stormwater flows but can be designed to avoid or at least reduce increasing the risk of damage to existing and future homes and other dwellings in the area during extreme rainfall events.

The Low Impact Development (LID) approach to stormwater management and site development is becoming popular as a mechanism to provide localized, small-scale source water control. This approach uses natural features like rain gardens, retention basins and swales, as an alternative or supplement to traditional stormwater management infrastructure like underground piping, gutters or curbs.

THE TRIGGER

Six storms in Canada have each resulted in more than one billion dollars in damage to homes, businesses and infrastructure. Half of these events were in Calgary, in 2005, 2010 and 2013. The City has also experienced a number of other damaging extreme rainfall events over the past few decades, with losses affecting the cost of providing municipal services, the price of insurance and ultimately, the cost of living in Calgary.

Currie Barracks presents a novel approach to urban flooding. Local awareness of the potential adverse impact of severe weather has been particularly evident in Calgary after the many extreme events experienced in the city, events that oriented the approaches taken to enhance this re-development project.

THE APPROACH

Canada Lands Company and the City of Calgary were looking to redevelop Currie Barracks, a former military site near the downtown of the City. This brownfield site was to become a medium- to high-density residential development. Calgary was seeking an innovative approach to stormwater management because of restrictions in the capacity of the downstream storm sewer system stormwater systems to accept the projected increases in runoff from the site.

The consulting engineer for this project developed a Low Impact Development design to ensure that the rate of the runoff leaving the site would not exceed the capacity of the downstream stormwater system. In particular, abandoned fields were converted into rain gardens, vegetated swales and gravel infiltration trenches were incorporated at strategic locations as part of the green space in the new urban fabric.

Figure 25 : *The pictures above show an infiltration trench built in the Currie Barracks Brownfield re-development project. An infiltration trench is an excavated trench backfilled with stones to create a narrow underground reservoir. Stormwater runoff diverted into the trench drains from the bottom of the trench into the subsoil and eventually to the water table.*
(Source: City of Calgary)

The rain gardens were designed with topsoil blended with compost and drywall surplus materials with a thickness of over 1.0 m compared to 10 to 15 cm of topsoil in a traditional development. This type of soil combined with the use of vegetated swales made it possible for the area to accumulate most of the rainwater long enough for it to seep and replenish groundwater. The amount of hard area in Currie Barracks is similar to, or actually even higher than pre-development conditions because of the higher density. However, it is dealt with in a better way by making the landscaped areas act as a sponge. The water is then distributed around the site and does not overwhelm the city's stormwater system.

THE OUTCOME

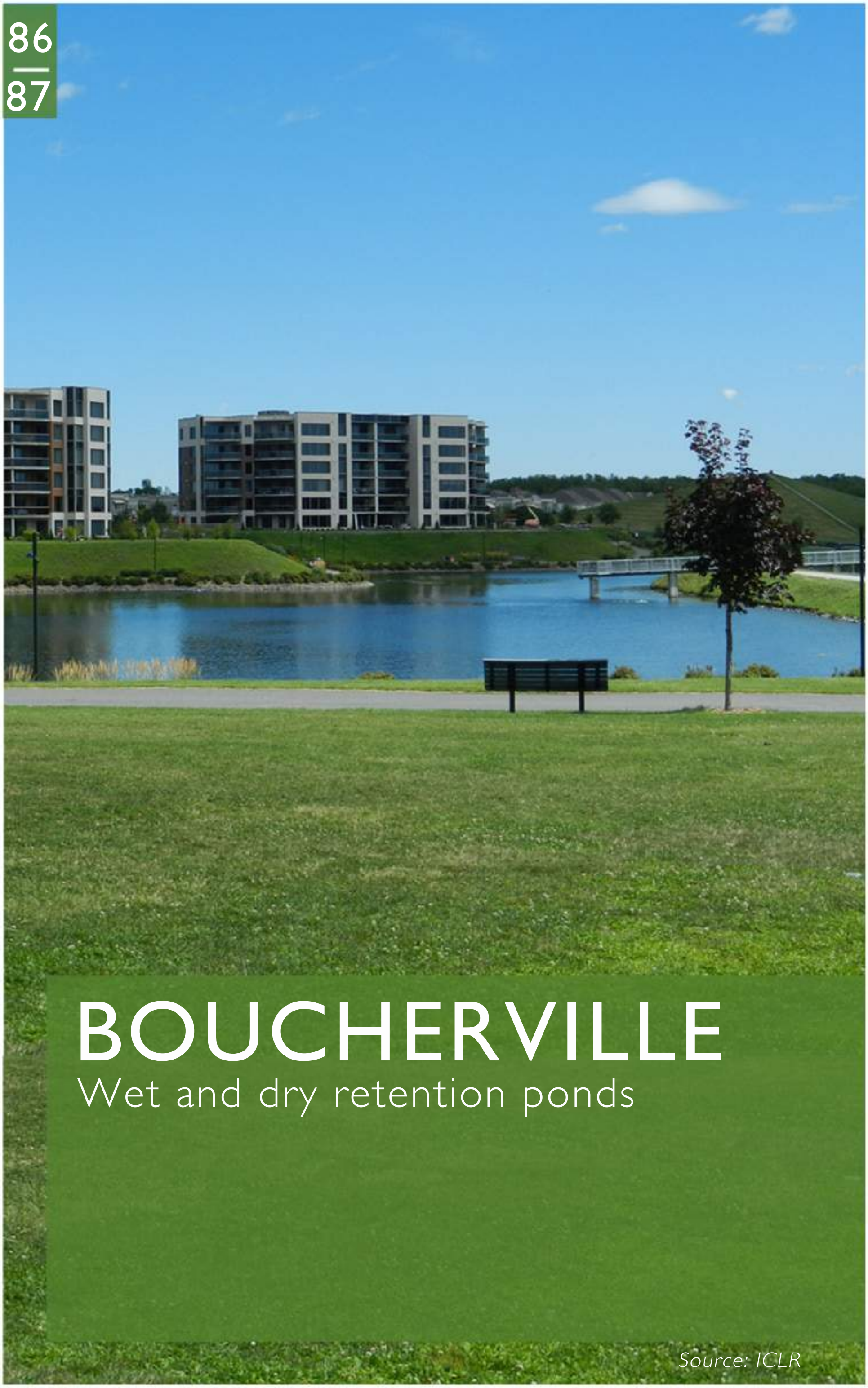
The Currie Barracks brownfield project was successful in retaining most peak rainfall on site, meeting the design challenge of limiting discharge from the property. The project also addressed concerns about the functionality of the design feature during winter freeze-thaw events. Low Impact Development projects rely on soil moisture, evapotranspiration and infiltration to absorb heavy rainfall but these natural processes may not perform as well in cold climates. In addition, traditional catch basins tend to clog during Chinook conditions, common in Calgary, due to the bottom outlet design being at risk of clogging and freezing. This problem was addressed in the project with the design of a raised outlet with a non-clogging tie-in to the storm sewer system.

During the approval process of the project, several meetings were held that included various stakeholders such as the design team, approvals departments and senior management. Together they worked through the specific differences between the proposed Low Impact Development design and more traditional stormwater management designs. In addition, multiple meetings as well as weekly site meetings were held with the entire team to ensure that the principles and goals behind the design of the Currie Barracks brownfield project were properly understood by everyone. In parallel, the City of Calgary developed a Stormwater Source Control Handbook to address design criteria for Low Impact Development applications within the city. Before releasing the Handbook, the City of Calgary made sure that the personnel assessing the design and granting approval were well trained and had a good understanding of Low Impact Development principles.

The Currie Barracks brownfield re-development project was also used as a pilot project in Canada for LEED Neighbourhood Development, a rating system that integrates the principles of smart growth, urbanism and green building into a system for neighborhood design. The approved site plan of the project has received a Stage 2 Gold rating. The project also received the Consulting Engineers of Alberta award for progressive engineering for its Low Impact Development stormwater design.

A WORD FROM CALGARY

At the time the Currie Barracks brownfield project was developed, the concept of Low Impact Development was fairly new to the City of Calgary. For this reason, the approval process was more challenging since City staff was not familiar with the specificities of Low Impact Development as many of the proposed features were not standard. Currently, the City of Calgary continues to develop Low Impact Development applications throughout the City. "Any upcoming greenfield development and redevelopment will need to be very Low Impact Development intensive to meet new stormwater targets and guidelines," said Bert Van Duin, Senior Development Engineer for the City of Calgary. Mr. Van Duin concluded by mentioning that as long as Low Impact Development features are used appropriately, they should be implemented on all future projects.



BOUCHERVILLE

Wet and dry retention ponds

Source: ICLR

THE SCIENCE

Greenfield developments sometimes transform farmland, forests and pastureland into modern, high-density housing. Land that previously had considerable capacity to absorb and slow rainfall flows may become covered with roads, buildings, shopping malls and other impermeable surfaces with little capacity to absorb rainfall. There can be a considerable change in the flow of stormwater in the area that is developed and to adjacent regions. Changes in stormwater flows both negatively affect the environment and increase flood risk. Also, established, downstream homes some distance away may begin to experience an increased risk of basement flooding and water damage as rainfall during extreme events quickly flows out of impermeable, developed lands into established neighbourhoods overwhelming the capacity of existing stormwater management systems.

THE TRIGGER

The City of Boucherville wanted to grow and welcome new development. When the City decided to develop the Harmonie neighbourhood, they faced a stormwater management problem. The Sabrevois River located nearby could only safely cope with a limited amount of stormwater runoff before encountering the risk of environmental problems. Also, the cost of installing new high-capacity sewer systems and rainwater collectors would be expensive - a cost that the City did not want to impose on developers and new residents.

Boucherville chose to orient the development of this neighbourhood in a way that would reduce the expected peak flow of stormwater from the new neighbourhood into the river during extreme rainfall events, and to ensure that waters that eventually flow into the river were naturally filtered to absorb pollutants from rooftops and paved surfaces. Boucherville also identified the potential of the new development to provide recreation features for residents, including attractive natural paths for walking, jogging and cycling.

THE APPROACH

Consulting engineers conducted preliminary studies that included hydrologic simulations to help determine the best stormwater management practices for the new Harmonie neighbourhood. The research identified an approach using double drainage principles. There would be wet and dry detention ponds in the neighbourhood. Two ponds or small urban lakes would have permanent water retention (wet detention ponds), and two ponds would be dry most of the time but would have capacity to temporarily hold water in the eventuality of heavy rainfall events (dry detention ponds). Drainage pathways were created to connect the dry ponds to wet ponds.

The four ponds protect the quality of urban water runoff from roads, parking lots, residential neighbourhoods and other impervious areas. The ponds also help to reduce peak stormwater runoff rates by providing temporary storage

Figure 26 & 27 : *Drainage pathways were created along the multifunctional corridors to connect the dry ponds to the wet ponds.*
(Source: ICLR)

during heavy rainfall events. The wet detention ponds have plants that provide a natural filter for storm water. Dry detention ponds are designed to drain within 24 hours after a storm. The four ponds provide a capacity to retain extreme rainfall water volumes similar to that present before the development, minimizing the risk of increase stormwater flowing into established neighbourhoods and resulting in flood risk reduction.

THE OUTCOME

The small urban lakes created in Boucherville were used as the starting point of the neighbourhood's development. After their construction, they were connected to municipal parks by multifunctional corridors for cyclists and pedestrians. These corridors surrounded by drainage ditches were used for draining purposes, but also to connect the new parts of the neighbourhood with the rest of the city. Through this land use planning, the city created 'blue' and 'green' networks that increased the popularity of the area.

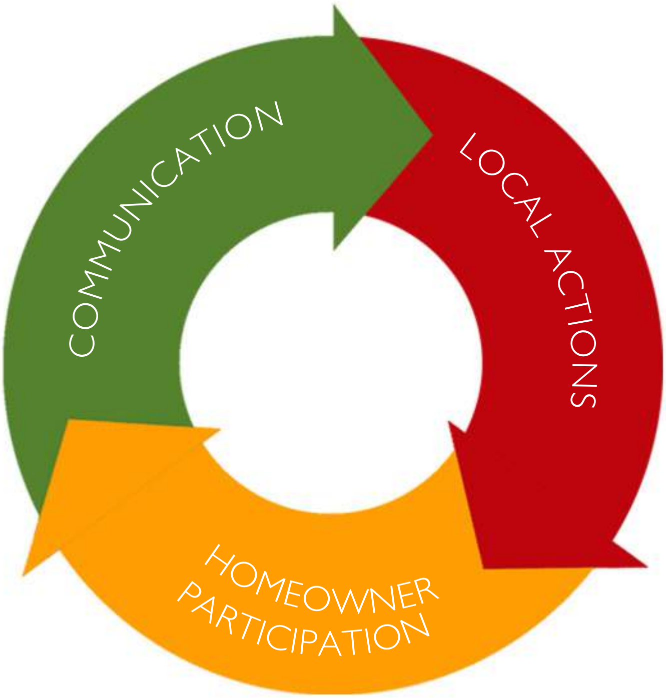
One of the urban lakes created in the project was also conceived as a mitigation measure to control erosion on the Sabrevois River by procuring better waterflow control. This same lake also allowed best stormwater management practices because of its high retention capacity that helps prevent flooding in the event of a one in 50 year extreme rainfall, compared to the one in 10 year capacity of traditional systems in the City.

The Harmonie project received Quebec's Consulting Engineering Award for its stormwater management system. The project has been popular with the citizens of Boucherville and demonstrates sustainable approaches to new development, where actions to support growth can be consistent with environmental protection.

A WORD FROM BOUCHERVILLE

When asked for his thoughts on the project, Claude Poirier, Engineer for the City of Boucherville responded that "the project has been successful and extremely well received by the population because the City was not afraid to be visionary. Many stakeholders were involved and decided to join their efforts and worked together in the same direction. There was a vision for that neighborhood. Instead of just digging big holes in the ground, we were able to create an attraction that became highly popular in the neighbourhood," says Mr. Poirier.

The project achieved a number of recreational and environmental objectives beyond minimizing the impact of the new development on the stormwater management capacity in existing neighbourhoods.



BEST PRACTICES

A comprehensive local plan

Source: ICLR

Local action has the potential to significantly reduce the risk of damage to homes from sewer backup and basement flooding resulting from extreme rainfall. Ideally, local governments should pursue a comprehensive strategy that includes communication, local actions and incentives for action for private property owners. Critical elements of a plan are set out below:

COMMUNICATION

Sewer backup and basement flooding during extreme rainfall events has recently emerged as the leading cause of damage to homes in Canada. Water damage to homes has increased significantly over the past five to 10 years, and a further increase is inevitable over the next few decades unless steps are taken to reduce risk.

Surprisingly, homeowner awareness about the peril is very low. A primary objective of local government communication should involve informing property owners about the risk. All homes connected to the sanitary and stormwater systems are at some risk of damage from backup. Overall damage to homes is presently in excess of $2 billion a year with most of the damage being preventable

The Government of Canada issues more than 13,000 severe weather warnings each year. Most do not result in damage to homes. Most homes in Canada are well built and well maintained. In circumstances when extreme rainfall results in damage to homes property owners typically blame their local government. Local governments are seen to "own" the issue of basement flooding.

Wastewater and stormwater in municipal sewers can back up into homes and cause damage due to decisions made by local governments and also decisions made by private property owners. Communications should identify the need for action by both the government and property owners, while stressing the importance of leadership from the local government.

In some circumstances, like the efforts of the City of London in Sherwood Forest, communication will involve local officials visiting individual property owners in their homes to discuss implementing specific plans to protect their particular home. In other circumstances, like Quebec City's effort in Maizerets, escalating communication was required over a period of almost three years before 100 percent homeowner participation was secured.

The effort in Halifax Region focuses on educating homeowners about the costs and benefits of a broad range of options that could be implemented by property owners. In contrast, communication in Toronto needed to increase awareness that a voluntary program funded by the City had evolved into a mandatory program funded by homeowners.

Some programs, like the one offered by Moncton, targeted homes at high risk of basement flooding, and needed to include information about why these homes were selected. Other programs, like the incentive program in Winnipeg, is available throughout the City to any household that does not yet have a backwater valve, focusing the program on the benefits of action.

Some programs target new home construction, like those in Markham, Ottawa, Edmonton and Collingwood, so the primary audience includes builders, developers, landscapers and building code enforcement officials. Other programs aim at influencing the behaviour of existing homeowners, so the communication and policy challenges can use a variety of tools including information, financial incentives, regulatory requirements and even fines.

An exciting recent development involves the use of Low Impact Development design in new developments with the object of retaining stormwater in the new development while minimizing the impact on the capacity of the existing stormwater system. Low Impact Development, like that in Calgary, is expected to emerge across the country as an important tool for managing stormwater in new developments and reducing the potential adverse impact of development on existing homes.

Communication needs to be tailored to the specific circumstances of the basement flood reduction program, with considerable scope to learn from the experience of other communities across Canada. Communication will often need to be sustained over several decades, like that in Edmonton and Winnipeg. Communication needs to acknowledge the importance of local leadership while introducing the idea that local governments and private property owners share responsibility for managing the risk.

LOCAL ACTIONS

Local and regional governments are responsible for the systems that treat sanitary wastewater and for stormwater management. Local decisions about the design and management of these systems can increase or reduce the risk that untreated waste and water are driven into homes during extreme rainfall events.

Wastewater from toilets, sinks and other plumbing flow through sanitary sewers to treatment facilities. The risk that sanitary sewers backup and damage homes is associated with the initial construction, and ongoing maintenance of the sewers. Moreover, the risk is significantly affected by inflow and infiltration of excess water into sanitary systems.

Ongoing performance monitoring is an essential element of managing this risk. Victoria seeks to ensure that wet water flows never exceed four times dry water flow through sanitary sewer pipes. Local governments should set a performance target and monitor the system to determine when action is required.

Detailed research is often required to determine the source of problems. The City of London determined that weeping tile connections increase the inflow of rainwater into sanitary sewers.

Surrey determined that inflow and infiltration in their community was the result of private storm lateral failures. Quebec City and Toronto chose to focus on downspout disconnection. Some communities use smoke tests to find illegal cross connections between sanitary and stormwater systems. Local action can be clear when the problem is well understood.

The decision in Metro Vancouver to replace all combined sewers is a bold step to reduce the risk of basement flooding. Moreover, the primary objective of this program is to eliminate the discharge of untreated waste into streams, rivers and the ocean.

Considerable progress has been evident in recent years in the management of stormwater. Many existing systems were put in place decades ago, using historic rainfall intensity, duration and frequency information that no longer reflects current knowledge about risk. Communities should reassess the capacity of their stormwater management systems based upon a current assessment of the risk of extreme rainfall. This assessment should also seek to take into account uncertainties associated with climate change and other risks. For example, London conducted some pioneering research concerning the local impact of climate change and assumes that stormwater flows will increase by 21 percent.

Most communities across Canada design their overland major stormwater management system to cope with the expected intensity of a 100-year rainfall event. Stratford has chosen to focus on the more severe 250-year event, with peak flow rate 15 percent higher than the 100-year storm. Communities choose the degree of safety that will be provided through the design and maintenance of the stormwater management system and we anticipate that progressive communities will seek to provide higher safety margins due to the growing evidence of major losses resulting from current levels of protection.

Best practices for local governments require updating climate information and adding scope to deal with uncertainty associated with risks like climate change. This may involve targeting the 250-year storm, or targeting the 100-year storm with at least 10 to 20 percent adjustment to deal with uncertainty.

Furthermore, the minor stormwater system of sewers and underground infrastructure typically has focused on the five year rainfall event. Increasingly local and regional governments are now designing their buried infrastructure to address the 10-year event, again using more current information about rainfall intensity and perhaps an adjustment for climate change.

Shifting to a higher standard typically results in the installation of somewhat larger diameter sewer pipes. Larger pipes have a higher purchase cost than smaller pipes but may reduce the cost of stormwater management. The cost of the pipes is a very small component of the overall cost of sewer installation and replacement. Moreover, sewers with larger pipes are less vulnerable to early redundancy with a likely increase in future rainfall intensity.

Local governments have primary responsibility for managing the risk of damage from sanitary and stormwater. Failure to provide adequate protection can result in legal action, as was experienced in Stratford. The significant values at risk suggest that local and regional governments will take action to increase the degree of protection that they provide. This will involve higher capacity in buried infrastructure and change in the ability of overland systems to cope with extreme rainfall. Uncertainty associated with climate change further increases the incentive for local governments to build in conservative assumptions for the design and maintenance of sanitary and stormwater management systems.

HOMEOWNER PARTICIPATION

A particular focus of the Institute for Catastrophic Loss Reduction has been on securing participation of private property owners in the management of the risk of damage from extreme rainfall. Many of the specific actions are well known and enjoy widespread support among local government experts – install a backwater value, install a sump pump, maintain appropriate lot grading, maintain sewer laterals, disconnect downspouts. The challenge is for local governments to get largely uninformed private property owners to participate.

The foundation for involving private property owners begins with understanding property owners motivations and providing outreach to inform homeowners about the importance of working together to confront the risk of damage. This involves a shared understanding about the factors contributing to the risk of damage, and the scope of the problem. Local governments find relatively few partners that can join in the communication of this information. There has been a growing recent interest by academics, local contractors and plumbers, renovation experts and home appraisal professionals. An important new partner in sharing information is found in the insurance industry, a group with a shared interested with homeowners and local governments to aggressively confront sewer backup and basement flooding risk.

Backwater valves represent a critical element of homeowner action to reduce the risk of basement flooding. Some communities, like Edmonton and Winnipeg, have required backwater valves in all new homes for more than three decades. Federal and provincial actions to mandate backwater valves in new homes through the building code continue to result in thousands of new homes built each year in Canada without a backwater valve, a disappointing ambiguity in the code that can be resolved by local action, like that found in Edmonton, Winnipeg, Ottawa, Collingwood and elsewhere.

A greater challenge has been encouraging the installation of backwater valves in existing homes. Every home connected to the sanitary sewer system is at some risk of damage from backup, while those with a history of flooding are at high risk. Some communities target high risk homes. Saskatoon secured a high participation rate among high risk homes by offering financial incentives immediately following three major basement flooding events.

Some communities require installation of backwater valves in existing homes when homeowners decide to conduct a significant renovation. This may involve a requirement to install backwater valves or may be a general requirement to bring the home up to the standards of the current building code, which may be interpreted to require a backwater valve. Some day communities may mandate installation of a backwater valve in all existing homes, as has been done in Toronto for downspout disconnection.

A comprehensive strategy for local governments to reduce the risk of damage to homes from sewer backup and basement flooding should involve actions to require backwater valves in all new homes, likely through a by-law; and incentives or regulations to encourage homeowners to install valves in existing homes. Manitoba has been willing to share in the funding of the program offered in Winnipeg, so it will be interesting to determine the potential future role of provincial governments. In addition, the experience in Ottawa demonstrates that homeowner knowledge about the maintenance of backwater values is important to effectively reduce this risk so local governments should become involved in education programs.

The experience in Quebec City provides guidance about actions to secure 100 percent homeowner participation in downspout disconnection. The first phase of communication includes information about why compliance is required and informing homeowners that the City is willing to pay all costs. The second phase would clarify that compliance is mandatory and fines are possible. And the final phase would indicate that fines will be issued unless participation is immediately ratified. It would be interesting to see how this approach could be modified for mandating some of the other important actions that would reduce the risk of basement flooding like the installation of backwater valves, sump pumps, storm lateral replacement or lot grading.

Surrey has implemented a strategy for inspecting and replacing sewer laterals when significant renovations are planned for homes. Participation is mandatory, but must be triggered by the choice of homeowners to renovate. This approach is less intrusive than mandating participation for all existing homeowners.

Local governments have adopted a number of approaches in terms of willingness to pay for action by private property owners. In some instances the government will pay the full cost, like downspout disconnection in Quebec City and weeping tile disconnection in London. In some instances the government mandates compliance but makes no financial contribution, like downspout disconnection in Toronto and sewer lateral replacement in

Surrey. Many communities will pay 50 percent or more of the cost of installing backwater valves, although incentives may be restricted to homes at high risk or property owners with lower incomes. There is no consensus about best practices found in the experience of local governments or the academic literature. The most effective programs in terms of high rates of homeowner participation do not necessarily provide the most generous incentives.

Experience does show that local actions generally escalate over time, in part due to poor uptake rates by homeowners. Most local action is triggered by a large loss event. An initial response provides information to homeowners about potential actions, with few homeowners choosing to change their behaviour. A second or third loss event may lead to a local program encouraging voluntary action, perhaps with a financial incentive, but again most homeowners fail to participate. A fourth or fifth loss event may lead to regulations mandating action by homeowners with the local government willing to pay most costs, resulting in higher compliance. Subsequent events ultimately lead to more aggressive regulations mandating action, perhaps introducing fines and often withdrawing local subsidies. Increasingly local governments may move quickly to mandate action by local property owners given the large number of other communities across Canada that have adopted similar action. Practices with respect to the generosity of financial incentives will likely be influenced by local decisions about financial incentives with respect to other issues affecting the community.

CONCLUSION

Damage to homes from sewer backup and basement flooding is largely preventable, yet has been growing at an alarming and unsustainable rate. Local action is essential to address this important issue. Dozens of communities across the country have begun to confront this issue. And there is a strong consensus about the specific actions that would best reduce this risk. The present challenge is to secure greater participation by local governments and private property owners. This book seeks to celebrate the leadership of 20 communities that are taking action now, actions that can be replicated in other communities across Canada. Through local action it is possible to break the alarming and unsustainable trend of rising damage to homes from sewer backup and basement flooding as a result of extreme rainfall.

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