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URBAN FLOODING AND GROUND-RELATED HOMES IN CANADA: AN OVERVIEW

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ABSTRACT: Urban flooding associated with extreme precipitation is a significant cause of disaster damages for municipalities, homeowners and insurers in Canada. Over the past few years, Canadian insurers have seen dozens of individual urban flood events that have resulted in millions of dollars in payouts. Losses associated with urban flooding are expected to increase over the coming years as a result of increasing urbanization, deteriorating infrastructure and the expected impacts of climate change on precipitation regimes across the country. Several approaches have been applied to reduce risk associated with urban flooding at the municipal and homeowner scales, including limiting excess water contributions to municipal sanitary sewer systems, accommodating extreme stormwater flows in subdivision design, and protecting individual homes from flooding. Insurers have also become engaged in managing this risk through interactions with individual policy holders, and have been involved in a number of initiatives aimed at better understanding urban flood risk and risk mitigation options in Canada.

Key Words: Urban Flooding, Canada, Private-Side, Municipal-Side, Insurance, Sewer Backup, Infiltration, Stormwater

1. INTRODUCTION

Cities across Canada are experiencing severe and repeated urban flood events. Recent urban flooding events associated with extreme rainfall and resulting in widespread basement flooding occurred in the cities of Montréal and Thunder Bay in May, 2012 (CBC, 2012a; CBC, 2012b), Calgary in July, 2012 (CBC, 2012c), Hamilton and Toronto in 2012 (Caton & Wong, 2012; Moloney, 2012; Van Dongen, 2012a,b), Winnipeg in 2010 (Skeritt, 2012), Mississauga, Ontario in 2009 (Inouye, 2012), southern Alberta and the Greater Toronto Area in 2013 (Government of Alberta, 2014; PCS Canada, 2014) among many other events across the country. These events frequently result in the flooding of 100s if not 1,000s of homes and $10s if not $100s of millions of dollars in damages.

The costs of individual urban floods can be significant. In 2013, two of the most expensive floods in Canadian history occurred in southern Alberta and southern Ontario. In June, 2013, many communities in southern Alberta, including significant portions of the City of Calgary, were affected by the most expensive flood event in Canadian history. This event resulted in approximately $5 billion in government losses and $1.7 billion in insured losses (Government of Alberta, 2014; PCS Canada, 2014). A significant portion of these losses were experienced by homeowners affected by surcharged storm and sanitary sewer systems. In July, 2013, an extreme rainfall event flooded thousands of homes in the Greater Toronto Area (GTA) of southern Ontario—the most populous urban area of Canada. This event resulted in approximately $940 million in insured losses for Canadian property and casualty (P&C) insurers (PCS Canada, 2014).

Water damage claims associated with failure of household plumbing systems and basement flooding have become one of the most significant causes of home insurance claims in Canada. In 2012, the Insurance Bureau of Canada (IBC) estimated average yearly insurance payouts for water damage at $1.7 billion (IBC, 2012). Further, Aviva Canada, one of the country's largest home insurers, has reported that 51% of claims paid to homeowner clients in 2013 were associated with water damage, and that the average value of water damage claims had increased from $8,944 in 2003 to $20,537 in 2013 (Aviva Canada, 2014).

Urban flooding events also have serious implications for local governments and homeowners. Aside from damage caused to infrastructure and costs associated with response and recovery, several Canadian municipalities have faced class action lawsuits from residents affected by regional sewer backup events, including the municipalities of Thunder Bay, Kenora and Stratford, Ontario, Port Alberni, British Columbia and St. John's, Newfoundland (Campbell *et al*., 2007; City of Stratford, 2010). The cities of Thunder Bay and Mississauga are currently facing class-action lawsuits from residents affected by 2012 and 2013 flooding events totalling $200 million and $300 million respectively (Zizzo, 2013).

Homeowners are particularly negatively affected by urban flooding events. In Canada, homeowner sewer backup insurance coverage is widely available, but the majority of Canadian homeowners are not insured for damages caused by groundwater (infiltration) flooding and overland flooding (e.g., stormwater flows that enter homes through windows and doors) (Sandink *et al*., 2010). Except for rare cases, flooding caused by overflowing of surface water bodies, including lakes and streams, is also unavailable for homeowners in Canada (Sandink *et al.*, 2010). Further, repeated sewer backup claims may result in limiting or discontinuation of insurance coverage, increasing the liability of homeowners for expensive basement flood damages and rebuilding costs (Applied Systems, 2013). Homeowners must also cope with the loss of irreplaceable items and reduced liveability of homes as a result of basement flood damages, especially in the case of sanitary sewer backup, which results if the flooding of homes with raw sewage.

Health effects associated with poor indoor air quality caused by dampness and mould growth have been linked to the occurrence of flooding in homes in urban environments (Dales *et al*., 1991a,b; Ivers & Ryan, 2006; Kesik & Seymour, 2003; Ross *et al*., 2000; Taylor *et al*., 2011). Specifically, flooding associated with sewage can lead to faecal-oral transmission of disease (Ahern *et al*., 2005), and contamination of building materials with floodwaters that contain sewage can facilitate the growth of human pathogens deposited during flooding (Taylor *et al*., 2011).

Various environmental and infrastructure-related factors may result in increasing urban flood risk in Canada over the next few decades. For example, it is expected that climate change will have implications for stormwater management in Canadian urban municipalities (Institute for Catastrophic Loss Reduction, 2012; Mailhot *et al*., 2010; Mailhot & Duchesne, 2010; Mladjic *et al*., 2011; Nguyen *et al*., 2007; Peck *et al*., 2012; Prodanovic & Simonovic, 2007). For example, Cheng *et al*. (2011) revealed that 1 in 100 year three-day accumulated rainfall amounts in the Thames, Grand, Humber and Rideau River basins of Ontario could increase by 34%, 73%, 50% and 30% respectively by the year 2050. Prodanovic and Simonovic (2007) revealed that 24 hour precipitation amounts in London, Ontario that were historically associated with 1 in 100 year return periods could have 1 in 30 year return periods as a result of climate change. Further, Mailhot *et al*. (2012) argued that rainfall intensities in Canada could increase by 12 to 18% (median values—1968-2000 vs. 2041-2070) depending on rainfall return period, duration and region.

It is also well established that urban development can affect urban hydrology, resulting in numerous impacts including increased peak stormwater flows during rainfall events (Booth & Jackson, 1997; Burby, 2006). Nirupama and Simonovic (2006) revealed a relationship between development and increasing flow rates in the Upper Thames River in London, Ontario. In 1970, a 400 mm precipitation event resulted in a flow of 350 m^3/s in the Thames River at the Byron monitoring station. By 2000, a 200 mm precipitation event resulted in a flow of 800 m^3/s at the same monitoring station—an indication of the impact of increasing urbanization on the watershed (Nirupama & Simonovic, 2006). The impacts of climate change combined with increasing development and lack of funding and maintenance for municipal sewer infrastructure (Mirza, 2007) suggest that urban flood related damages and impacts will increase in Canada without the application of appropriate risk mitigation measures.

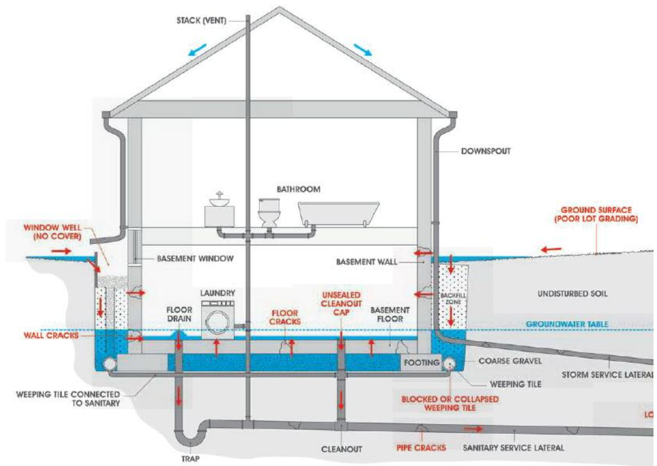
Section 2 of this paper reviews the major types of flooding experienced by ground-related homes during urban flooding events associated with short-duration, extreme rainfall events in Canada. In the following sections, a sampling of major municipal-side approaches to urban flooding, including the management of inflow and infiltration (I/I) in sanitary sewer systems and techniques for managing stormwater flows are discussed. Private-side (or household-level) approaches to urban flood mitigation are then discussed. The paper also provides a brief discussion of the role of the Canadian P&C insurance industry in urban flood mitigation. This paper focusses on ground-related homes serviced by separated municipal sewer systems.

2. FLOODING OF HOMES DURING EXTREME PRECIPITATION EVENTS IN URBAN AREAS

2.1 Infiltration Flooding/Seepage

A common cause of flooded basements across Canada is infiltration flooding, or seepage. This type of flooding can occur during extreme rainfall events when surface water percolates into porous soil in the "backfill" area next to foundation walls. This type of flooding can also occur during spring snow-melt seasons and when groundwater level heights exceed the lowest level of basement floors (see Figure 1). This type of flooding is not typically insured for private homeowners in Canada, though Quebec homeowners may be offered coverage for seepage flooding.

Figure 1: Lot-Level Infiltration Flooding in a Ground-Related Home

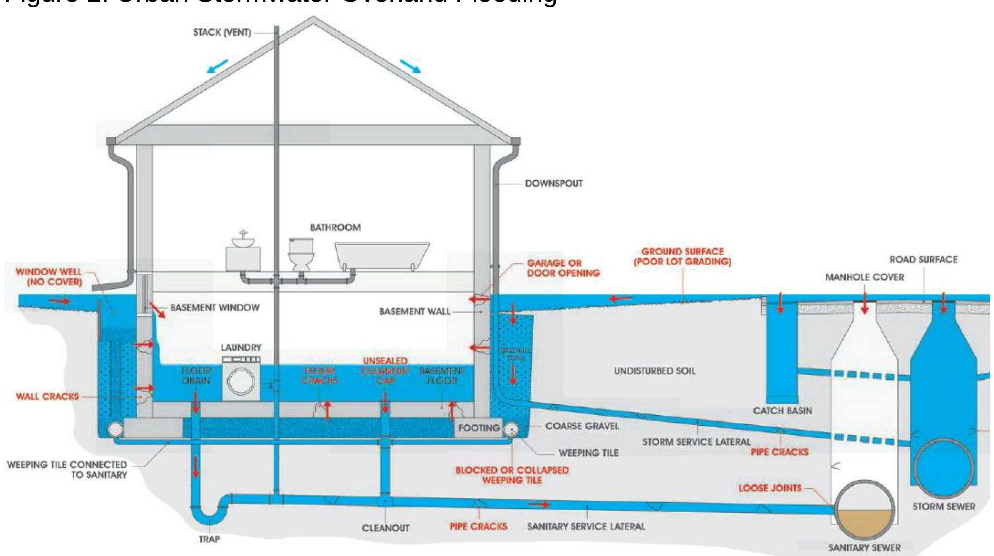


Source: Sandink, 2009

2.2 Overland Flooding

Several sources of overland flooding may affect ground-related homes, including flooding from surface water (rivers, streams, lakes, etc.) and stormwater flooding. Stormwater overland flooding occurs when rainfall exceeds design standards of urban stormwater management infrastructure (see Figure 2). Newer urban areas are typically serviced by a "major" and "minor" stormwater management system. Major systems include overland conveyance systems and are typically designed to handle 1 in 100 year peak flows. Minor systems are underground storm sewer systems, typically designed to convey 1 in 2 to 1 in 25 year peak flows. A 1 in 5 year peak flow standard is

Figure 2: Urban Stormwater Overland Flooding



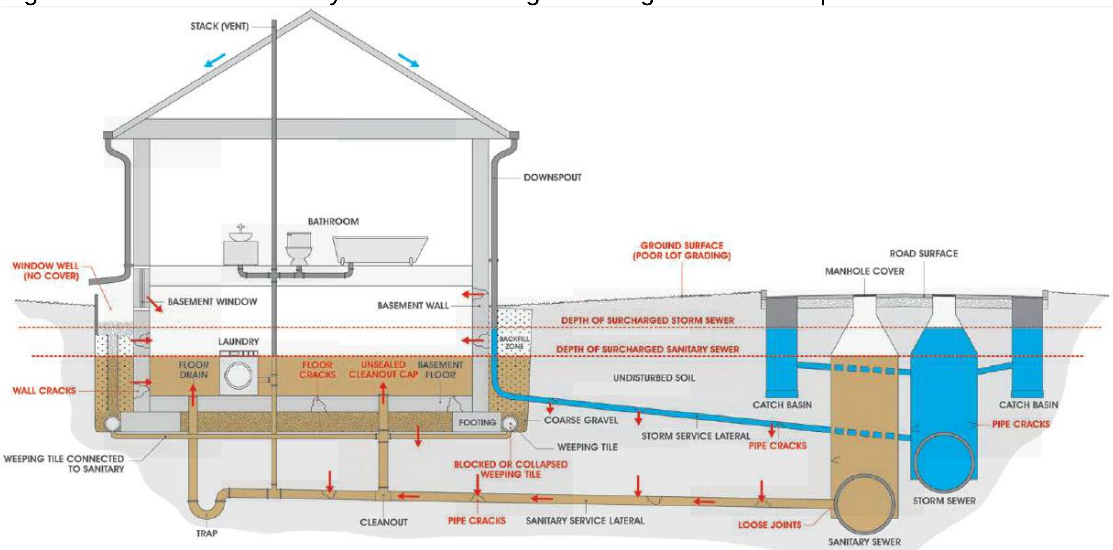
Source: Sandink, 2009

adopted in many parts of Canada for minor stormwater management systems. Older subdivisions (i.e., those built before the mid-1900s) are infrequently serviced by major stormwater management systems, and are thus more vulnerable to overland flooding from extreme short-duration rainfall events (see Section 3.1.2).

2.3 Sewer Backup

Sewer backup flooding is frequently caused by surcharging of underground public storm and/or sanitary sewer systems. When sewer systems surcharge, sewage is pushed back into homes through sewer connections resulting in flooding. This type of flooding can occur in combined systems, where both stormwater and sanitary sewage are conveyed in the same sewer network, and in separated systems, which include separate underground conveyance for storm and sanitary sewage. Figure 3 provides an example of sanitary and storm sewer surcharge causing sewer backup in a home serviced by a separated sewer system. As discussed above, this is the only widely insured type of flooding in Canada, and has been driving the majority of property insurance claims for urban flooding.

Figure 3: Storm and Sanitary Sewer Surcharge causing Sewer Backup



Source: Sandink, 2009

It is important to note that subdivisions and homes vary considerably throughout Canada, resulting in different types of flood vulnerability. This is especially the case for sewer backup. For example, many homes in Canada are serviced only by sanitary sewer connections whereas others are serviced by both storm and sanitary connections. Policies adopted by municipalities relating to service connections, foundation drain connections and downspout connections also vary widely. Different types of connections have resulted in differing levels of flood vulnerability from storm and sanitary sewer surcharge.

3. REDUCING URBAN FLOOD RISK: MUNICIPALITIES, HOMEOWNERS AND INSURERS IN CANADA

3.1 Municipal-Side Factors

Communities across Canada have been adopting measures to reduce risk to urban flooding events associated with intense precipitation. Measures can be applied either at the municipal-side or private-side. For the municipal-side, this paper provides a brief summary of measures related to managing I/I and stormwater flows.

3.1.1 Managing Inflow and Infiltration

Inflow has been defined as excess water entering sanitary sewer systems, both on the municipal- and private-sides, “from the ground through such means as defective pipes, pipe joints, connection or manhole walls” (FCM & NRC, 2003). In contrast, inflow includes water that is discharged to public- and private-side sanitary sewer systems from sources including roof downspouts, area drains, foundation drains, drainage from natural sources (e.g., springs and swampy areas), manhole covers, cross-connections with stormwater management systems, and other sources (FCM & NRC, 2003; Kerr Wood Leidal Associates Ltd., 2008).

Excessive I/I may occur in wastewater systems as a result of gradual deterioration (e.g., shifting of pipes, tree root penetration, corrosion) or through defects that occur unintentionally, including design flaws and inappropriate connections made either at the time of construction or over the service life of the infrastructure. Cross-connections between storm and sanitary sewer systems have been cited as a factor in I/I leading to sanitary system surcharge causing sewer backup. Cross connections can occur on the private-side, for example, through connection of downspouts or private stormwater catch basins into municipal sanitary sewer systems, or on the municipal-side, for example, through accidental connection of storm catch-basins to sanitary sewer systems (City of Hamilton, 2013; Gainham, 2013; Metro Vancouver, 2013; Pawlowski *et al*., 2014).

I/I is an ongoing problem in municipalities across Canada, and many municipalities have developed programs or projects aimed at addressing I/I in existing sanitary sewer systems (for example, see Metro Vancouver, 2011; Cole Engineering, 2013; York Region, 2012). Aside from increased risk of flooding caused by sewer backup, I/I can reduce the capacity of sanitary systems to convey and treat wastewater, may increase wastewater infrastructure and treatment operating costs for municipalities and can result in sanitary system overflows, generating negative environmental externalities including introducing substantial volumes of microbial, chemical and sediment pollutants into surface water during combined or sanitary sewer overflow events (FCM & NRC, 2003; Pawlowski *et al*., 2014). The impacts of I/I are especially severe during intense rainfall events, as rainfall derived I/I (RDII) can result in acute additional loads on sanitary systems (Pawlowski *et al*., 2014).

It is important that both private- and municipal-side I/I sources are remediated to reduce the risk of sewer surcharge, as private-side sources are often significant contributors to I/I in public sanitary sewer systems. For example, Metro Vancouver, British Columbia has estimated that as much as 70% of this City’s I/I contributions are sourced from leaky private-side sanitary sewer connections (City of Surrey, 2009), and the Region of York in southern Ontario has estimated that 60% of I/I contributions can be sourced to private-side sanitary laterals (Cole Engineering, 2013). Foundation drain and downspout connections have also been identified as significant sources of I/I at the property level. For example, Pawloski *et al*. (2014) found that 98% of private-side I/I could be attributed to these types of connections, based on a case study in Columbus, Ohio, USA.

Various approaches have been applied by Canadian municipalities to address I/I in existing urban subdivisions. These measures have included both measures at the municipal- and private-sides. On the municipal-side, measure include maintenance hole and sewer sealing (e.g., chemical grouting), sealing of manholes (e.g., sealing manhole chimneys, using solid manhole covers and manhole cover gaskets), disconnection of cross-connected storm catch basins, and pipe re-lining to reduce infiltration (City of Hamilton, 2013; Cole Engineering, 2013; Gainham, 2013; Metro Vancouver, 2013; City of Surrey, 2009). On the private-side, measures have included application of education and financial assistance (subsidy) programs, and various policies and by-laws to encourage or require private-side I/I reduction. Specific measures that may be encouraged or required at the private-side include foundation drain disconnection (for example, see City of Winnipeg, 2014), sanitary sewer lateral re-lining or replacement (for example, see City of Brantford, 2014; City of Surrey, 2014), and downspout disconnection (for example, see City of Toronto, 2014a).

Many municipalities have had difficulty reducing I/I at the private side. These difficulties are associated with limited municipal government jurisdiction on private lands, which result in the requirement for private homeowner permission to access properties to investigate I/I issues. Further, even when specific I/I issues have been identified, it is extremely difficult to encourage homeowner to adopt measures to limit these connections. A common approach to limiting private-side I/I has been to use education and subsidy programs to encourage downspout and foundation drain disconnection. However, these programs have been met with limited success—indeed, frequently as few as 10% of eligible homeowners may choose to participate in these programs (Sandink, 2013).

An alternative to limiting I/I is to provide temporary storage of excessive sanitary flows. This approach has been applied in many Canadian municipalities, and typically includes either in-line or off-line storage (see City of Edmonton, n.d.; City of Saskatoon, 2012; City of Toronto, 2014b; Region of Halton, 2014). This approach provides temporary storage of large volumes of sanitary sewage generated during high I/I events, so that flows can be safely discharged once extreme I/I events have ended.

3.1.2 Managing Stormwater

The vulnerability of urban subdivisions to stormwater-related overland flooding is influenced by the history of stormwater management approaches in Canada. Hulley *et al*. (2008) and Watt *et al.* (2003) identified three historical eras of stormwater management in Canada, which include the Storm Sewer Era (roughly 1880-1970), the Stormwater Management Era (roughly 1970-1990) and the Urban Stormwater BMP (Best Management Practice) Era (roughly 1990-current). These historical eras of stormwater management are summarized in Table 1.

Table 1: Historical Eras of Stormwater Management in Canada

Era	**Duration**	**Summary**
Storm Sewer Era	~1880-1970	• Provision of sewer network to transport stormwater flows from upstream urbanized areas to downstream receiving waters (e.g., creeks, rivers, lakes, etc.). • Design criteria generally allotted capacity for 1 in 2 to 1 in 10 year return period peak flows (occasionally 1 in 25 year storms).
Stormwater Management Era	~1970-1990	• Stormwater ponds and the major (overland) system, to convey stormwater when capacity of minor system (pipes and ponds) is exceeded, were now incorporated into stormwater management systems to manage increased urban stormwater flows. • Minor system generally designed to handle 1 in 2 to 1 in 10 year peak flows; major system generally designed to handle 1 in 100 year flows.
Urban Stormwater BMP Era	~1990-current	• Water quality considered along with water quantity issues; efforts made to reduce stormwater pollution in receiving waters through application of Best Management Practices (sometimes referred to as Green Infrastructure or Low Impact Development).

Source: Bolivar-Phillips, 2013; Hulley *et al*., 2008; Watt *et al*., 2003

The shift away from exclusive reliance on underground sewer networks designed to handle relatively frequent extreme events toward inclusion of a major or overland stormwater management system is an important consideration for the current vulnerability of homes to overland flood damage. While frequently intended to management stormwater quality, a recent shift toward “green infrastructure” (or Low Impact Development--LID) has also been identified as a means of reducing vulnerability of urban municipalities to extreme precipitation events (Bolivar-Phillips, 2013). Testing of LID measures in several jurisdictions within the Credit River watershed, west of the City of Toronto, has indicated that LID measures can have a relatively significant impact on reducing stormwater quantity, as well as attenuating and delaying peak flows during extreme rainfall events. Further, test sites in the City of Mississauga, Ontario revealed that LID features that promote rainwater infiltration reduced stormwater volume by 50-60% for rainfall events that exceeded 30 mm in total accumulation (Zimmer, 2013).

The updating of stormwater management infrastructure design standards (specifically, Intensity-Duration-Frequency curves) has been identified as one of the most commonly adopted approaches to managing stormwater flood risk resulting from changing precipitation regimes under changing climate conditions in

Canada (Bolivar-Phillips, 2013). Several examples of adapting stormwater management design criteria to reflect changing precipitation regimes are provided in Table 2. As indicated in this Table, estimated impacts of climate change vary based on locality within Canada.

Table 2: Examples of Incorporating Climate Change Impacts into Stormwater Management Design Standards (IDF Curves) in Canada

Municipality	Stormwater flood mitigation measure
City of Guelph, Ontario	During an IDF curve updating process, the City found that existing IDF curves were relatively conservative. However, the City continued to use existing IDF curves to help offset uncertainties associated with climate change.
City of London, Ontario	Updating of IDF curves based on a modified dataset generated through Global Circulation Model for climate change. The analysis revealed that rainfall magnitude would increase by 10.7-34.9% under climate change scenarios, with an average increase of 21%. City Council adopted a rainfall magnitude increase of 21%.
City of Welland, Ontario	Similar to Guelph case study described above, an analysis of existing IDF curves revealed that climate change impacts would reduce the intensity of short-duration rainfall events (under 2020 and 2050 scenarios) for many duration/return intervals. The municipality chose to continue to apply existing IDF curves (developed in 1963) and re-assess IDF curves after further investigation.
City of Barrie, Ontario	A 15% increase in rainfall depth and intensity was adopted by the City based on climate change literature reviews.
Province of Quebec	Similar to the City of London case study presented above, research by Mailhot *et al*. (2007) identified a range of potential impacts of climate change on rainfall regimes in the province of Quebec. The analysis revealed that rainfall intensities in 2041-2070 could increase 4-21% depending on return period and rainfall duration, when compared to 1961-1990 (see Appendix). As an interim measure and until analysis could be improved, it was recommended that a rainfall intensity increase of 20% be incorporated into the design of minor systems (return periods from 2 to 10 years) and to 10% for the design of major networks and retention structures (return period from 25 to 100 years) in Quebec. Individual municipalities have authority to adopt recommended changes in design standards in Quebec.

Bolivar-Phillips, 2013; C.C. Tatham and Associates Ltd., 2011; City of Barrie, 2009; Rivard, 2011

Several municipalities have adopted new IDF curves based on sophisticated modeling approaches, while others, including the City of Barrie, adjusted IDF curves to accommodate general trends identified through literature reviews. In some cases, as exemplified through the Guelph and Welland examples, climate change impacts were predicted to result in decreases in rainfall intensity—however, both of these communities chose to continue to apply relatively conservative historical IDF curves (see Table 2). Table 2 should not be considered exhaustive, as several other Canadian municipalities including the City of Windsor (City of Windsor, 2012) and the City of Thunder Bay (City of Thunder Bay, 2013) are currently investigating updating or adapting IDF curves to account for climate change impacts.

3.2 Private-Side Measures

There are a number of adjustments that can be adopted at the private-side that work in concert with municipal-side measures to reduce urban flood risk. Private-side adjustments can be categorized as "behavioural" (measures related to changing of behaviour or adopting specific behaviours to reduce risk) or "physical" (physical changes made to buildings and properties to limit I/I and reduce the risk of flood waters entering homes). Individual private-side adjustments may serve to partially address overland flooding, infiltration flooding or sewer backup or a combination of several types of flooding (Table 3). Detailed descriptions of measures presented in Table 3 are provided in the following sections.

Table 3: Private-side Adjustments for Urban Flood Risk Reduction

Adjustment		Flooding Type			Function	
		O[1]	I[2]	SB[3]	Private-Side Risk Reduction	Private-Side I/I Reduction
Behavioural	Seek out/read information on urban flood reduction	X	X	X	X	X
	Inform municipal government about flood experiences	X	X	X	X	X
	Plumbing & drainage investigation	X	X	X	X	X
	Review insurance coverage			X	X	
	Avoid pouring FOGs down drains			X	X	
	Keep storm sewer grates clear	X			X	X
	Reduce water use during heavy rainfall events			X	X	X
	Maintain eavestroughs & downspouts		X	X	X	X
	Change use of basement (e.g., remains unfinished)	X	X	X	X	
Physical	Seal cracks in foundation walls, basement floors		X		X	
	Identify/seal overland flood entry points	X			X	
	Extension of downspouts/splash pads		X	X	X	X
	Lot grading/backfilling/swales		X	X	X	X
	Backflow protection device(s)			X	X	
	Sewage ejector/overhead sewer system			X	X	
	Maintenance, repair of sewer laterals			X	X	X
	Window wells/well covers	X			X	
	Downspout disconnection from municipal sanitary/combined/storm sewer			X		X
	Weeping tile disconnection & sump installation			X		X

[1] Overland Flooding, [2]Infiltration Flooding, [3]Sewer Backup Flooding

3.2.1 Behavioural Measures

Several behavioural measures may be adopted to directly or indirectly reduce the risk of flooding for homeowners and neighbourhoods. Homeowners may choose to seek out and read information about basement flood reduction, which may be available through their municipality or other sources. Ideally, homeowners would seek information from their own municipality, as municipal-specific information will be more reflective of local sewer system and plumbing characteristics. It is also important that residents inform their municipality of flooding they have experienced in the past. This information may be used by a municipality to identify areas of concern and may assist in the prioritization of infrastructure projects or other measures that alleviate urban flood risk (City of Hamilton, 2006).

A further important behavioural measure is becoming informed of one's own home plumbing by hiring a licensed professional to conduct a plumbing investigation. Proper plumbing investigations can ensure that property owners install the proper measures to reduce flood risk. The importance of plumbing investigations is reflected by their incorporation into several municipalities' homeowner sewer backup mitigation subsidy programs, including the City of Ottawa, the City of St. Cathrarines, Halton Region and the City of Welland (City of Ottawa, 2010; City of Ottawa, 2006; City of St. Catharines, 2012; City of Welland, 2012; Halton Region, 2010). Other programs require third party inspections by licensed professionals before subsidy funds are disbursed (City of Toronto, 2010).

Previous research has revealed a considerable lack of homeowner awareness of insurance coverage related to flooding and water damage. It has been found that a large portion of Canadian homeowners—approximately 70%—believe that they have coverage for overland flooding (ICLR, 2004 cited in Sandink *et al*., 2010). A 2014 survey of Quebec homeowners revealed that roughly 50% believed they were insured for flooding associated with rivers and other surface water bodies (*Canadian Underwriter*, 2014). A 2007 survey of homeowners in Toronto and Edmonton revealed that close to a third of respondents who had experienced sewer backup at some time in the past did not know whether or not their insurance covered sewer backup (Sandink, 2007). Similarly, Sandink (2011) revealed that 45% of residents in a high-risk urban flood subdivision could not indicate whether or not their home insurance included coverage for sewer backup. Thus, talking to one's broker or insurance provider or carefully reviewing one's policy is an important behavioural risk mitigating measure.

Fats, oils and grease (FOGs) can accumulate in both home sanitary sewer laterals and municipal sanitary or combined sewer systems, resulting in reduced capacity to convey heavy flows of water and leading to blockages in the system, which may directly cause sewer backup. Thus, avoiding pouring FOGs down household drains can reduce sewer backup risk for both homeowners and the community. Further, the blockage of storm sewer grates by leaves, snow and ice or other debris may result in increased surface flows during a heavy rainfall event (UMA, 2005). Thus, either clearing out or reporting blocked sewer grates can reduce overland flows during extreme rain events. Reducing water use during heavy rainfall events, including delaying running of dishwashers, washing machines and using showers and bathrooms helps reduce stress on municipal systems.

The maintenance of eavestroughs and downspouts can also reduce flood risk. Eavestroughs and downspouts may become plugged with leaves or debris resulting in water pouring over the side of the eavestrough and landing directly next to the home and foundation wall. This water may enter window wells and windows and cause basement flooding. Further, water pouring over the side of eavestroughs may increase the amount of water that enters the homes foundation drains, which may increase loads on municipal sanitary and/or storm systems, depending on the drainage characteristics of the home. Homeowners may also change the way they use their basements, including choosing not to store or locate valuable or expensive items in basements and choosing not to use basements as living space (i.e., leaving basements "unfinished").

3.2.2 Physical Measures

Physical measures include those that result in the alteration of plumbing or other components of the home and property. Like behavioural measures, physical measures may directly reduce flood risk for a household by limiting the probability that water will enter the home, or may provide a community-level flood risk reduction function by limiting private-side I/I (see Table 3).

Identifying and sealing cracks in basement floors and foundation walls can serve to reduce the risk of infiltration flooding, and the identification and sealing of cracks in basement walls or other unsealed openings around utilities (wires, pipes) in the foundation above ground level may reduce the risk of water entering the basement from overland flooding. Window well covers may also help prevent overland flow water from entering basement through basement window wells and windows. Extending eavestroughs away from the side of the foundation wall helps keep eavestrough drainage away from the soil directly adjacent to foundation walls, thus reducing the amount of water that enters foundation drains. Lot grading should accommodate water flows from the property during rainfall and snowmelt events.

Backwater valves and sewage ejector systems serve to reduce the risk of sewer backup at the homeowner level. Backwater valves are placed in either the main sanitary sewer connection (mainline valves) or in branch connections throughout the home (inline valves). When the municipal sanitary sewer surcharges, backwater valves prevent flows from entering the home. If a backwater valve has been installed, residents should refrain from the use of any household plumbing during extreme rainfall events, as the valve may be closed and water will not be able to exit the home through the sanitary lateral. The installation of sewage ejector systems includes increasing the height of the main sewer connection where it enters the home above the potential flood level in the municipal sewer. Basement plumbing drains are then directed to a sump where they are pumped up into the lateral by the sewage ejector (Tinley Park, n.d.). Sewage ejector systems are rarely applied alternative to backwater valves in Canada (see City of London, 2010). Indeed, most municipalities that encourage private-side sewer backup risk reduction promote the use of backwater valves (see Sandink 2013; 2011),

As discussed above, private-side sewer connections may serve as a significant source of I/I in separated sewer systems. Further, blockages on private property, including those caused by tree roots or a build up of FOGs, can cause isolated sewer backup events. Thus, laterals should be inspected and repaired if necessary. As an example of a municipal program designed to address sewer laterals, the City of Surrey, British Columbia requires replacement of sewer laterals for redeveloped land or major upgrades to homes if camera inspections reveal that the lateral is in poor condition. The city may also require replacement of the lateral if it is over 30 years old without camera inspections (City of Surrey, 2014).

Foundation drains consist of perforated pipes that surround the outside of the foundation footing and serve to drain excess groundwater away form foundation walls. When connected to a home's sanitary sewer lateral, foundation drainage can contribute significant amounts of water to the municipal sewer system and result in or exacerbate the risk of sanitary sewer surcharge (Pawlowski *et al*., 2014). Subject to lot conditions and local drainage infrastructure, foundation drains can be routed into a sump pit and pumped out of the home onto the surface of the lot. Municipalities may also allow connection of foundation drains into municipal storm or "third pipe" systems via private-side storm sewer connections. Downspout connections into sanitary sewers may also contribute substantial quantities of water into municipal sanitary sewer systems and exacerbate sewer backup risk (Pawlowski *et al*., 2014). Given appropriate lot characteristics, downspouts can be disconnected from sanitary or combined sewer systems and made to drain over the surface of the lot.

Foundation drain and downspout disconnection do not directly reduce a home's risk of basement flooding. However, if numerous homeowners serviced by a particular sewershed remove these extraneous sources of inflow from the sanitary or combined sewers, sewer backup risk can be reduced at the neighbourhood scale. Further, disconnection of foundation drainage and downspouts from sanitary laterals is crucial for proper backwater valve installation. "Self flooding" may result from the connection of downspouts and foundation drains to laterals upstream of backwater valves, as water will not be able to drain out of the homes when the valve is in the closed position. Thus, when the backwater valve closes, foundation drainage and downspout water may be forced up through floor drains or other bathroom drains and result in basement flooding.

3.3 Insurance Industry

As a result of drastically increasing losses associated with basement flooding and sewer backup, Canadian primary P&C insurers have begun to take steps to reduce risks associated with sewer backup for their companies and clients. These measures may be experienced by individual insured homeowners through two primary mechanisms: Financial risk reduction/pricing and encouraging private-side flood risk reduction. These approaches and examples are presented in Table 4.

Water damage and sewer backup endorsement wordings provided by Applied Systems (2013) indicate that home insurers are applying financial mechanisms to partially address increasing basement flood claim frequencies associated with sewer backup. As water damage and sewer backup are typically offered as an "add-on" endorsement to home insurance policies, financial incentives typically apply only to sewer backup or water damage coverage, rather than homeowner policies in general.

The raising of premiums for water or sewer backup endorsements is a common approach to mitigating insurance risk associated with urban flooding. Risk levels are frequently determined based on historical claim frequencies of both the individual insured and the geographical area in which the insured is located, usually delineated by postal code (Friedland *et al*., 2014). Application of sub-limits is also a common approach, which includes limiting the payout an insured would receive in the event of a claim. This approach may be applied to high risk individuals, as determined by historical claim frequencies. Policy holders may have sub-limits incorporated into their policies even if they have never experienced a claim, but are located in a postal code area that has experienced a high frequency of claims. Insureds may be offered an opportunity to pay an additional premium to increase their sub-limits for sewer backup or water damage (Applied Systems, 2013). Deductibles may be applied in the same way—for instance, higher water damage deductibles may be applied for high risk insureds. Finally, the availability of water damage coverage may be affected by sewer backup risk. Insurers, for example, may choose to no longer offer sewer backup coverage to an insured that has experienced two sewer backup claims in five years or three sewer backup claims in 10 years (Compu-Quote, 2011).

Table 4: Insurance: Financial Risk Reduction and Private-Side Mitigation

Approach	Examples measures	Description of measures
Financial risk reduction, pricing	Adjust premiums to reflect risk	• Acquire appropriate municipal- and private-side risk information to appropriately price coverage • Adjust policy pricing to reflect historical claims occurrence
	Sub-limits	• Adjust payout limits to reflect risk for specific perils, such that higher risk insureds would receive a lower payout in the event of a claim
	Deductibles	• Adjust deductibles to reflect risk such that higher risk insureds would be responsible for higher deductibles
	Limit availability	• Limit the availability of water damage or sewer backup coverage for high risk property owners
Encouraging private-side mitigation	Educate policy holders, brokers	• Provide seminars, develop education materials to educate brokers about sewer backup mitigation options to help brokers educate insureds • Develop, distribute education materials to insureds
	Incentivize adoption of mitigation measures	• Apply financial mechanisms (premiums, caps, deductibles, coverage availability) to encourage private-side risk reduction

Sources: Applied Systems, 2013; Friedland *et al*., 2014; Canadian Underwriter, 2013; Compu-Quote, 2011

Each of the abovementioned financial mechanisms have been applied by insurers to incentivize the adoption of private-side risk reduction measures. Measures incentivized by insurers typically include backwater valves and sump pump systems. Installation of these measures may result in reduce premiums, increased deductibles, increased sub-limits and/or increased sewer backup coverage availability, depending on the insurer (Applied Systems, 2013; Compu-Quote, 2011).

Increasing understanding of risk to improve pricing for sewer backup coverage is also being pursued by Canadian P&C insurers. A recent report released by the Canadian Institute of Actuaries (Friedland *et al*., 2014) revealed that historical claims are not an appropriate indicator of sewer backup risk, and that insurers need to better incorporate municipal- and private-side risk factors, including factors related to private-side risk reduction (e.g., backwater valves), I/I, policy holder behaviour, climate change and deteriorating public infrastructure into water damage and sewer backup endorsement pricing. Increasing understanding of sewer backup risk is an ongoing initiative that will likely be pursued by individual insurers as well as insurance industry groups (including the Insurance Bureau of Canada and the Institute for Catastrophic Loss Reduction) over the foreseeable future.

Aside from working to limit financial exposure by appropriately pricing water damage coverage and incentivizing mitigation at the private-side, the Canadian P&C insurance industry has been working on a number of other approaches to mitigate urban flood at the national level in Canada. These approaches include development of a local-level risk assessment to for sewer backup, lobbying governments for improvements in infrastructure spending and supporting knowledge and research in urban flood risk reduction.

The Insurance Bureau of Canada has participated in the P&C insurance industry's work on urban flood risk reduction through two primary avenues: Developing a sewer backup risk assessment tool (the Municipal Risk Assessment Tool) and government relations efforts to encourage increased investment in municipal infrastructure. IBC's Municipal Risk Assessment Tool (IBC MRAT) seeks to combine infrastructure and climate data to provide risk assessment for sewer backup in Canadian municipalities. As a prospective underwriting tool, the MRAT may allow insurers to assess risk of sewer backup based on future potential occurrences as well as historical claims data. IBC also purports that participation in the risk assessments will provide several benefits to municipalities, including updated rainfall and climatic information and a basis for prioritization of infrastructure investments (Sandink, 2011b). IBC has also promoted the climate change adaptation agenda to municipal, provincial and federal governments in Canada. For example, in 2012, IBC commissioned a report that emphasized potential implications of climate change for Canadian insurers, which has been used to highlight the need to adapt municipal infrastructure to climate change impacts in Canada (see Institute for Catastrophic Loss Reduction, 2012).

The Canadian P&C insurance industry has also been supporting the work of the Institute for Catastrophic Loss Reduction (ICLR), which has been working to mitigate urban flood risk at the municipal- and private-sides across Canada. Specific initiatives that have been developed by ICLR with backing from the Canadian P&C insurance industry have been motivated by ICLR research which has identified limited public awareness of their role in urban flood risk reduction, and limited adoption of mitigative behaviours at the private-side (see Sandink 2011; 2007). Thus, ICLR has emphasized better understanding of public perceptions and behaviours related to urban flood risk reduction and incorporation of mitigation measures during key “windows of opportunity,” such as at the time of construction of new homes and urban residential subdivisions. As such, over the past few years, ICLR has focussed their work in the following areas:

- Risk perception and mitigation research on urban flooding in the Canadian context (see Kovacs & Sandink, 2013; Sandink, 2007; 2011; 2013);
- Development of educational materials for relevant stakeholders (e.g., municipal staff, plumbing and construction industries and homeowners) (see, for example, Sandink, 2009 and www.basementfloodreduction.com);
- Participation in provincial and national code development processes to integrate urban flood mitigation measures into provincial and national building and plumbing codes (see, for example, Sandink, 2013);
- Development of guidance for new subdivisions to reduce the risk of I/I over the lifespan of infrastructure serving ground-related homes (see Kesik, forthcoming);
- Improving design standards for new stormwater management infrastructure; and;
- Promoting property-level mitigation through application of social marketing principles.

4. CONCLUSION

Urban flooding resulting in overland, sewer backup and infiltration flooding of ground-related homes remains one of the most pressing issues facing municipalities, insurers and many urban homeowners in Canada. The costs and impacts associated with urban flooding have risen dramatically over the past few decades, and are likely to intensify as a result of aging infrastructure, increasing and intensifying urban development and climate change impacts on local precipitation regimes, among other factors.

Several options have been applied at the municipal- and private-sides to reduce urban flood risk in Canada. Many of these options relate to municipal- and private-side management of I/I, limiting the risk of flood waters entering homes at the private-side and managing extreme stormwater flows. As a result of the significant costs borne by the insurance industry, P&C insurers have become involved in managing flood risk through a number of avenues. Measures applied by the P&C insurance industry include application of financial approaches to manage risk, application of incentives for private-side risk reduction and funding mitigation initiatives by insurance industry groups, such as the Insurance Bureau of Canada and the Institute for Catastrophic Loss Reduction.

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6. APPENDIX

Average Regional Rainfall (mm) calculated for current climate (from 1961-1990) and future climate (2041-2070) at the stations scale, Province of Quebec

Duration (hours)	Return Period (years)	% Increase in Intensity (1961-1990 vs. 2041-2070)
2	2	20.6
	5	18.1
	10	15.8
	25	13.0
6	2	13.9
	5	14.5
	10	13.1
	25	10.1
12	2	11.0
	5	10.0
	10	8.2
	25	5.1
24	2	10.6
	5	8.8
	10	6.9
	25	3.9

Adapted from Rivard, 2011 Table 2.10