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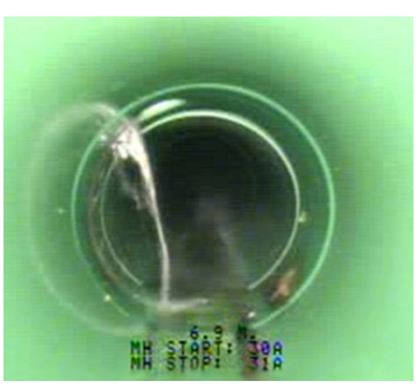
Reducing the Risk of Inflow and Infiltration (I/I) in New Sewer Construction

A National Foundational Document
for the Development of a National Standard of Canada

By Barbara Robinson, Dan Sandink and David Lapp

November 2019



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ICLR research paper series – number 64

Authored by:
Barbara Robinson, Norton Engineering Inc.
Dan Sandink, Institute for Catastrophic Loss Reduction
David Lapp, Engineers Canada

Published by
Institute for Catastrophic Loss Reduction
20 Richmond Street East, Suite 210
Toronto, Ontario, Canada M5C 2R9

Cover photos:
Top: Shutterstock
Bottom left and right: B. Robinson, Norton Engineering Inc.

ISBN: 978-1-927929-22-3

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Acknowledgements

The authors and project sponsors would like to gratefully acknowledge the advice, input and guidance provided by the Expert Stakeholder Committee. Members of the Expert Stakeholder Committee included:

- Susheel Arora, Director of Wastewater and Stormwater Services, Halifax Water
- Michael Cappucci, Engineer II, City of Windsor
- Paul De Berardis, RESCON
- Eric Gagnier, Conseiller technique en plomberie, Régie du bâtiment du Québec
- Larry Gill, Manager, Codes and Standards, IPEX Management Inc.
- Robert Lee, Sewer Engineer, City of Surrey
- Norm Litchfield, Manager of Design & Construction Services, Meritech Engineering
- Allen Lucas, Manager, Research and Projects, Utilities Kingston
- James McAloon, Engineering Technician, Capital Regional District
- Anthony Parente, Director, Wastewater, Region of Peel
- Dave Potter, Chief Building Official, Town of Newmarket
- Jitender Singh, Technical Advisor, Codes Canada, National Research Council
- Chris Smith, Project Manager, Business Strategy and Improvement, Wastewater, Region of Peel
- Claudio Spagnuolo, Backflow Specialist, Environmental Control, Region of Peel
- Olivier Trudel-Beaulieu, Ingénieur en réglementation de la gestion de l'eau, City of Montreal
- Perry Wager, Plumbing and Gas Tech Advisor, Municipal Affairs, AB
- Robert Walton, General Manager, Operations, County of Brant
- Andrew Wiens, Senior Water Resources Engineer, Associated Engineering

The authors and project sponsors would further like to recognize the thoughtful input provided by the many attendees of the National Stakeholder Input Webinar held on June 25, 2019.

Errors and omissions are the responsibility of the authors alone.

About Norton Engineering Inc.

Norton Engineering Inc. was established in 2015. Norton's primary area of interest is the phenomenon of inflow and infiltration (I/I) in new construction, a topic Norton's founder, Barbara Robinson, has been working on since the mid-2000s. Norton leads a variety of ongoing projects looking at all aspects of this phenomenon across Ontario and Canada. Every year, Norton delivers dozens of presentations, workshops, training and media spots on this and related topics. Norton staff chaired the CSA committee that developed CSA Z800: Basement Flood Protection and Risk Reduction Guideline (2018).

For additional information, visit www.nortonengineeringinc.ca

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Suggested Citation

Robinson, B., Sandink, D., and Lapp, D. 2019. Reducing the Risk of Inflow/Infiltration (I/I) in New Sewer Construction: A Foundational Document. Toronto/Ottawa: Institute for Catastrophic Loss Reduction/Standards Council of Canada.

Project Team

- Barbara Robinson, Norton Engineering Inc.
- Dan Sandink, Institute for Catastrophic Loss Reduction
- David Lapp, Engineers Canada

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Abbreviations

CAO: Chief Administrative Officer

CCTV: Closed-Circuit Television

GWT: Groundwater table

I/I: Inflow and Infiltration

LID: Low Impact Development

MECP: Ministry of the Environment, Conservation and Parks (Ontario)

MH: Maintenance Hole

MMAH: Ministry of Municipal Affairs and Housing (Ontario)

MOE/MOECC: Ministry of Environment/Ministry of Environment and Climate Change

NBCC: National Building Code of Canada (Note: Unless otherwise stated, all references are to the 2015 NBCC)

NPCC: National Plumbing Code of Canada (Note: Unless otherwise stated, all references are to the 2015 NPCC)

NSC: National Standard of Canada

OBC: Ontario Building Code

OPS: Ontario Provincial Standards

RDII: Rainfall-Derived Inflow/Infiltration

ROI: Return on Investment

SDHI: Short-Duration, High-Intensity

SBS: Sanitary Building Sewer

SDO: Standards Development Organization

SPS: Sanitary Pumping Station

WWTP: Waste Water Treatment Plant

Definitions

Clear-water waste: Waste water with impurity levels that will not be harmful to health and may include cooling water and condensate drainage from refrigeration and air-conditioning equipment and cooled condensate from steam heating systems, but does not include stormwater.[1]

Groundwater table (GWT) or water table: Upper level of an underground surface in which the soil or rocks are permanently saturated with water.[2]

Inflow: Includes sources of water that flow directly into sanitary sewer systems, such as residential roof downspouts, storm catch basins that have accidentally been connected to sanitary sewer systems, leaky sanitary sewer maintenance hole covers, and basement stairwell drains, among other factors.[3]

Infiltration: Water other than sanitary waste water that enters a sewer system from the ground through defective pipes, pipe joints, connections or manholes. Infiltration does not include inflow.[4]

Low impact development: Systems and practices that use or mimic natural processes that result in the infiltration, evapotranspiration or use of stormwater in order to protect water quality and associated aquatic habitat.[5]

Private-side lateral: The portion of the lateral that runs from the property line to the private building. This pipe is typically referred to as the sanitary building sewer (SBS) in building codes.

Public-side lateral: The portion of the lateral that runs from the mainline sewer to the property line.

Sanitary building drain (SBD): A building drain that conducts sewage to a building sewer from the most upstream soil-or-waste stack, branch or fixture drain serving a water closet.[6]

Sanitary building sewer (SBS): A building sewer that conducts sewage.[7] In engineering terms, this pipe from the building to the property line is termed the "private-side lateral."

Seasonally high GWT: The highest elevation of the water table during the wettest season in a year of above-average precipitation.

Sewage: Any liquid waste other than clean-water waste or stormwater.[8]

Stormwater: Water that is discharged from a surface as a result of rainfall or snowfall.[9]

Executive summary

Inflow/Infiltration (I/I) is a term used to refer to water other than domestic, commercial or industrial waste water that enters sanitary sewer systems. Inflow includes sources of excess water that flow directly into sanitary sewer systems, and infiltration includes sources of indirect flow of water, for example water that migrates through the ground and enters cracks and loose joints in underground sewer pipes.

Negative impacts of I/I include increased waste water treatment costs, waste water treatment plant expansion costs, reduced capacity in trunk sewers, reduced opportunity for municipal revenues associated with development, increased administration costs for municipalities, reduced lifespan of sewers, and increased risk of insured and uninsured damages associated with basement flooding.

I/I is a known issue in existing and older sewer systems across Canada. While addressing I/I in existing sewer systems is important, identifying sources of I/I in existing systems is costly, and results are not always conclusive. Remediation of identified sources is not always effective, as water frequently finds the next available entrance point into the sewer system. As a result, addressing I/I in existing systems is a long, costly and frequently frustrating process. The return on investment (ROI) of this type of work is not often favourable.

Therefore, opportunity exists to address root causes of I/I during construction of new infrastructure. This foundational document provides background information on I/I in new construction and proposes a framework for development of measures to reduce the risk of I/I. The primary objective of this project, developed with funding provided by the Standards Council of Canada (SCC), is to provide a basis, in the form of a foundational document, for the creation of a National Standard of Canada (NSC). The NSC may take the form of a standard or a guideline.

The foundational document and the NSC development process

The current project concerns development of a "seed" or "foundational" document (henceforth referred to as a foundational document), the purpose of which is to establish a foundation of knowledge and stakeholder insights for the eventual development of a standard. Technical topics have been flagged in the report for the purposes of setting the basis for further discussion.

While the document is a source of useful information, it cannot be used for certification, verification or regulatory purposes. No part of the foundational document should be considered prescriptive or adopted as a vetted best practice by any agency. Development of an NSC would be conducted by a separate and distinct project, managed by SCC.

Project basis and stakeholder input

This foundational document relied upon extensive background work conducted by Norton Engineering Inc. in Ontario between 2015 and 2019, which included analysis of flow monitoring data, site inspections, and research into codes, standards, guidelines and specifications, as well as extensive consultation and interviews with municipal engineering and building staff, consultants, contractors, developers, drain layers, plumbers and other related groups. This work is documented elsewhere.[a]

[a] See www.nortonengineeringinc.ca/i-i-in-new-subdivisions

National stakeholder input was also extensively incorporated into the foundational document. The project was supported by an 18-member national Expert Stakeholder Committee (ESC), composed of representatives from municipalities and municipal utility agencies, national and provincial construction code development agencies, consulting companies, industry associations and manufacturers from across Canada.

Further, a national stakeholder consultation webinar was held in June 2019. The webinar was attended by 120 stakeholders from municipalities and municipal utilities, consulting agencies, construction and home building associations, the development industry and construction material manufacturers, as well as the insurance industry and provincial and federal agencies. Attendees were located and/or worked in many regions of Canada, including British Columbia, Alberta, Saskatchewan, Ontario, Quebec, New Brunswick and Nova Scotia. All attendees were offered a draft copy of the report for review and were requested to provide formal, written comments.

The issue of I/I in new construction

An initial review of flow monitoring data for 35 new subdivisions in southern Ontario indicated that 34 of them demonstrated excessive I/I rates. Information provided directly by municipalities indicates that 85 subdivisions in Ontario demonstrated excessive I/I. Extensive consultation and interviews with key stakeholders indicated that excessive I/I in new construction was related to multiple factors, including construction practices on the public and private sides of the property line (i.e., construction that was inconsistent with existing codes, standards and guidelines); inconsistent application of testing and quality assurance practices; construction in locations where groundwater is located above the lowest sewer elevations; lack of clarity in codes, standards and guidelines; and jurisdictional issues notably related to responsibilities and construction requirements on private and public sides of the property line.

Mitigating I/I in new construction will require concerted action on both the private and municipal sides of the property line by everyone involved in the development of new subdivisions, from conception to final acceptance.

This foundational document contains a framework for reducing I/I risk on both the public and private sides of the property line. Strategies for use by municipal engineering/development departments are summarized under the categories of conceptual/system management, planning, pre-design, design, construction, inspection and testing, and acceptance. Strategies for work on the private side of the property line (some of which likely need to be performed by municipal/engineering departments) are summarized under planning, pre-design, design, construction and acceptance. In addition, owner behavioural measures are included.

Finally, conclusions and next steps, including further work required, are presented.

Target audience

The primary target audience of the proposed NSC will be municipal government employees and those directly involved in the design, construction, inspection and assumption of new sanitary sewer systems (both public and private side). Specific target audiences include:

- Municipal administrators (CAOs, municipal managers)
- Development departments

- Building departments
- Engineering departments (stormwater and sanitary)
- Operations staff
- Planning departments
- Site inspectors
- By-law officers

Additional users of this report may include:

- Provincial waste water and stormwater regulators
- Federal and provincial code development agencies
- Professionals involved in the building industry, including officials who interpret construction codes
- Building material and component manufacturers and suppliers, builders' associations and related professionals
- Homeowners, particularly those who are in the process of buying or building a new home, conducting significant structural changes/renovations to existing homes or implementing basement flood protection measures
- Developers and contractors
- Property and casualty insurers
- Other stakeholders concerned with mitigation of basement flood risk and the impacts of extreme weather in general

Relationship to national and provincial adaptation strategy documents

The project supports ongoing work towards modifying Canada's construction codes and standards, as well as municipal and provincial guidelines and standards concerning sanitary sewer systems, to increase resilience of buildings and municipal infrastructure to the impacts of extreme rainfall events.

The project supports objectives outlined in national climate change adaptation policy documents, specifically the Pan-Canadian Framework on Clean Growth and Climate Change, which includes objectives concerning building climate resilience through infrastructure. The foundational document also supports development of new and/or revised national codes and standards concerning residential, institutional, commercial and industrial facilities.

Because I/I has the potential to be affected by climate change impacts concerning extreme rainfall, managing I/I in new construction supports numerous provincial climate change adaptation policy documents. For example, provincial climate change adaptation plans have highlighted the need to adjust codes and standards to increase resilience to extreme natural events and climate change, and have highlighted the need to address flooding associated with short-duration, high-intensity rainfall events.

Next steps

Extensive national consultation and stakeholder input has indicated that the issue of I/I in new construction is nationally relevant. It is recommended that SCC pursue development of an NSC concerning I/I in new construction.

1. Introduction

This section presents a brief introduction into inflow and infiltration in sewer systems and defines "excessive" I/I. It also describes the costs associated with this I/I and the challenges of calculating actual costs. In addition, this section discusses the intersection of excess I/I with potential climate change impacts and associated basement flooding, the private-side contribution to excess I/I, and suggested resident behaviours and their potential contributions to excess I/I (and hence flooding).

1.1. What is inflow and infiltration, and why Is it problematic?

With increasing urban populations, infill development and aging infrastructure, inflow and infiltration (I/I: see side box) and its negative impacts have become chronic problems across North America. Excessive I/I has numerous negative consequences, including impacts on the environment, public health and safety, as well as acute and ongoing financial impacts for municipalities, insurers, taxpayers and homeowners.[10] The negative impacts of I/I are expected to intensify in many regions under projected changes in extreme rainfall due to climate change. Further, recapturing capacity in existing sewer systems is becoming increasingly important, as highly developed urban areas across Canada continue to emphasize infill development.[11]

Inflow/Infiltration (I/I)

Inflow/Infiltration is an industry term that refers to clean water that enters sanitary sewer systems. I/I may affect both existing and new sewer systems.

The US EPA defines inflow and infiltration as follows:

Inflow – Water other than sanitary waste water that flows directly into sanitary sewer systems and includes sources such as residential roof downspouts, storm catch basins that have been accidentally connected to sanitary sewer systems, leaky sanitary sewer manhole covers and basement stairwell drains. Inflow does not include infiltration.

Infiltration – Water other than sanitary waste water that enters a sewer system from the ground through defective pipes, pipe joints, connections or manholes. Infiltration does not include inflow.

The US Environmental Protection Agency (EPA) has summarized the issue of I/I and where remediation of I/I may be considered necessary:

> There are three major components of waste water flow in a sanitary sewer system, [including] base sanitary (or waste water) flow, groundwater infiltration and rainfall-derived inflow and infiltration, more commonly referred to as inflow. Virtually every sewer system has some infiltration and/or inflow. Historically, small amounts of I&I are expected and tolerated. However, infiltration and inflow may be considered excessive when it is the cause of overflows or bypasses, or the cost to transport and treat exceeds the cost to eliminate it. In cases where the I&I may not be considered *"excessive"* from a cost-to-eliminate perspective but causes health or environmental risks, corrective actions are required.

It is generally expected that I/I rates in sanitary sewer systems increase as the physical condition of systems deteriorates over time.[12] Factors influencing deterioration include physical defects, design flaws, illicit connections, root penetration, poorly adjusted manholes, corrosion, soil conditions and aggressive groundwater.[13]

Theoretically, new sewers should have very little I/I, as it is expected that new sewers will have been designed and constructed in an acceptable fashion. Recent research undertaken in Ontario, however, indicates that I/I in new construction is much higher than expected. This work is described in Chapter 2.

1.2. Costs and impacts of excessive I/I

Inflow and infiltration are normal components of waste water and, as such, the costs to treat it are expected. However, the costs of treating excess I/I in sewer systems can be considerable. The US EPA reports, for example, that

> Wastewater collection and treatment cost can range from $2 to $5 per thousand gallons ($0.50 to $1.30/m^3). An annual I&I volume of 150 million gallons (567,800 m^3) would cost between $300,000 and $750,000 per year to transport and treat. For many older collection systems, infiltration can be quite substantial and has been calculated as high as fifty percent of the flow.[14]

A multitude of additional negative impacts of I/I have been identified aside from direct costs (see side box). I/I results in loss of capacity in pumping stations, trunk sewer systems and the related loss of revenue for municipalities where development freezes due to limited sewer system capacity. I/I also affects the life of a sewer and may reduce its years of service. Where I/I exists, soil particles may start to migrate into the sewer, causing the sewer to shift as its bedding shifts and only getting worse with time. This impact is largely unseen until the later stages of the sewer's life.

Negative impacts of I/I also include operational difficulties at waste water treatment plants associated with high wet weather peaking, as well as overflow bypasses at pumping stations and secondary bypasses at waste water treatment plants, which represent significant water quality risks for surface water systems.

While the costs of treating excess I/I are frequently listed (as above) and include many components, the *calculation* of these costs is difficult because many of the costs are either future impacts that cannot be predicted or costs (such as lost revenue from development) that are too complex to be able to estimate.

The Costs and Impacts of Inflow/Infiltration (York Region, 2011)

The Region of York's comprehensive Inflow & Infiltration Reduction Strategy outlines the varied negative impacts of I/I, reproduced here with additional notes added by the authors:

Natural Environment

- Sewage overflows, markedly at peak capacity, damage sensitive ecosystems and the natural environment.
- Any overflow affects groundwater, local ecosystems and water quality in lakes, streams and rivers.
- Clear water entering the system through infiltration could be a major factor contributing to lower groundwater levels and could affect local water resources.

Potential Health & Safety Risk

- Sewage overflows, bypasses and basement flooding present public health risks.
- The extra flow can overload the sewage collection system pipes, causing backups or surcharging.
- Raw sewage can potentially overflow at locations, including basements, before it reaches the treatment plant.

Financial Impacts

- During wet weather events, the increased flows in the sanitary system raise the operational and capital costs at facilities and treatment plants, as the additional flows must be conveyed and treated.
- I/I decreases the life of a sewer pipe because its support structure (bedding & embedment) erodes as I/I enters the sewer. This erosion could require new or accelerated capital works to replace pipes and facilities.
- Decontamination measures to treat sewer overflows and basement backups (e.g., compensation claims management procedures) can be extensive and costly.
- Excessive I/I flows consume sewer capacity that could be required for existing residents and future approved growth.

In summary, reducing I/I flows provides a number of benefits, such as cost savings from reduced conveyance costs (pumping), reduced treatment costs and hydraulic benefits (plants and pipes will be in service longer and cost less to maintain), as well as reduced health risks, property damage and environmental effects.

Source: Region of York.
https://www.york.ca/wps/wcm/connect/yorkpublic/7311896a-b49e-41e7-9927-86d3ddb6fdc1/Inflow_and_Infiltration_Reduction_Strategy.pdf?MOD=AJPERES

One way to estimate the cost of treating excess I/I is to use the cost of purchasing treatment at a waste water treatment plant. This is based on the assumption that what a municipality charges its customers to treat their waste water is a relevant indicator of the real cost of operating a waste water system. This estimate is not the marginal costs of the last m^3 treated, but the total cost per m^3. This approach is especially logical in a two-tier government system where the lower-tier municipality pays the upper tier for waste water treatment services.

Using current Canadian numbers, treating 1 L/s of sewage flow of I/I (which is roughly equivalent to flow from a fully open garden hose) costs $95,000 per year for treatment alone (assuming a treatment cost of $3.05/$m^3$, Region of Waterloo, 2019).[15 b] This has the potential to cost Canadian taxpayers, who ultimately pay for the treatment of excess I/I, billions of dollars per year.

1.3. I/I and climate change

The potential impacts of climate change on I/I in separated sewer systems are increasingly recognized in national climate change assessment reports and climate change adaptation–related guidance documents.[16] While it is widely acknowledged that the projected impacts of climate change will have direct implications for stormwater management systems, sanitary systems are also expected to experience impacts associated with I/I.[17] In general, rainfall-derived I/I (RDII) is expected to increase with higher rainfall intensity/accumulation,[18] and short-duration, high-intensity (SDHI) rainfall events are expected to increase in frequency and severity under changing climate conditions.[19]

A number of other potential climate change impacts may also exacerbate or otherwise affect I/I. Because frozen ground is less conducive to infiltration, reduced periods of frozen ground due to higher temperatures may result in increased infiltration during the winter.[20] Coastal regions may also face increasing risk of I/I, as sea level rise increases groundwater table levels and saltwater intrusion may compromise system integrity.[21] Changing climate conditions may also affect antecedent conditions (i.e., rainfall and moisture conditions before/between SDHI events), with further implications for RDII.[22]

The presence of excess I/I from new subdivision construction in sewer systems will only exacerbate climate change impacts and make systems less resilient to the higher flows expected.

1.4. Basement flooding and I/I

Basement flooding is one of the most significant drivers of disaster loss in much of Canada. As reported in the Government of Canada's recent report, Infrastructure and Buildings Working Group Adaptation State of Play,[23] there is concern in many regions of Canada that risk associated with SDHI rainfall events will intensify as a result of increasing urban development and density, aging public- and private-side infrastructure, sewer construction issues,

> **"Sewer backup is typically the primary driver of insured losses during extreme rainfall–related urban flood events."**
>
> Sources:
>
> Catastrophe Indices and Quantification. 2019. CatIQ Database. Toronto.
>
> Friedland, J., Cheng, H., and Peleshok, A. 2014. Water Damage Risk and Property Insurance Pricing. Prepared by KPMG. Ottawa: Canadian Institute of Actuaries.
>
> Sandink, D., Kovacs, P., Oulahen, G., and Shrubsole, D. 2016. Public relief and insurance for residential flood losses in Canada: Current status and commentary. *Canadian Water Resources Journal/Revue canadienne des ressources hydriques,* 41(1-2): 220-237.

[b] This cost calculation is challenged by the expert stakeholder committee because treatment costs have traditionally only been calculated on the marginal cost of the last m^3 treated. See Chapter 7: Conclusion and Next Steps.

and the potential increased frequency and intensity of extreme rainfall events associated with climate change, among other factors.

Several mechanisms result in regional flooding of buildings during SDHI rainfall events, including:[24]

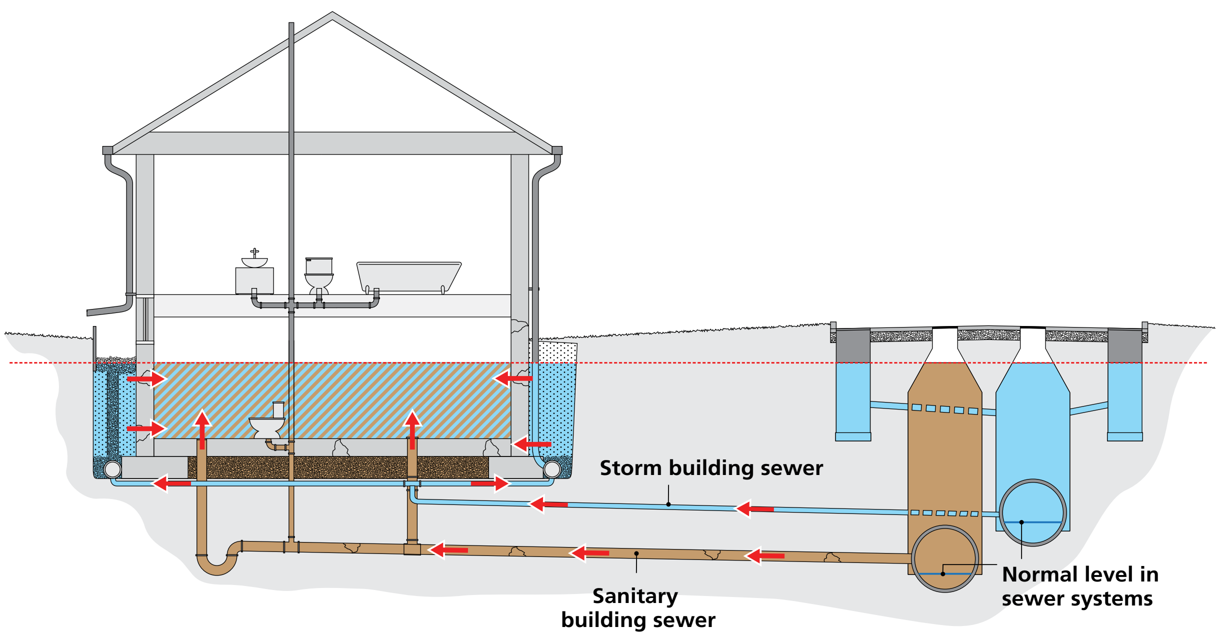
- Overland flow of stormwater
- Seepage of ground and surface water
- Sewer backup

> **Underground linear infrastructure that are the sewers, waterlines and utility ducts servicing communities create an extensive French drain system when trench backfill and pipe bedding are permeable materials. Permeable utility trenches drain their service area, conveying rainwater runoff and groundwater to the lowest trench points. As sanitary sewer trenches are typically constructed lower than other utility trenches, the other trenches will drain to the sanitary sewer and cause sanitary sewer pipes, joints, tie-ins and laterals to become submerged in trench groundwater – I&I will then enter sanitary sewers through any open defect.**
>
> Metro Vancouver. 2019. Controlling Inflow and Infiltration in the Metro Vancouver Area. Liquid Waste Subcommittee of the Regional Engineers Advisory Committee Vancouver: Metro Vancouver. Page 21.

One of the most significant impacts of I/I is the increased risk of surcharged sanitary sewer systems and utility trenches (e.g., backflow through pipe bedding) during high-intensity rainfall events, resulting in basement flooding associated with sewer backup. The impacts of I/I on sanitary sewer systems during SDHI rainfall events are depicted in Figure 1. In this example, the sanitary sewer system in a separated sewer area has become overwhelmed and is surcharging as a result of I/I, causing sewer backup into a home.

Additional I/I from upstream subdivisions or other construction increases the flow downstream. This additional flow contributes directly to the risk of flooding downstream, even if flooding does not occur within the new subdivision itself.

Figure 1: Surcharging sewer systems causing sewer backup



In the example presented here, the sanitary sewer system in a separated sewer area has become overwhelmed and is surcharging, causing the backup of sanitary sewage into a home.

Adapted from ICLR, 2009/CSA Z800-18.[25]

Table 1: Recent high-intensity rainfall events

Event date, insured loss (if published)	Rainfall accumulation, intensity information
Peterborough, ON, July 15, 2004 Insured loss: $109 M (2017 CAD)[26]	~80 mm in 1 hr, ~260 mm in 24 hrs[27]
Toronto/GTA, ON, August 19, 2005 Insured loss: $762 M (2017 CAD)[28]	132 mm in 2 hrs, 12 hr accumulation of 149 mm (Toronto/North York)[29]
Toronto, ON, July 8, 2013 Insured loss: $982 M (2017 CAD)[30]	102 mm in 2 hrs, 6 hr accumulation of 126 mm (Toronto/Pearson)[31]
Burlington/Halton/GTA, ON, Aug. 4, 2009 Insured loss: $81 M (2017 CAD)[32]	~120 mm in 2 hrs, ~200 mm over 8 hrs, intensities reaching 50 to 60 mm/hr[33]
Saskatoon, SK, to Thunder Bay, ON, June 2016	50 mm (up to 90 mm total) in 3 hrs (Thunder Bay, ON), 44 mm (Estevan, SK), 140 mm, 303 mm/hr (West Hawk Lake, MB), 104 mm (Killarney, MB), 60 mm (Grandview, MB)[34]
Estevan, SK, to Edmonton, AB, July 8–11, 2016	~130 mm in 2 hrs *(100 yr: 69 mm over 2 hrs)* (Estevan, SK), 49 mm (Clearwater, MB), 86 mm (Lloydminster, SK), 89 mm (Yorktown, SK/area)[35]
Windsor/Tecumseh, ON, Sept. 28, 2016	195 mm (total), 100–110 mm in 5 hrs in Tecumseh, 115–230 mm in Windsor (24 hrs)[36]
Southern ON and QC, April 5–7, 2017	30–40 mm (parts of S. ON/QC, Apr. 4), 50–85 mm (parts of S. ON/QC, Apr. 5–7), 70–85 mm in Montreal[37]
Windsor/Tecumseh/Essex, ON, Aug. 28–29, 2017 Insured loss: $165 M (2017 CAD)[38]	290 mm in LaSalle, 220 mm+ in Windsor, 190 mm in Essex[39]
ON/QC, Oct. 2017	Remnants of Tropical Storm Phillipe (112 mm in Ottawa, 74 mm in Kingston)[40]

Table 1 provides several recent examples of high-intensity rainfall events that resulted in significant losses associated with sewer backup and other types of flooding. The vulnerability of urban communities was specifically highlighted during the July 8, 2013, urban flood event in the Greater Toronto Area. With total insured losses estimated at $1 billion (2018 CAD),[41] this was the most expensive insured loss event in Ontario's history and the most expensive urban flood event in Canada's history. Sewer backup is typically the primary driver of insured losses during extreme rainfall–related urban flood events.[42]

1.5. Private-side issues

This report concerns topics relevant to both the private and public sides of the property line. The difficulty of addressing private-side issues, due to private ownership of private-side sewer connections and limited willingness of property owners to engage in maintaining their private plumbing and lateral, has generally resulted in lack of action on behalf of municipalities to reduce private-side I/I.

Multiple agencies have developed estimates that indicate the potential private-side contribution of I/I to municipal sanitary systems. In 2015, Kesik reported that "most I&I problems originate from the private side."[43] A pilot study in London, Ontario, indicated that disconnecting foundation drainage systems had a substantial impact on managing I/I in a subdivision previously affected by basement flood hazards.[44] Private-side lateral programs have been a focus of I/I management in Metro Vancouver, as roughly 50% of the total length of sewer pipe is located on the private side of the property line.[45]

Research conducted in the United States has also indicated high rates of I/I originating on the private side of the property line. For example, a survey of 58 US agencies conducted by the Water Environment Research Foundation revealed that all but one agency considered I/I into sanitary systems a problem. In addition, 26 of these agencies provided estimates for private-side contributions to overall I/I, ranging from 7 to 80%, with an average estimation that 24% of I/I is contributed from private-side laterals.[46]

A 2005 report from Columbus, Ohio, indicated that 55% of I/I originated from the private side of the property line.[47] An additional 2014 study focused on Columbus, Ohio, by Pawlowski et al. indicated that residential I/I sources accounted for 35% of total I/I for SDHI rain events (with dry antecedent conditions), and 7% of total I/I under low-intensity, long-duration rainfall events with wet antecedent conditions. Private-side downspouts and laterals accounted for 98% of private-side I/I contributions.[48] A 2007 report prepared for the Neponset River Watershed Association (Massachusetts, United States) reported that as much as 40% of sewer system infiltration originates on the private side of the property line.

1.6. Resident behaviour

Resident behaviour related to household and private-side plumbing infrastructure is an important factor in the potential for introducing I/I into sanitary sewers.[49] Specifically, building inspectors and waste water utility staff across Canada have reported that residents connect or reconnect sump pumps, weeping tiles and sometimes roof drainage (in older homes where former connections existed) into the sanitary sewer.[50] These types of connections are illegal in most jurisdictions in Canada (e.g., in Ontario these connections are largely prohibited by municipal sewer use by-laws), and they directly contribute I/I to the public system.

Private-side factors are also important considerations for flood risk.[51] Critical lot-side factors that affect flood risk include improper grading, broken or cracked pipes or connections, illegal connections to sanitary systems, blocked or damaged laterals, incorrect or improper plumbing, and failed sump pumps and/or backwater valves, among other factors. Many municipal representatives noted a lack of responsibility taken by residents for ensuring the maintenance of leak-acceptable infrastructure on their property.

Urban and basement flooding already drives hundreds of millions of dollars in insured and uninsured losses each year in Canada. Increasing frequency of extreme rainfall events is expected to increase risk of urban flood in the future, exacerbating the impact of resident behaviour as it contributes to I/I. This foundational document provides strategies for decision makers and households related to plumbing and flood risk reduction on private property. Additionally, methods for addressing building owner behaviour on the private side of the property line are discussed, including application of potential mandatory measures (e.g., by-law enforcement).

2. Excess or unacceptable I/I in new construction (Norton Engineering Inc. primary research)

Norton Engineering Inc. has been examining excess or unacceptable[c] I/I in new construction in detail since 2015. While this research was undertaken largely in Ontario, input from an Expert Stakeholder Committee (ESC) and public stakeholder consultation undertaken during this project has indicated that it is assuredly an issue across Canada, and additional discussions with municipalities across Canada (and the United States) indicate that this is a wide-ranging problem.

The findings of Norton's work are the result of detailed interviews with hundreds of stakeholders in the development industry over ten years. Stakeholders include municipal engineering and building staff, consultants, contractors, developers, drain layers, plumbers and other related groups. Stakeholders helped to identify gaps in guidelines, standards and codes, construction practice, inspection and testing, certification, jurisdiction, education and process, which contribute directly to the issue of excess I/I in new construction. Issues exist on both the public side of the property line (under the jurisdiction of the engineering departments) and the private side of the property line (under the jurisdiction of the building departments and the building codes). Findings of this work are documented in detail elsewhere.[d]

Norton has developed two very important user groups over the years of research into this topic: staff working in municipal engineering and staff working in building departments. Each group also contains relevant parties from provincial and federal agencies who deal with new construction. These groups have developed organically, and they provide input to Norton as the research evolves.

One of the most important aspects of Norton's research is that information has largely been collected anonymously. As will be demonstrated in this chapter, it is not always easy for staff to report issues with poor construction. The various factors contributing to this phenomenon are described in the next sections.

2.1. Original data set, collected 2015 to 2017

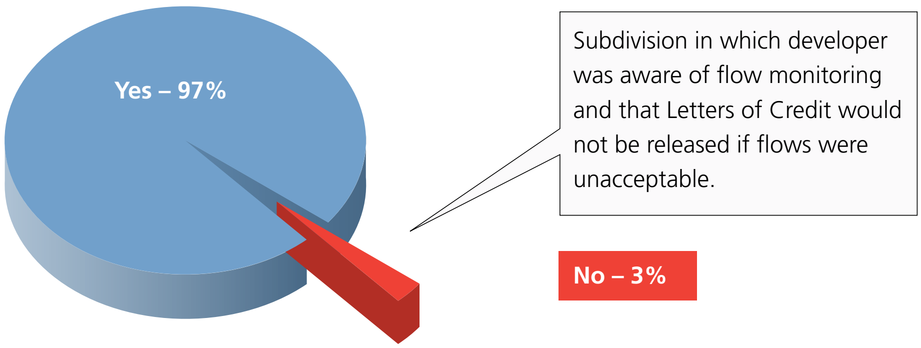
The first data set Norton collected followed a request made to municipalities across Ontario to share any data they had (i.e., the request was not for data showing high I/I) that monitored sanitary sewer flows coming from new subdivisions (the monitoring of new subdivision sanitary flows was rare at this time). Norton distributed the request through various organizations and contacts. Data were collected with the promise of anonymity, since it was presumed that municipalities would be reluctant to reveal that I/I was occurring in their subdivisions.

Data received between 2015 and 2017 from 35 new subdivisions in Ontario indicated that 97% of these subdivisions demonstrated "excessive" rates of I/I (Figure 2).[52] The municipalities themselves, and not Norton Engineering Inc., made the determination of excessive I/I. Norton only included actual flow monitoring graphs or data from either in-sewer monitoring or downstream sanitary pumping stations (SPS) in this data set.

[c] These terms are defined in Section 2.3.

[d] See https://www.nortonengineeringinc.ca/i-i-in-new-subdivisions

Figure 2: Original data collection of new subdivision flow monitoring (Norton, 2015)



New subdivisions that have been flow monitored and demonstrate excess I/I
Subdivisions reporting: n = 35

The single location where leak-acceptable flows were measured was a site where the developer's engineering consultant knew that flows were being monitored and that the municipality would hold back funds if it found excessive leakage. Evidently, it is possible to construct new subdivision sewers to be leak acceptable. Results in this data set are staggering, with 97% of subdivisions leaking, but it cannot be concluded that 97% of subdivisions across Ontario are leaking. The number of subdivisions leaking overall is not known at this time.

Since the original data set was collected as described above, Norton has continued to receive information and/or data from municipalities across Ontario. Norton has now been advised directly by municipalities of 85 subdivisions across Ontario that are leaking. No data set is available to Norton to indicate how many subdivisions overall in Ontario (i.e., what percentage of them) demonstrate excessive I/I.

Following the collection of the data that demonstrated the problem, Norton's work turned to an examination of some of the causes and conditions that resulted in excess I/I. Groundwater and stormwater were getting into systems through cracked pipes, joints and connections. These issues are related to construction practices – but why were they happening? It became apparent that not all of the required inspection and testing practices were being followed across Ontario. Norton then conducted a detailed survey of municipal staff concerning their observations, with a particular focus on inspection and testing procedures.

2.2. Survey of Municipalities: Current practices around behaviour around inspection and testing, 2016

Norton surveyed municipal staff, working on both the public side (engineering/development) and private sides of the property line (building), in 2016/2017, posing a series of specific questions concerning practices likely to affect I/I on each of the public and private sides. Approximately 35 municipalities participated in the original survey. Table 2 summarizes the results from the public side, and Table 3 the results from the private side. As shown in Tables 2 and 3, the surveyed municipalities are not requiring tests that would identify potential or actual I/I sources on each of the public and private sides of the property line.

Table 2: Summary of 2016 municipal survey results around inspection and testing, public side

Required test per Ontario Provincial Standards (OPS) or Ministry of Environment and Climate Change (MOECC)	Percentage of municipalities reporting requiring the test
Feeler gauge test of each gasket	0%
Mandrel (out of round) test on sewers	29%
Air or water tests of sewers	28%
Maintenance hole infiltration or exfiltration tests	20%
CCTV inspection of laterals to property line	12%

Norton Engineering has continued to survey municipalities about these practices (both by email and in person). Ongoing results align with the results obtained in 2016 (i.e., testing and inspection practices are not being performed as required).

Table 3: Summary of 2016 municipal survey results around inspection and testing, private side

Required test per Ontario Building Code	Percentage of municipalities reporting requiring the test
3 m water column/air test of each sanitary building sewer (SBS) (e.g., private-side lateral)	5%
Ball test of SBS	25%
Inspection of connection of SBS to public-side lateral at property line	28%

2.3. Description of "excessive" versus "unacceptable" I/I in new subdivisions

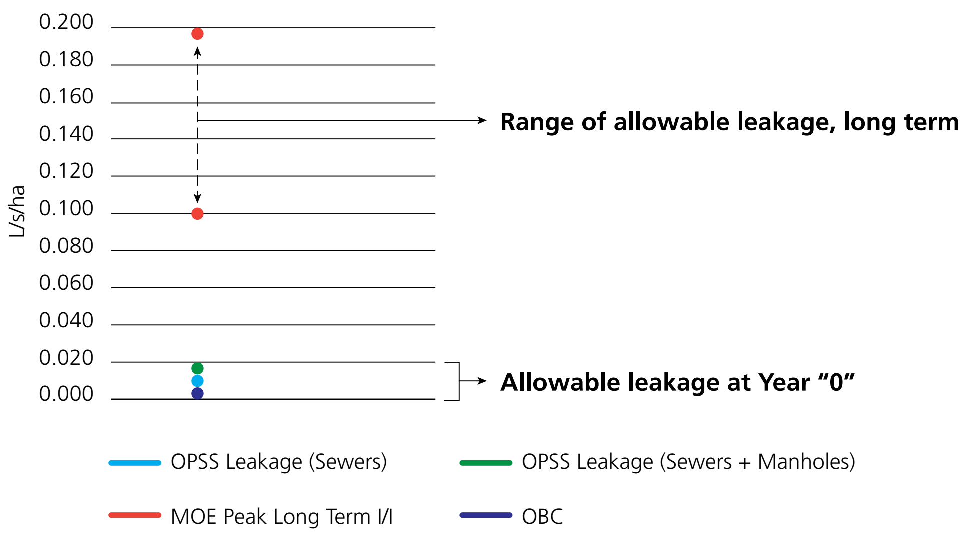
Norton's research refers to two terms when describing I/I in new subdivisions, in accordance with how the information received has been evaluated.

The term "excessive" is used by the US EPA[53] to describe I/I. For the purposes of Norton's research, "excessive" refers to I/I that is obviously (to the person undertaking the assessment) higher than it should be, without actual measurement or comparison to a known standard. The original data set from 35 subdivisions collected by Norton can be characterized as having excessive I/I.

The term "unacceptable" has a specific meaning in the context of Norton's research. I/I is defined as unacceptable when the amount of I/I exceeds the amount allowed at inception, as calculated per existing standards, codes and guidelines. There are allowable I/I values (e.g., leakage) at acceptance prescribed in Ontario Provincial Standards (OPS) and Ministry of Environment (MOE) documents and the Ontario Building Code. The sum of the allowable leakage in each component of a sewer system (on both the public and the private sides) is the allowable leakage for the subdivision. Therefore, the term "unacceptable" is used when the I/I has been compared to allowable and exceeds it.

Figure 3 shows a sample calculation of allowable leakage in a new sewer system. The sum of allowable leakage at year zero in this example is less than 0.02 L/s/ha. The graph also shows the lower end of the long-term peak allowable leakage range used across Canada (0.10 to 0.28 L/s/ha). Note that this long-term peak I/I value should never be used to interpret leakage at year zero.

Figure 3: Sample calculation of allowable leakage in a new subdivision



The terms "excessive" and "unacceptable" I/I both refer to I/I that is higher than it should be, but the first is based on observation and the second is based on calculation. From these concepts has emerged the concept of *leak-acceptable infrastructure* – infrastructure showing minor leakage in the range of allowable values as prescribed in guidelines, standards and codes. This term is used by Norton Engineering in ongoing research. As discussed in Chapter 7, continued work on this topic, in the form of the development of an NSC, should include detailed discussion concerning definitions of excessive and unacceptable I/I.

What is leak-acceptable infrastructure?

Leak-acceptable infrastructure is infrastructure that meets acceptance testing when it is installed. This is the sum of acceptable leakage on the public and private sides. This value can be calculated for each sewershed based on area, number of houses or pipe length. Norton has coined this term for use in this kind of research.

2.4. Building code regulations and engineering standards as they relate to I/I

Norton Engineering has undertaken research into all of the technical specifications in OPS/MOECC (public side) and the OBC/NPCC (private side) with respect to specific construction practices related to I/I risk and compared them. In addition, it obtained and investigated the underlying standards and guidelines (as developed by CSA, ASTM, etc.). It examined general pipe design; pipe design with respect to foundation drain connections; pipe design with respect to storm drainage; jointing, bedding and backfill; leak testing of new pipe, and; inspection of lateral connection at property line.[54]

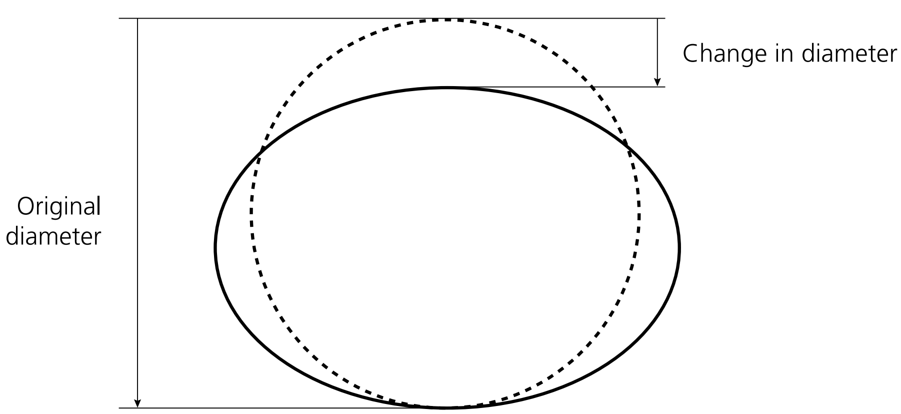
Norton identified some gaps in building and plumbing codes that allow connections to the sanitary sewer that are considered illegal by engineering or by-law departments (e.g., connection of foundation drains to sanitary sewers). Most of these had been identified by others.[55] These gaps in the building codes should be addressed to reduce the risk of I/I in new sewer systems (see Section 7).

Since the OBC is best interpreted by experts, Norton established a building officials user group, currently containing 73 building officials and related staff from across Ontario and Canada. Norton sent the group a variety of questions concerning interpretation of the building codes as they relate to construction practices that may introduce I/I risk, including specific questions about items in the code, and the results informed their research. One of the major findings of this research is that PVC pipe is not being installed according to the required standards on the private side, and this appears to be leading directly to I/I.

Installation of the PVC pipe on the private side of the property line has been examined in detail by Norton Engineering. The NPCC's and Provincial Plumbing Code's "Materials" sections specify the PVC pipe to CAN/CSA 182.1, but the "Piping" Section, which specifies how PVC pipe must be installed (e.g., ensuring appropriate bedding, haunching, grade and backfill, use of high-quality joints and pipe materials), does not explicitly refer to CAN/CSA 182.11, which is the installation standard recommended by PVC pipe manufacturers in Canada. This lack of guidance in the code increases the likelihood of construction quality issues.

To function as designed, PVC pipe must be provided with structural support from the surrounding soil and the pipe bedding and embedment, which must be compacted to prevent the soil load on top of the pipe from compressing the pipe out to the sides. The pipe must be installed properly to perform as intended and to reach its desired design life. Figure 4 depicts the deflection behaviour of PVC pipe.

Figure 4: Plastic pipe deflection behaviour



$$\% \text{ Deflection} = \frac{\text{Change in diameter}}{\text{Original diameter}} \times 100$$

Norton research has revealed that PVC pipe specifications are the same on both sides of the property line across Canada (i.e., each side specifies CAN/CSA 182.1 for pipe type). Since the pipe type is specified in construction codes, it is inferred that the associated required installation methodology for that type should be used. All major PVC pipe manufacturers in Canada recommend that the pipe be installed according to CAN/CSA 182.11.[56] The code is already adequate to require correct pipe installation, but this practice is not being observed (likely due to lack of education), increasing risk of I/I.

Another issue on the private side is that construction codes allow solvent weld joints (glued). These are not used on the public side of the property line. Glued joints are very sensitive to installation methodology, and because glue-jointed pipe forms one continuous length, the risk of joint separation associated with any differential settlement along the pipe length is a concern. Indeed, no recommendations on the installation of glued PVC pipe systems (i.e., not just the joints, but the jointed system) in buried applications were found from any PVC manufacturer in North America. A major North American manufacturer further noted that "the joints of a solvent weld system are rigid, and thus have no capability to offer flexibility or deviation at the joint."[57] These findings highlight the need to develop strategies to reduce the risks associated with I/I in new construction on the private side of the property line.

2.5. Critical factors contributing to I/I in new subdivisions

Due to Norton Engineering's extensive work in this space since 2015, they have identified a myriad of factors that contribute to excessive I/I in new subdivisions.[58] I/I is always caused by water entering the sewer system at joints, connections, pipe defects or illegal connections. Norton has examined the causes and conditions determining *why* these defects are permitted to form in new sewer construction.

Critical factors identified in the research include:

- Inadequate construction practices on both the public and private sides (i.e., construction does not adhere to existing codes, standards and guidelines)
- Testing and quality assurance practices, standards and guidelines as outlined in design and construction codes, specifications and guidelines, not being applied for reasons including:
  - Perceived pressure from development industry and/or senior management to approve works without delay
  - Lack of education in development industry with respect to critical public-side issues that contribute to I/I
  - Lack of education in building industry with respect to critical private-side issues that contribute to I/I
  - Staffing limitations
- Potential issues concerning who is undertaking the site inspection of the new construction (e.g., municipal staff vs. developer's agent vs. third party engineer)
- Use of the SBS for a drainage outlet
- Construction in locations where the natural groundwater (before dewatering) is above the elevation of the lowest sewer elevation
- Lack of clarity in codes, standards and guidelines
- Jurisdictional issues

2.6. Development of best practices to reduce I/I risk in new construction: Public and private sides (2018 to 2019)

Norton's research has resulted in the collection of extensive information on best practices across Ontario and Canada from municipalities trying to reduce I/I risk. In addition, since the work has resulted in two large municipal user groups (engineering/development and building), strategies can be proposed to municipal staff for comment. Using this comprehensive approach, Norton is assembling best practice manuals for each of the public and private sides of the property line. These will be published in 2019.

These best practices were developed by examining practices across Ontario (and, to a lesser extent, Canada), establishing which appear to be working best for municipalities and represent sound engineering practice (with a cost/benefit implied), and sending draft proposed strategies for comment to the municipal user groups. Comments were collated and a proposed strategy was developed. The draft strategies included in this foundational document are based on this detailed and comprehensive research. Over 100 municipalities in Ontario have provided comment on various aspects of this research.

The way in which sewer systems are constructed has not changed markedly in decades; if we do not change how we construct new public- and private-side sewer systems, the problem of excessive I/I will persist.

Norton's research into the phenomenon of unacceptable I/I on both the public and private side is unique, in that most of the information has been collected directly from the people doing the work, frequently those working on construction sites. In this sense, it is apolitical (i.e., not subject to political pressure). One of the most interesting results of this ongoing research has been that staff at different levels within the same municipality have different understandings of the behaviours and practices within the municipality. Also, collecting the information anonymously (typically) allows front-line staff to be frank about the issues around reducing I/I.

Most of the best practices in Norton's work are proposed as a starting point; it is recommended that feedback be collected and the practices be re-evaluated and updated every few years.

2.7. Is this an issue across Canada?

Although Norton's primary research has taken place in Ontario, it has consulted widely across Canada. Norton works with various organizations across Canada on I/I-related work (e.g., CSA Z800 Basement Flood Protection and Risk Reduction Guideline), so has a wide network of sources, all of whom report similar issues to those found in Ontario.

The phenomenon of unacceptable I/I in new construction is reported across Canada, in places such as Metro Vancouver, Surrey, Capital Regional District (Victoria), Calgary, Montreal and Halifax. Although provinces operate under different guidelines, standards and codes, they are similar, particularly regarding issues related to I/I. As discussed above, significant stakeholder consultation for this project has further indicated that I/I in new construction is a widespread issue.

The outline of this foundational document was presented to a geographically diverse Canada-wide audience as part of its development. In all the valuable commentary received, not a single jurisdiction reported that unacceptable I/I was not a problem in its area.

2.8. Summary

Over the past five years, Norton has collected information on the causes and conditions underlying the phenomenon of I/I in new construction in Ontario.

Concurrently, best practices have been collected from municipalities or developed based on input received. All indications suggest that I/I in new construction is a problem that exists across Canada and should be investigated as such.

Measures outlined in this report are expected to be useful for stakeholders involved or affected by municipal sanitary sewer system planning, design, installation, construction and operation. The report is intended to serve as a foundational document for the development of an NSC. The next section describes the specific goals of this document.

3. Foundational document for Standards Council of Canada

This foundational document was prepared by the project team for the Standards Council of Canada.

3.1. Purpose

This foundational document has been prepared to provide a framework for the development of an NSC. The project team carefully developed the framework based on its extensive experience with the subject matter. This foundational document has been nationally vetted (see Section 3.4 for detail on stakeholder engagement).

The project team has designed the proposed framework for use by a variety of stakeholder groups, including residents, and organized such that each stakeholder group can easily find the measures that apply to them. It is recommended that the developers of the NSC retain this approach. The project team is not providing a recommendation at this time regarding whether the NSC document should be a standard or a guideline. While implementing the measures herein is essential to reducing I/I in new construction, the topic is so complex that a standard may become unwieldy. It is recommended that the developers of the NSC make this determination at the appropriate time.

This foundational document discusses a set of topics that could assist in developing best practices for managing I/I in new construction in Canada. The document does not cover construction in adverse conditions (such as permafrost). It is recommended that the developers of the NSC continue to focus on construction in regular conditions as it will be most relevant to the vast majority of users.

The framework has been prepared to provide the following:

- A baseline of information and understanding of key I/I issues as they relate to new construction
- Process-related issues that contribute to excess I/I in new construction (e.g., conflicts of interest, difficulties in enforcing guidelines)
- Improvements that can be made to public-side design and construction guidelines and standards to limit occurrence of I/I
- Methods applicable to NBCC Part 9/NPCC construction aimed at reducing risk of excess I/I on the private side of the property line
- Risk areas that have not yet been formally addressed in existing codes and guidelines (e.g., life expectancy of most private-side sewer components may be significantly shorter than the life of a house)
- Guidance/standards related to monitoring and enforcement of design and construction standards to improve construction quality and limit excess I/I

This foundational document is laid out such that users can identify and find recommendations for reducing I/I risk at all stages in the development process, including conception, planning, design, construction, inspections, acceptance, maintenance and operations, and other issues to be addressed in a national standard or guideline. The NSC should highlight the important role that different infrastructure stakeholders have in minimizing excess I/I.

In developing the framework, the project team attempted to summarize existing practices across Canada for various stages of a sewer system's life. The process, however, quickly became unwieldy and was abandoned. There is clear value, however, in a full understanding of all practices that affect risk of excess I/I in new construction at a national scale. It may be useful to include a detailed review of all relevant practices as part of the standard development process.

3.2. Guiding principles

Measures presented in this document are intended to support and, where appropriate, discuss potential improvements to existing behaviors, methodologies, codes, standards and guidelines, and implementation and monitoring of public- and private-side sanitary sewer construction. The measures reflect recurring issues identified based on stakeholder consultation and existing work by the study team concerning basement flood hazards and I/I in new and existing sewer systems. The measures also reflect a set of screening criteria intended to ensure the efficacy and practicality of proposed I/I management measures.

As outlined in this document, minimizing the risk of excess I/I from new construction represents good engineering practice. It has multiple benefits, including reducing costs, limiting risk of property damage, extending infrastructure life and limiting restrictions on development capacity. Though climate change is expected to increase the frequency and severity of extreme rainfall events, measures presented in this document are applicable independent of the impacts of climate change.

To be included in the standard or guideline, I/I management measures should:

Support or fill gaps in existing codes and standards. Provinces and municipalities across Canada publish standards for sewer design, construction and inspection. The standard should seek to apply these existing best practices where relevant and should provide a basis to increase application of construction standards through administrative procedures (e.g., inspections, information sharing and coordination between relevant decision makers) where appropriate.

Be flexible. Proposed measures should provide for flexibility and emphasize process- and objective-based elements in place of prescriptive measures wherever possible. Measures should also reflect administrative environments and existing standards, codes and guidelines in place in municipalities and local authorities responsible for sanitary sewer systems.

Be data- and evidence-based. Proposed measures should be based on the best available information on management of I/I in new subdivisions.

Be effective. Measures should have demonstrated effectiveness and measurable reduction in I/I in sanitary sewer systems.

Have ROI that reflects lifecycle phase. Lifecycle phase should be considered when assessing ROI of specific I/I management methods. ROI of many of the most effective measures for managing I/I risk will vary based on infrastructure lifecycle phase. For example, measures related to pipe material and construction will have limited ROI during retrofit, but a good ROI when incorporated in new construction. Note that ROI data may not be available for all measures, since many are new.

Be practical. To the extent possible, measures should be practical, and implementation should be administratively straightforward.

3.3. Target audience and potential users

The primary target audience of the NSC will be municipal government staff and those directly involved in the design, construction, inspection and assumption of new sanitary sewer systems (both public and private side). Specific target audiences include:

- Municipal administrators (CAOs and senior managers)
- Development departments
- Building departments
- Engineering departments (stormwater and sanitary)
- Operations staff
- Planning departments
- Site inspectors
- By-law officers

Though several sections of the standard focus on technical aspects of I/I management, the standard also provides context and justification intended to inform a wide audience. Additional users of this report may include:

- Provincial waste water and stormwater regulators
- Federal and provincial code development agencies
- Professionals involved in the building industry, including officials who interpret construction codes
- Building material and component manufacturers and suppliers, builders' associations and related professionals
- Homeowners, particularly those who are in the process of buying or building a new home, conducting significant structural changes/renovations to existing homes, or implementing basement flood protection measures
- Developers and contractors
- Property and casualty insurers
- Other stakeholders concerned with mitigation of basement flood risk and the impacts of extreme weather in general

The project team recommends that the NSC include tables for each specific user group outlining the sections that are likely of interest to them.

3.4. Foundational document stakeholder input

Extensive national stakeholder input was a critical aspect of this project. Stakeholder input was conducted to provide strategic direction for the project and report, for the purposes of technical review and input for multiple drafts of the report, and to verify and explore I/I in new construction as a national issue worthy of an NSC.

Two formal methods were applied for stakeholder input: formation of an Expert Stakeholder Committee (ESC) and the organization of a national engagement webinar.

The ESC was developed in the early stages of the project. The project team approached ESC members based on their significant technical expertise and professional backgrounds in topics related to I/I, such as stormwater management, waste water systems design, construction and operation, municipal infrastructure/waste water system management, construction code development, building and plumbing inspections, home building and construction industries, and materials manufacturing and supply.

The ESC was invited to provide input through reviewing draft versions of the document and attending an in-person meeting in Toronto on May 16, 2019, and an additional web meeting on July 29, 2019.

The project team also led a formal national stakeholder engagement webinar on June 25, 2019. The webinar was developed to inform a large audience of the existence and intent of the project and to garner general and specific feedback on the written report. The webinar began with a detailed introduction to the scope and intent of the project, followed by a technical presentation by Barbara Robinson, President, Norton Engineering Inc., on the issue of excess I/I in new construction and extensive time for participant questions, answers and feedback.

A total of 120 attendees participated in the webinar, representing a range of industries and regions in Canada (see Tables 4 and 5). All attendees were invited to review a draft PDF of the report and submit written comments.

Table 4: National stakeholder webinar participation by region

	n	%
ON	57	48
AB	23	19
BC	20	17
National	6	5
SK	4	3
NS	4	3
NB	3	3
QC	2	2
US	1	1
Total	**120**	**100***

* Figures rounded

Table 5: National stakeholder webinar participation by sector

	n	%
Municipality	76	63
Consultant	14	12
Municipal utility	14	12
Construction, home building associations	5	4
Developer	4	3
Materials manufacturers	2	2
Other	2	2
Insurance	1	1
Provincial agency	1	1
Federal agency	1	1
Total	**120**	**100***

* Figures rounded

The project team carefully considered all comments received both during the webinar and following distribution of a draft report to interested participants. The team held a web meeting with the ESC to discuss feedback from the webinar and from formal written comments received on the draft. Many of the comments received from national stakeholders were directly incorporated into this draft of the report. Additional comments that were considered out of scope for this project were compiled and supplied to SCC as an additional, unpublished report. It is intended for this report to be provided to the technical committee developing the NSC, should SCC decide to pursue an NSC.

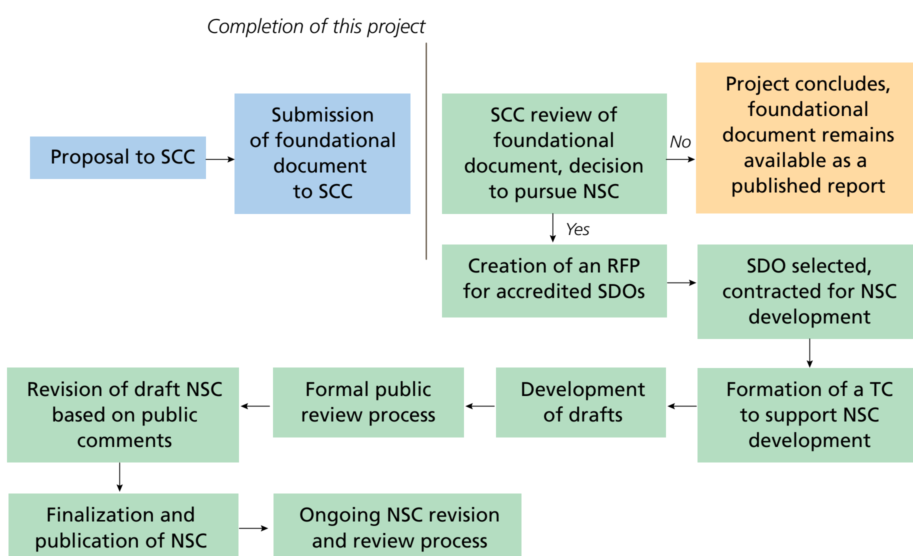
3.5. The foundational document and the NSC development process

The current project concerns development of a "seed" or "foundational" document, the purpose of which is to establish a foundation of knowledge and stakeholder insights for the eventual development of a standard. Technical topics have been flagged in the report for the purposes of setting the basis for further discussion.

While the document is a source of useful information, it cannot be used for certification, verification or regulatory purposes. No part of the foundational document should be considered prescriptive or adopted as a vetted best practice by any agency. Development of an NSC would be conducted in a separate and distinct project, managed by SCC. NSC development is likely to incorporate the following steps (see Figure 5):

- Creation of a request for proposals by SCC, which would be distributed to accredited standards development organizations (SDOs)
- Selection of an experienced SDO to undertake the project
- Formation of a technical committee (TC) by the SDO to support development of the NSC, using a TC membership matrix to ensure broad representation from industries and stakeholders across Canada
- Development of several drafts of the NSC
- A formal public review and comment period for the draft NSC
- Revision of the NSC based on feedback received during the formal public comment period
- Finalization and publication of the NSC
- An ongoing revision process (e.g., reformation of the TC and revision every five years)

Figure 5: Foundational document in relation to National Standard of Canada development process



4. Mitigating public-side I/I

Managing I/I on the public side requires a combination of construction, administrative, management and operational measures. These measures can be performed at every step in the development process, including:

- Conceptual/system management
- Planning
- Pre-design
- Design
- Construction
- Inspection and testing
- Acceptance

Measures that may be applied at each stage of the development are summarized here.

4.1. Conceptual/system management[e]

4.1.1. Collect and plot daily waste water treatment plant (WWTP) influent data against monthly and yearly water billed or pumped data, population data or waste water catchment area

Municipalities should actively manage their sewer systems by proactively tracking sewer flows against water data.

This measure is meant to improve a municipality's understanding of I/I conditions in sanitary systems. The municipality should review this data regularly to establish trends or inconsistencies, as well as undertake granular analysis of sewer flows after large I/I events to improve understanding of sewer system response to rainfall.

This exercise is low cost and based on largely available data. It can provide a high-level understanding of how the sewer system operates.

4.1.2. Collect and plot daily and monthly waste water pumping station (WWPS) flows

Municipalities should collect and plot daily waste water pumping station (WWPS) flows and plot them monthly. They should review this data regularly to establish trends or inconsistencies and undertake granular analysis after large I/I events to improve understanding of sewer system performance in wet weather.

The intent of this measure is to improve a municipality's understanding of I/I conditions in sanitary systems.

This exercise is based on largely available data and can provide high-level understanding of how the sewer system operates. As new developments come online upstream of an existing WWPS, this data can be used to indicate if flows are leak acceptable. Measured flows can also be compared to other parameters such as sewershed area and pipe length to establish areas of concern.

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[e] Standard developers may choose to place this section in an appendix, since it is somewhat outside the immediate measures recommended during new development. However, both the Expert Steering Committee and participants from the National Stakeholder Consultation strongly supported keeping this section, as it is sorely needed by municipalities. See Chapter 7: Conclusion and Next Steps.

4.1.3. Maintain, update and regularly calibrate sanitary sewer system models

Municipalities should be aware of the intent and use of the model they develop (e.g., a trunk model should not typically be used to size local sewers). Also, they should consider the level of calibration when using the model to make capital decisions.

The model should be updated with new development infrastructure as needed (e.g., in areas where systems are nearing capacity, more frequent updates are recommended). Flow monitoring should be used regularly to confirm model performance.

Sanitary sewer system models are most likely to be used in larger/well-resourced municipalities. It may be difficult to justify the cost of a sewer model in smaller systems that are not subject to development freezes. A calibrated sanitary sewer model provides an acceptable tool for anticipating and identifying potential flood risk areas.

The intent of this measure is to ensure that sanitary sewer models are being used as intended when they were developed and to make municipal staff aware that models have limitations and need to be used accordingly.

4.1.4. Consider time of year of CCTV inspection and age of CCTV inspection data when making capital decisions based on CCTV data

The time of year when CCTV inspection was undertaken, and age of the CCTV inspection should be considered when interpreting CCTV data.

Time of year of CCTV inspection (e.g., spring or summer) has a significant impact on results. In addition, if CCTV data is out of date, then capital decisions related to replacing assets are not optimized. Some municipalities conduct CCTV inspections on a twenty-year cycle. Municipalities should collect information more frequently where possible, considering the capital dollars involved with sewer replacement.

The intent of this measure is to ensure that municipalities have up-to-date empirical information concerning the condition of sanitary sewer systems.

4.1.5. Enforce sewer use by-law provisions

Municipalities should be made aware that they likely currently have the jurisdiction to enter property to ensure that there are no illegal connections to the sanitary sewer.[59] The intent of this measure is to ensure conformance with regulations and by-laws concerning I/I on the private side of the property line to reduce the risk of private-side I/I.

Sewer use by-laws can also be enforced during new construction if the contractor is using the sanitary sewer to drain excavations, which is prohibited under commonly applied sewer use by-laws. Municipalities should consider the cost/benefit of deploying resources in this way (for various purposes, including reducing flood risk).

4.1.6. Educate homeowners on their responsibilities to maintain their sanitary building sewer (where owned by the lot owner)

The intent of this measure is to increase homeowner awareness of their responsibilities with respect to maintaining and managing the private-side sanitary sewer (where it is owned by the homeowner, as is typical in Canada).

Residents are largely unaware that they own the sewer from the house to the street and that it needs to be maintained, much like the sewer on the street. Municipalities should implement measures to increase building owner awareness of sewer connections and encourage residents to maintain their private-side lateral. This can be achieved by education, subsidy, mandatory measures, time-of-sale requirements and related measures.

4.1.7. Explore "Inspection of Lateral at Real Estate Transfer" programs[f]

The intent of this measure is to implement I/I risk reduction measures as part of the window of opportunity associated with the real estate purchase/sale process.

The real estate transaction process is a decision point at which it is possible to reduce private-side I/I on an ongoing basis. This approach has been successfully implemented in several jurisdictions in California. Metro Vancouver has investigated this approach since the mid-2000s but have not implemented it.

4.1.8. Encourage plumbing inspections at time of sale

The intent of this measure is to implement I/I risk reduction measures as part of the window of opportunity associated with the real estate purchase/sale process.[60]

Real estate agents and homebuyers are largely unaware of the importance of a sound private-side lateral in reducing basement flood risk. While many buyers will engage a home inspector prior to purchase, undertaking a plumbing-specific inspection of the sanitary sewer (including CCTV inspection) is rare. It is recommended that municipalities start working with their local real estate communities to educate them about the benefits of a plumbing inspection of the private sewer prior to purchase.

4.1.9. Create standardized development processes and procedures at the provincial scale

Municipalities within each province should create and implement standard development processes and procedures (with options where required). This measure is intended to improve efficiency in development processes and to identify and implement standard procedures to assist in delivering leak-acceptable infrastructure.

A standardized approach will assist in identifying and standardizing best practices to reduce I/I risk across regions. This approach has been used with sewer use by-laws in Ontario: the Ontario Ministry of Environment (now Ministry of the Environment, Conservation and Parks – MECP) publishes a widely adopted model sewer use by-law for municipalities.

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[f] ESC members had mixed opinions as to whether this is feasible in Canada. Developers of the NSC should investigate further. See Chapter 7: Conclusion and Next Steps.

4.1.10. Consider having the mainline sewer contractor construct the private lateral in order to reduce I/I risk

Municipalities should consider requiring the mainline sewer contractor to construct the private-side lateral. This measure is intended to eliminate multiple construction-related issues on the private side, including the risk of I/I that exists at the interface between the public and private sides (see side box). Having one contractor construct the entire sewer lateral could reduce this risk substantially.

In addition, both the public side and private side of the sewer lateral should be constructed to CAN/CSA 182.11. Water main and sewer contractors are familiar with this standard, as it is applied consistently on the public side.

This work should be designed and constructed according to public-side standards and inspected by someone with experience in pipe-laying requirements. This measure is currently being piloted in Hamilton, Ontario.

I/I and Municipal Stub-to-SBS Connections

The stub-to-SBS connection has been identified as a likely source of I/I in new construction, since it is a common source of infiltration in existing sewer systems.

Municipal-side sewers are typically constructed first in a subdivision, followed by private-side SBSs. The result is the potential for differential settlement, straining the glued joint between the SBS and municipal stub. Inconsistencies between private- and public-side sewer construction guidelines also result in risk of excess stress placed on this connection (i.e., differential bedding and backfill requirements).

4.2. Planning

4.2.1. Review urban flooding implications of new development to reduce I/I risk

This measure is intended to encourage municipalities to examine new development through a lens of urban flood risk reduction during the planning stage. Municipalities should carefully examine risks, including both sanitary and storm sewer surcharge floods, in the area under development (e.g., hydraulic grade line of storm and sanitary systems, downstream experience with flood exposure and maintenance issues) and evaluate exposure of buildings and risk of stormwater entering sanitary sewers via maintenance hole covers, sewer cleanouts, and related above-ground openings.

Conditions in the sewershed need to be considered at the planning stage in development, since this is when the nature and extent of the development is determined and approved.

4.2.2. Review existing riverine flooding issues within intermediate area to reduce I/I risk

This measure is intended to reduce risk that development occurs within areas known to be prone to overland flooding, which may introduce inflow into the sanitary sewer system.

Local flood hazard conditions should be considered early in the development process. Ensuring that subdivisions are not vulnerable to flood hazards both directly protects buildings from flood impacts and reduces risk of I/I during flood events.

The latest information on surface flood hazards should be confirmed with the municipality or appropriate local authority (overland flood hazard information is continuously being updated across Canada). Flood hazards may include those associated with rivers, coastal areas, stormwater or other surface flood hazards deemed relevant by the municipality or relevant local authority.

A pre-design approach should be developed to minimize flooding risk. The potential impacts of climate change on flood hazards should also be considered.

4.2.3. Design low impact development (LID) to minimize I/I risk

The intent of this measure is to reduce the risk that LID features may increase I/I and its associated risks on the private side of the property line.

LID features that introduce clean water into the ground in the vicinity of sanitary and storm laterals and bedding may increase I/I in these pipes. Potential implications of LID systems with respect to infiltration of excess surface water into sanitary conveyance systems should be considered as part of the design process. LID features should be designed to discharge to the rear yard if possible.

Residents are unlikely to maintain LID features; designs should take this into account.

LID and I/I

Stormwater management features that promote infiltration of stormwater into the ground surrounding buildings and SBSs increase the potential for I/I, notably if appropriate setbacks and soil conditions are not accounted for in design and placement.

4.3. Pre-design

4.3.1. Create slopes at the upstream dead ends of the sewer system to achieve the minimum design flushing velocity (typically taken to be 0.6 m/s)

The intent of this measure is to reduce risk of deposition of solids due to inadequate flow velocities, which has been widely reported by development stakeholders. Most sanitary sewer design sheets calculate the velocity at actual flow, but velocities well below the recommended minimum of 0.6 m/s might be ignored.

With the advent of low water use fixtures, flows in upper reaches of new sewer systems are often insufficient to reach flushing velocity, resulting in deposition of solids. This can become a maintenance issue and/or lead to blockage, which can increase risk of sewer backup flooding.

In order to address this problem, auto flushers are sometimes installed to reduce maintenance costs in the appropriate sewer leg. Introducing potable water into the sewer system to solve a maintenance issue is a source of unacceptable inflow and should not be used to solve a design problem.

Some municipalities across Canada have already started to implement minimum slopes in upstream reaches to address this issue. Other municipalities use 150 mm diameter pipe to increase the velocity (e.g., Sudbury, Ontario). It should be noted that concerns about blowback during flushing have been raised for 150 mm diameter sewers.

4.3.2. Design sewage pumping stations (SPSs) to operate under all flow conditions, including early low-flow conditions

This measure is intended to reduce the risk of inflow associated with pumping station operators needing to use potable water to assist in operating new or newer pumping stations.

For new subdivisions serviced by a pumping station, the pumping station must be designed such that it can operate effectively under all flow conditions (e.g., provision for early low flows must be built in). The intent of this measure is to limit inflow by reducing the likelihood that potable water is required for the SPS to operate adequately. (Ontario municipalities have reported having to fill new wet wells with potable water to provide adequate turnover of the sewage.)

This use of excess water introduces unnecessary inflow into the sanitary sewer system.

4.3.3. Use different materials to differentiate sanitary and storm building sewers

Cross connections are frequently found in existing sanitary sewer systems, and standard practices where pipe may not be appropriately differentiated increases risk of cross connections in new construction. Pipe used for sanitary and storm building sewers should be differentiated in a manner that reduces risk of cross connections. Specifically, sanitary building sewers could be 100 mm in diameter and green in colour, and storm building sewers could be 125 mm in diameter and white in colour.[g]

It may also be appropriate to have the sanitary pipe always on the right side facing the street, and the storm on the left.[h] This is already standard in a few locations in Canada, including Quebec.

A larger size may be selected for storm infrastructure to avoid reducing the velocity in the sanitary sewer which could lead to solids deposition (already identified across Canada as an issue associated with low water use fixtures). Also, storm flows are more likely to be higher than sanitary flows.

Many municipalities across Canada indicate that they are moving to this approach; it is prudent to standardize this concept across all municipalities to minimize the risk of I/I due to cross connection.

4.4. Design

4.4.1. Place maintenance holes (MHs) near the high elevation of the roadway cross-section unless no alternative exists

This measure is intended to reduce risk that stormwater overland flow routes will direct water over manholes and MH covers. MHs in low-lying areas are a known source of inflow and infiltration.

If it is necessary to locate an MH in a low-lying area, it should be designed with a means of preventing entry of overland flow (e.g., external wrap, special frame and grate, lid).

4.4.2. Construct sewers and MHs located in high water conditions to be leak-proof

Sewers and MHs that must be located in high water conditions should be designed to water system standards for watertightness. The intent of this measure is to recognize that sewers and manholes that are constructed below the groundwater table are at much higher risk of I/I. If this type of construction cannot be avoided, the sewer's design should reflect site conditions.

I/I is largely inevitable in high water conditions unless special provisions are made to ensure that sewers and manholes are watertight. The sewer's design should be undertaken according to water system design standards. MHs should be constructed with watertight techniques as discussed above.[i]

Note that widespread plugging of MH pick holes (or use of inflow protectors if they form a seal) in a sanitary sewer system is not recommended, as it interferes with the venting of the sewer system, increasing the risk of explosive gas buildup.[61]

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[g] Access to these pipe sizes has been identified as a potential concern in some jurisdictions. See Chapter 7: Conclusion and Next Steps.

[h] The feasibility of this should be confirmed with developers. See Chapter 7: Conclusion and Next Steps.

[i] Costs and benefits may require further work. See Chapter 7: Conclusion and Next Steps.

4.4.3. Protect MH joints in normal conditions from I/I

The intent of this measure is to address leakage that is frequently observed between MH joints in existing sewer systems.

Many readily available technologies and approaches limit risk of infiltration into sanitary systems via MH joints. Depending on site conditions, this can be careful application of the gasket, or more elaborate measures as determined by the municipality.

4.4.4. Specify MH riser rings as per the best available technology economically achievable

The intent of this measure is to reduce the risk of I/I entry into MHs that is frequently observed at the riser rings in existing systems.

A number of technologies are available to mitigate this risk (e.g., combined frame and grate) and should be considered by municipalities.

4.4.5. Provide new subdivisions with an MH at the downstream end that is suitable for flow monitoring before flows reach the municipal system

This measure is designed to provide municipalities with a suitable location from which to monitor new flows and ensure leak-acceptable construction. Typically, this will call for a straight-through MH with similar upstream and downstream slopes.

This measure reflects the fact that it is sometimes difficult to monitor flow at the limits of a subdivision because an appropriate MH is not available. Accurate flow monitoring requires laminar flow (since it uses Manning's equation to calculate the flow), best achieved by a straight-through MH with similar slopes upstream and down. This measure is already in place in a few municipalities in Canada (e.g., Woolwich, Ontario).

4.4.6. Design the connection of the laterals to the mainline sewer based on site-specific conditions

This measure is intended to reduce the risk of I/I into sanitary sewer systems at the connection of the lateral stubs (sanitary sewer stubs) to the mainline sewer. This location is a frequent source of I/I in existing systems.

The means of connecting the lateral to the mainline sewer should be carefully designed based on site-specific conditions. It is recommended that a waterproof fitting be required in areas where the connection is below the seasonally high GWT.

4.5. Construction

4.5.1. Install flow monitors at the downstream end of new subdivisions as soon as the trunk system is established. The use of flow monitoring should be identified at the pre-construction meeting

This measure is intended to provide municipalities with means to confirm leak-acceptable infrastructure prior to acceptance. Installation of flow monitoring as soon as the trunk sewer system is established provides the municipality with maximum information regarding likely sources of I/I (e.g., public- or private-side).

At the pre-construction meeting, all stakeholders should be advised that flow monitoring (where feasible) will be used by the municipality to confirm leak-acceptable infrastructure prior to acceptance.

This recommendation reflects findings in Ontario that poor construction leading to I/I is observed, even when the developer is aware that flows are being monitored (presumably because the contractor was not informed).[62]

Flow monitoring may not be possible for small or infill developments. In these cases, the municipality should carefully undertake other means of checking for leaks (e.g., visual, CCTV, Mandrel tests).

4.5.2. The municipality should carefully review their requirements for the engineers' sign-offs following completion of a new development

This measure is intended to bring to the attention of municipalities that a professional engineer cannot sign off on construction,[63] although municipalities sometimes ask for this sign-off. This measure is intended to keep the risks associated with poor construction practices with the appropriate party.

The engineer, like the building inspector, has an oversight role only in the construction of new infrastructure. It is inappropriate for a municipality to ask for a sign-off that the engineer cannot actually provide.

4.5.3. The municipality's engineering inspector should attend the site regularly

The intent of this measure is to improve construction outcomes by having a secondary check on construction activities to achieve leak-acceptable infrastructure.

This clause is included in this foundational document as it was reported widely to Norton during research that perhaps this needs to take place.[64] However, this approach may suggest to the site inspector that he/she is not required to be as diligent, and it may also confuse site authority. Furthermore, the developer's consultant is already being paid to undertake this task. It is recommended that the NSC's developers consider whether this approach or something similar has widespread appeal.

4.5.4. Provide I/I training/education for municipal and consultant inspectors

All inspectors (municipal and consultant) should receive regular training concerning I/I, its impacts and the construction of leak-acceptable infrastructure.[65]

4.5.5. Regularly inspect sediment traps and replace where necessary

Sediment traps in new construction should be inspected frequently (e.g., biweekly) and replaced if necessary. This measure applies to sediment traps placed around both catch basin inlets and site perimeters, and it is intended to minimize flood/blockage risk, which may result in inflow to the sanitary sewers.

Sediment trap maintenance should include removing collected solids, which should be disposed of according to material quality. This measure reflects experience that these traps frequently do not perform as designed (i.e., preventing sediment from entering storm sewers and hence waterways) and may introduce flood and inflow risk to sanitary sewers when blocked.

4.6. Inspection and testing

4.6.1. Inspect all new sanitary sewers by CCTV

All new sanitary sewers should be CCTV inspected, including mainline sewers and laterals to property line. This measure is meant to ensure that the private- and public-side sewers have been constructed according to specifications.

OPSS MUNI 409 (2017) (Ontario) specifies the requirements for CCTV inspection of new pipelines, as follows (excerpt):

> *The work shall include a CCTV inspection of new and existing pipelines, which include storm and sanitary sewers, water mains, pipe culverts or other accessible conduits and the preparation of all video, digital and written reports.*

The specification includes new sewers that are accessible, which necessarily includes the lateral to property line.

Municipal staff should be aware of the time of year in which the CCTV is taken, since I/I varies based on the time of year. Evidence of I/I (e.g., weeping joints, calcification, corrosion) does not generally form on new sewers, and leakage can only be identified if it is seen.

CCTV inspections should be reviewed accordingly. Consideration should be given to conducting final CCTV inspection when ground and surface water conditions are likely to result in high risk of I/I (e.g., spring, winter snowmelt periods, depending on region in Canada). Conducting inspections during times of potential high-water conditions helps ensure that active I/I is more likely to be observed.

CCTV inspection should always include lateral camera launch, since the public-side lateral is also a source of I/I.[j]

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[j] The costs and benefits for this measure should be verified. See Chapter 7: Conclusion and Next Steps.

4.6.2. Compare written reports to CCTV recording and sign off on comparison

It has been observed in Ontario that written reports and CCTV recordings do not always match,[66] and deficiencies in the CCTV inspection recording are not always included in written reports.

The engineer should review and compare written reports to the CCTV tapes and sign off that they match. This measure is intended to improve record keeping and ensure that observations made during CCTV inspections are included in written reports.

4.6.3. Provide written reports and report interpretation for sewer and MH leak testing and mandrel test deflection results

Written reports of all sewer and MH leak testing and mandrel test deflection results and interpretation should be provided immediately upon completion. Reports should include staff in attendance, date and time of the tests, groundwater elevation (this determines air/water and infiltration/exfiltration test required) and recorded observations. This measure is intended to improve compliance in system testing through providing a record of leak testing. A standard form should be prepared for use in all new construction.

Providing records for mandrel testing (including locations of blockages, if any) is further intended to assist inspectors in making appropriate decisions in the event of the sewer failing the test (e.g., relaying information to appropriate authorities). Recording mandrel test results should also remind those performing the test of its limitations (e.g., if a pipe is deflected sufficiently to stop the mandrel a third of the way through a pipe section, the remaining two-thirds have not been tested unless the mandrel is pulled in the opposite direction).

Having records of these tests may be useful to the municipality in the event of a flood caused by poor construction.

4.6.4. Arrange for third party leak testing of manholes and sewers

The municipality should directly retain leak testing of the sewers and manholes, and costs should be recovered from the developer. This measure is intended to reduce the appearance of conflict of interest that may exist when the developer’s agent performs tests.

Third party leak testing of manholes and sewers would allow for consistent results and consistent mitigation measures should unacceptable leaks be identified. Numerous municipalities in Canada already use this approach.

4.7. Acceptance

4.7.1. Visually inspect MHs prior to acceptance

The municipality should undertake visual inspections of all MHs prior to acceptance and check for excess flows or signs of leakage. Starting at the upstream end, a municipal inspector should visually inspect all manholes, particularly if flow monitoring is not available. If possible, the MHs should be checked in wet weather. This measure is intended to limit I/I by ensuring that key I/I entry points are visually inspected prior to infrastructure acceptance by the municipality.

4.7.2. Develop acceptance package that includes all items called for by standards, specifications and development agreements

The municipality should request and receive from the consultant a complete acceptance package, including all items called for by standards, specifications and development agreements, which should be carefully reviewed by municipal staff. This measure is intended to ensure that infrastructure is constructed according to specification and assigns responsibility for construction according to specifications to the developer's professional engineer.

City staff should require sign-offs from the consulting engineer on all aspects of the sanitary sewer system inspection and testing, including weekly inspection reports, issues and resolution log, leak testing calculation and results, and other relevant items.

4.7.3. Use flow monitoring results to inform acceptance of new sewers for all new subdivisions

The municipality should use flow monitoring data and acceptable leakage values to determine assumption of the system. Flow monitoring indicates performance of the public-side system prior to installation of the private-side system and buildings. Flow monitoring should be maintained until leak-acceptable flows are observed for one continuous year.

Implementing flow monitoring is considered one of the most effective tools at the disposal of Canadian municipalities to ensure that new sanitary systems are good quality and adhere to appropriate design, construction and installation standards.

4.8. Summary

As outlined in this section, reducing public-side I/I to leak-acceptable levels is a complex process that involves a wide range of stakeholders. More careful planning, design, construction, inspection, testing and acceptance practices on the public side of the sewer system are required.

It is recommended that developers of the NSC include a flow chart depicting the stages of development (either here or at the start of the chapter) for easy reference. The next chapter discusses measures that can be undertaken to minimize I/I risk on the private side. (Many of these measures will occur at the planning and design phases and are covered in this chapter.)

5. Mitigating private-side I/I

Strategies for reducing I/I risk on the private side of the property line are organized according to the following categories:

- General
- Planning
- Design
- Construction
- Inspection and testing
- Acceptance

During construction, the private side falls under the aegis of building and plumbing construction codes. Many strategies, however, can be employed throughout the development process to encourage leak-acceptable development. Engineering and planning staff that oversee and approve decisions in the early stages of development will need to consider many of these strategies.

Throughout this section and in following sections, reference is made to several measures presented in CSA Z800-18. These measures are referenced here to highlight the linkage between private-side basement flood mitigation and management of I/I. Reference to Z800-18 measures also highlights the multiple benefits of the measures for both flood risk reduction and improved infrastructure sustainability, under both extreme rainfall scenarios and normal operating conditions for sanitary sewer infrastructure.

5.1. General

Ensuring that planning, design, construction, inspection and testing of private-side infrastructure minimizes excess I/I risk will require that building departments and development departments work together on issues such as protective plumbing (e.g., sump pumps, backwater valves) and the private-side lateral. Stakeholder input and I/I research in Ontario has indicated that jurisdictional issues (e.g., lack of, or gaps in, clarity under whose jurisdiction certain items fall) increase risk of I/I.[67]

CAN/CSA Z800-18, Guideline for Basement Flood Protection and Risk Reduction, should be consulted for extensive detail on strategies for mitigating private-side I/I.

5.2. Planning

Planning for relevant measures on the private side were addressed under the public-side section (Mitigating Public-Side I/I).

5.3. Pre-design

Because sewer system elevation is established at pre-design, recommendations related to pipe elevation are described here.

5.3.1. Connect sanitary building sewer to the sanitary building drain above seasonally high groundwater levels

The connection of the sanitary building sewer to the sanitary building drain should be located above seasonally high groundwater table (GWT) levels or as determined by a geotechnical engineer.

This measure is intended to reduce the risk of groundwater infiltration into drainage features and sanitary building sewers. The relation of the seasonally high GWT to the elevation of the connection at the property line has a direct impact on the risk of I/I and flooding, since this connection is known to perform poorly in reducing I/I risk.

It may not be feasible in all cases to construct above the seasonally high GWT. If it is necessary to construct sewers below the seasonally high GWT, the SBS should be designed to be leak acceptable under conditions of high GWT (e.g., to pressure pipe standards as described in Chapter 4).

5.3.2. Locate foundation drainage systems, basement floor slabs, and/or foundation footings above seasonally high groundwater tables

Foundation drainage systems, basement floor slabs, and/or foundation footings should be located above seasonally high GWT.[k] This measure is intended to reduce risk of groundwater infiltration into drainage features and sanitary building sewers, as above.

5.3.3. Locate buildings away from overland flood/stormwater hazards

Buildings should not be located in areas where there is a known or potential occurrence of overland flood/stormwater hazards. This measure is intended to reduce I/I risk associated with basement flood (e.g., in the event of basement flooding associated with overland flood, water may enter floor drains and substantially contribute to inflow into sanitary systems).

While development in flood hazard areas is already regulated in many parts of Canada, it continues in many flood plain areas, including reconstruction of flooded homes. Implementing a mandatory requirement to restrict building in flood hazard areas is essential to reduce risk of I/I and flooding across Canada.

5.3.4. Provide sump pump backup systems

Where new homes are provided with a sump pump, the design engineer shall determine the likely frequency of the sump pump being called to duty and provide redundancy accordingly. Although arguably a sump pump is always better with redundancy to reduce flood risk, a case can be made that this is not cost effective in all cases. The developers of the NSC should consider this concept.

This measure is intended to reduce risk of sump system failure during routine operation, which may result in foundation drainage water entering sanitary sewers via floor drains.

In applications where groundwater is expected, backup power and a backup sump pump, set to engage in the event of a power outage or mechanical failure of the primary pump, should be supplied with sump pump systems.[68] A failure alarm to notify homeowners of primary pump failure and/or high-water conditions in the sump pit should also be provided.[69] In addition, when a home is sold, the sellers shall supply manuals for all operating equipment to the buyer. This requirement should be carried in Subdivision Agreements with the developer (see previous chapter).

Some municipalities across Canada do not allow sump pumps in new development. This is an alternative approach to reducing the risk of sump pump failure leading to flooding and/or I/I.

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[k] Determine acceptable practice, opportunities for identification of prescriptive value. See Chapter 7: Conclusion and Next Steps.

5.3.5. Avoid conditions that may result in root penetration in SBSs

This measure is designed to encourage landscape architects or others designing plantings for new homes to be cognizant that the SBS represents a long-term risk for I/I. Plantings need to be designed and located accordingly.

Conditions that may result in root penetration in SBSs should be avoided. Vegetation, including trees, should be selected in a manner that considers risk of root penetration into laterals. Vegetation with aggressive roots should not be planted near the lateral, and trees in general should not be located in proximity to the sanitary and storm sewer laterals. This measure is intended to increase the lifespan of SBSs by limiting exposure to aggressive root systems.

5.4. Design

5.4.1. Design sanitary building sewer and storm building sewer to minimize flooding risk

Similar to public-side practices, the design of new sanitary building sewers and storm building sewers should be prepared under the advice of a geotechnical engineer to ensure that risks of flooding are minimized.

An engineer should design the sanitary building sewer with appropriate regard for soil type, groundwater elevation, expected load, required bedding, embedment and backfill. The design prepared for the sanitary sewer on the public side, along with the geotechnical report, should be used as a starting point. The drawings provided to the drain layer should include the design requirements.

This measure ensures that site-specific conditions are considered for these pipes to appropriately minimize I/I risk.

5.4.2. Locate utility penetrations above grade

All utility penetrations into new buildings should be located above grade. This measure is intended to limit risk of surface water entering the building and contributing to I/I via floor drains or related connections to SBSs.

Utility penetrations have been identified as a source of observed infiltration flooding in buildings. This water may find its way into the sanitary sewer as I/I and/or increase flood risk.

It is recommended that additional vigilance be applied to ensure that utility penetrations do not expose buildings to water infiltration/seepage, notably for existing homes and/or homes undergoing renovation.

5.4.3. Design site grading and drainage to direct water away from buildings and foundations

Homes should be designed such that site grading and drainage adequately direct water away from buildings and foundations. The intent of this measure is to limit the risk that overland water will accumulate near the building, thereby limiting risk that water will enter basements and building drainage features, which may increase risk of I/I.

Both rough and final grades should slope away from the building foundation (2% grade after settling, where appropriate, as approved by the municipality).[70]

Ideally, measures should be applied to limit risk of surface water entering the backfill zone (e.g., capping with an impermeable surface where possible).[71]

Many older homes have drainage directed towards the building, a known cause of flooding, suggesting that insufficient attention was paid to the need for grade *after settling* to be 2% away from the home.

5.4.4. Avoid area drains and catch basin connections that discharge into sewers

Area drains and catch basins on the private side of the property line should not discharge directly or indirectly to combined or sanitary sewers. The intent of this measure is to limit inflow into SBSs via area drains and catch basins.

Area drains and catch basins may include those servicing exterior stairwells or reverse slope driveways. Other surface drains should be considered as necessary, through consultation with the municipality.

5.4.5. Design window wells to ensure they do not become a source of water entry

Window wells should be avoided or designed to ensure that they do not become a source of water entry to the building. The intent of this measure is to limit risk of water entering floor drains during basement flood conditions.

5.4.6. Avoid exterior basement stairwells

Exterior basement stairwells should be avoided wherever possible. This measure is intended to limit risk of water entering floor drains during flood conditions.

If it is necessary to use exterior basement stairwells, the drain should be directed to a storm (and not sanitary) outlet. Since the elevation of the exterior basement stairwell's drain may require that the storm infrastructure be lowered, this type of design may be prohibitively expensive.

5.4.7. Avoid driveways that are likely to cause or contribute to runoff water entering or accumulating near or against a garage, building and/or foundation (e.g., reverse slope driveways)

Driveways that are likely to cause or contribute to runoff water entering or accumulating near or against a garage, building and/or foundation (e.g., reverse-slope driveways) should not be used. The intent of this measure is to reduce the risk that surface water will enter a home via a reverse-slope driveway.

Reverse-slope driveways have been restricted in some locations through application of lot grading, drainage and zoning requirements.[72]

5.4.8. Design downspout discharge points to extend away from foundation walls

Where possible, the downspout discharge points should be designed to extend to a minimum of 1.8 m from foundation walls.[73] The intent of this measure is to limit the risk that downspout drainage will enter basements via seepage or enter building drainage systems (e.g., foundation drainage).

Where lots are small, 1.8 m extensions may be difficult to achieve. Where site/drainage conditions do not permit 1.8 m extensions, discharge points should be beyond the line of excavation and backfill.[74]

The discharge should be directed towards appropriate drainage infrastructure (e.g., swales).[75]

This measure is meant to direct water away from building foundations and foundation drainage systems. Priority placed on this measure varies based on foundation drain connections (to sanitary, storm, third pipe, etc.).

5.4.9. Locate stormwater infiltration features away from building foundations

Stormwater infiltration features should be located away from building foundations and sanitary and storm sewer laterals. The intent of this measure is to limit the risk that water will enter building drainage features (e.g., foundation drainage), basements via seepage, or leaking SBSs via stormwater infiltration features.

Appropriate separations of low impact development (LID) features from foundations and foundation drainage systems reduce risk of water infiltrating into leaking foundation walls/basement floors or entering foundation drainage systems. It has been recommended elsewhere that LID/infiltration features have a 5 m separation from building foundations.[76] This recommendation may be achieved by locating LID features in rear yards.

5.4.10. Use gasketed sanitary building sewer pipe joints

Pipe used for the SBS should be gasketed rather than solvent welded. The intent of this measure is to reduce the risk that water will enter SBSs via pipe joints.

Research indicates that the solvent weld joints currently permitted in the building codes have not been tested and approved by any agency (PVC pipe with gasketed joints are the only pipes referenced in any of the approval standards).[77] In addition, observations indicate that the solvent welds may not be being applied correctly according to manufacturers' standards (e.g., 30 second hold time; 2 hours initial set schedule is the necessary time to allow before the joint can be carefully handled at 40 to 60 °F).[78] In addition, the special solvent weld joint instructions required for cold weather applications[79] may not be being applied.[80]

Ongoing consultations with municipalities have indicated limited enforcement of code provisions related to support for underground horizontal piping, embedment (backfilling) of pipe trenches, and provisions related to testing of drainage systems.[81] Gasketed pipes provide a safety factor when pipes are not properly tested, bedded and backfilled.

Since gasketed pipe can be installed more quickly than solvent weld pipe (if the solvent welds are applied as per the building and plumbing construction codes), this measure is likely to reduce installation costs.

5.4.11. Use appropriate sanitary building sewer pipe strength

Pipe used for the SBS should be SDR28. The intent of this measure is to improve the performance of the SBS and reduce the risk of I/I.

This recommendation would result in applying gasketed pipe for building sewers on the private side of the property line. Building officials have widely reported that the SDR35 pipe currently in use is prone to shattering.[82] However, shattering of this same pipe is not reported on the public side. It appears that construction methods/pipe handling on the private side may be responsible for this phenomenon. Therefore, SDR28 is recommended.

Many municipalities (e.g., Haldimand County, Waterloo Region) are starting to use SDR28 for the public-side lateral to improve pipe performance and reduce I/I risk. Since this risk exists on the private side, it is recommended that this pipe also be used for the SBS.

5.4.12. Ensure a minimum sanitary building sewer slope

Sanitary building sewers should have a minimum 2% slope. The intent of the minimum grade is to reduce risk of solids deposition due to inadequate flow velocities. This minimum grade is required to ensure the flushing of solids through the sewer, particularly in light of low-flow water fixtures that do not always provide adequate flushing velocity.[83] This slope may also improve the performance of normally open backwater valves placed on mainline connections during construction or in retrofit scenarios. Currently, building/plumbing construction codes recommend 2% for the SBS but allow 1%.

This measure will help ensure proper pipe performance, including reduced risk of blockage and accumulation of solids and debris. Minimum sanitary sewer pipe grades of 2% on public-side/sanitary sewer connections (sewer stubs) is common practice.[84]

5.4.13. Protect against backflow via infrastructure trenches

Design should incorporate means to protect against water flow through infrastructure (pipe) trenches where conditions warrant. The intent of this measure is to limit the risk of water flowing through pipe trenches and reaching points of entry to sewer systems.

Water flow through pipe trenches can lead to I/I in the municipal system and/or water backing up and entering basements and foundation drainage systems via utility/pipe trenches.[85] Trench plugs/dams can be utilized to limit this potential.[86] In addition, use of clear stone as bedding should be avoided, as this allows water to flow easily through the trench.

5.4.14. Extend storm and sanitary sewer connections onto private property

Connections to storm and sanitary sewers should be extended onto private property to minimize risk of interfering with other utilities (e.g., gas, electric, cables). The intent of this measure is to avoid conflict with many other utilities being installed beside the roadway in the municipal right of way. This approach has been implemented or is being contemplated by municipalities across Canada (including Surrey, British Columbia; Peel, Ontario; and Montreal, Quebec).

This measure is intended to reduce the risk of the SBS connection to the lateral stub and/or the sanitary cleanout at property line from being disturbed, which increases the risk of I/I.

5.4.15. Position sump pump discharge points away from the foundation, reducing risk of water recycling through the foundation drainage/sump system

When draining to the surface, sump pump discharge points should be at a sufficient distance from the building foundation to reduce risk of water recycling through the foundation drainage/sump system. The intent of this measure is to lower the load on sump pump systems by reducing risk of foundation drainage recirculation, thereby reducing risk of sump pumps system failure. The measure is also intended to reduce risk of water seepage into basements.

- Where possible, the sump pump discharge points should extend to a minimum of 1.8 m from foundation walls.
- Where site/drainage conditions do not permit 1.8 m extensions, discharge points should be beyond the line of excavation and backfill.

5.4.16. Protect sump pump float switch

Care should be taken to ensure that there is no interference with the foundation drain sump pump float switch.[87] The intent of this measure is to limit the risk of foundation drainage water entering sanitary sewer systems via floor drains, in the event of sump pump failure.

The sump pump should be located in the sump pit such that the float control will not come into contact with the side of the pit.[88] Power cords and related obstructions should not be draped over the float switch.[89] Floats should otherwise be located such that they are able to operate freely over the lifecycle of the pump.

Ensuring proper operation of sump pump systems reduces risk of sump pit overflow and I/I via floor drains connected to SBS. A recent review of sump pump failures indicated that issues associated with sump pump floats commonly cause failure in residential systems.[90]

5.5. Construction

5.5.1. Avoid over-excavation of the foundation

Over-excavation of the foundation should be avoided. Where over-excavation occurs, the voids shall be filled and compacted with appropriate material as directed by the geotechnical engineer. The purpose of this measure is to reduce the risk of pipes shifting during or after construction. Such shifts lead to differential settlement and potential leakage at pipe joints.

5.5.2. Seal entry points for overland/surface water

Potential entry points for overland/surface water should be carefully sealed. This measure is intended to limit risk of surface water entering the building and contributing to I/I through floor drains or related connections to SBSs.

Specific entry points that may be part of such an assessment may include building entrances, utility penetrations, basement windows and related openings.

5.5.3. Seal cracks in foundation walls and/or basement floors

Cracks in foundation walls and/or basement floors should be sealed to reduce the risk of infiltration flooding/seepage. This measure is intended to limit risk of surface water entering buildings and contributing to I/I through floor drains or related connections to SBSs.

Despite existing construction code requirements and construction practices, it is recommended that, due to the frequency of observed infiltration flooding in buildings, careful construction methods and additional vigilance be applied to avoid the development of these gaps.

5.6. Inspection & testing

Much of this section refers building inspectors to items required in design but often missed in construction. It is important that building inspectors understand these requirements – most of which are already contained in building and plumbing construction codes – and verify them during construction.

5.6.1. Ensure that site grading and drainage will direct water well away from buildings and foundations after settlement

Building inspectors should ensure that site grading and drainage will direct water well away from buildings and foundations after settlement. The intent of this measure is to limit the risk that overland water will accumulate near buildings, thereby limiting risk that water will enter basements and building drainage features, which may increase risk of I/I. This measure reflects the finding that, around some older buildings, grading after settlement no longer slopes away from the building.

Although the engineer reviews and approves the lot grading plan, building officials also have an opportunity to ensure that grading and drainage are adequate.

5.6.2. Ensure that private-side area drains and catch basins do not directly or indirectly connect to sanitary or combined sewers

Inspectors should ensure that private-side area drains and catch basins do not directly or indirectly connect to sanitary or combined sewers. The intent of this measure is to limit inflow into SBSs via area drains and catch basins.

Area drains and catch basins may include those servicing exterior stairwells or reverse slope driveways. Other surface drains should be considered where appropriate through consultation with the municipality.

Building and plumbing construction codes currently "permit" discharge of stormwater to a sanitary sewer where no storm sewer exists. However, these types of connections may be restricted in municipalities per sewer use by-laws. It is important to ensure these provisions are carried through via inspections.

5.6.3. Ensure that downspouts are not directly or indirectly connected to sanitary or combined sewer systems

Inspectors should ensure that downspouts are not directly or indirectly connected to sanitary or combined sewer systems. The intent of this measure is to limit inflow into sanitary sewers via downspout connections.

Direct or indirect eavestrough downspout connections to sanitary sewers are major drivers of I/I and have contributed to basement flooding during SDHI rainfall events.[91] As above, the building construction codes may permit these types of connections, while municipal regulations may prohibit them. It is important to ensure these provisions are carried through via inspections.

5.6.4. Ensure that downspouts are provided with extensions and that they are extended to a minimum of 1.8 m from foundation walls

See Section 5.4.8. Design downspout discharge points to extend away from foundation walls.

5.6.5. Inspect PVC sanitary building sewer installations per CAN/CSA 182.11

Inspection of the sanitary building sewer installation should be undertaken by staff familiar with requirements for the laying of PVC pipe in open cut per CAN/CSA 182.11. The intent of this measure is to ensure correct installation procedures for PVC pipe, including bedding, haunching, initial backfill, tamping and vibration, saturation, final backfill and compaction. All PVC pipe manufacturers recommend installation according to CAN/CSA 182.11.[92]

This measure reflects the observation by many stakeholders in the development industry that private-side pipe is not being constructed according to required (CAN/CSA 182.11) standards.

While dedicated plumbing inspectors likely have the appropriate experience to perform this inspection, either the building inspector will require appropriate training, or staff who have the training (e.g., a representative from engineering, since the Standard refers to "the engineer") should inspect the work. It may be necessary to alter the subdivision agreement[l] to explicitly call for this inspection.

Inadequate pipe bedding, embedment, backfill and compaction substantially increase risk of pipe joint failure. Pipe joint failure may result in a positive feedback loop, where pipe bedding material is transferred into the pipe, resulting in degraded pipe bedding and increasing stress on failed pipe joints.[93]

5.6.6. Test PVC sanitary building sewer per CAN/CSA 182.11

Staff familiar with the requirements of PVC pipe per CAN/CSA 182.11 should undertake testing of the sanitary building sewer. The intent of this measure is to ensure that testing required for PVC pipe is performed on private-side pipe installations. PVC pipe testing requirements on both sides of the property line are specified in CAN/CSA 182.1 to 11 [latest version 2018 (see excerpt in box below)].

[l] Norton Engineering Inc. is currently conducting research into the ability of municipalities to call for requirements in excess of the OBC.

This measure reflects the observation by many stakeholders in the development industry that private-side pipe is not being constructed and tested according to required standards. While dedicated plumbing inspectors likely have the appropriate experience to perform this inspection, building inspectors may require appropriate training, or staff who have the appropriate training (e.g., a representative from engineering, since the Standard refers to "the engineer") should inspect the work.

Inadequate pipe bedding, embedment, backfill and compaction substantially increase risk of pipe joint failure. Pipe joint failure may result in a positive feedback loop, where pipe bedding material is transferred into the pipe, resulting in degraded pipe bedding and increasing stress on failed pipe joints.[94] Testing will confirm adequate installation on the private side.

Excerpt from CAN/CSA 182.11–18:

8.4 Leakage test

8.4.1 General

Points for leakage measurement and the method of testing shall be specified by the engineer. Test methods that are suitable for various conditions are low-pressure air exfiltration, water infiltration and water exfiltration (see Clauses 8.4.2 to 8.4.4).

The engineer shall supply explicit instructions for the test methods specified in Clauses 8.4.2 to 8.4.4. Plugs, caps and branch connections shall be secured against blowoff during leakage testing.

8.4.2 Low-pressure air testing

The minimum duration permitted for a prescribed low-pressure air exfiltration pressure drop between two consecutive access holes shall be not less than that specified in Table 5. Safety precautions shall be followed when testing with air. The maximum air pressure shall be 35 kPa.

8.4.3 Infiltration testing using water

Infiltration testing shall be an acceptable method of leakage testing only when the groundwater level is above the top of the pipe throughout the length of the pipe being tested. The allowable infiltration for any portion of the sewer system shall be measured by a weir or current meter placed in the appropriate access hole and shall not exceed 4.6 L/mm of ID/km/d.

8.4.4 Exfiltration testing using water

Exfiltration testing shall be an acceptable method of testing only in dry areas. The allowable water exfiltration for any length of sewer pipe between access holes shall be measured and shall not exceed 4.6 L/mm of ID/km/d. During exfiltration testing, the maximum internal pipe pressure at the lowest end shall not exceed 7.6 m of water or 75 kPa and the internal water head shall be 0.6 m higher than the top of the pipe.

8.5 Deflection testing

The engineer may require the contractor to perform random deflection tests of pipe before final acceptance. All locations with excessive deflection shall be excavated and repaired by rebedding or replacement of the pipe. Devices for testing include photography, video camera, sewer ball, deflectometer, or "go" or "no-go" mandrel. To ensure accurate testing, the lines shall be clean

The dimensions specified in Tables 6 to 8 should be used for deflection mandrels.

5.7. Acceptance

5.7.1 The municipality should consider flow monitoring results before acceptance of the subdivision

The municipality should not accept the subdivision in its entirety until downstream flow monitoring demonstrates that the entire sanitary sewer system is leak acceptable. The intent of this measure is to ensure that the new sanitary sewer infrastructure on the private side is leak-acceptable, which can be measured by flow monitoring.

5.8. Summary of private-side measures

As outlined in this section, reducing private-side I/I to leak-acceptable levels is a complex process that involves a wide range of stakeholders throughout the planning, design, construction, inspection and testing of the new SBS and plumbing components.

It is recommended that developers of the NSC summarize the steps in the development process relevant to private-side construction (either here or at the beginning of the section) to aid the reader.

6. Owner behavioural measures to mitigate I/I

In addition to the measures that both the public and private sides can undertake during design and construction to reduce I/I risk, building owners may take many measures to manage the risk of I/I and flooding. Public education and involvement of residents through voluntary and mandatory measures are becoming essential in the effort to reduce flood risk, since many steps can only be taken once a building is occupied.

Building owners need to be educated to understand that appropriately maintaining and operating a building's plumbing and pipes is part of the obligation of ownership, similar to maintaining other key household components (e.g., furnaces, roof coverings and smoke detectors). Further, maintaining private-side sewer infrastructure benefits both the homeowner and the community by limiting the negative impacts of I/I and associated flood risk.

Municipalities and other stakeholders should start or continue public programs that educate homeowners of the responsibility they bear in reducing flood risk. Some of these measures are included in CAN/CSA Z800-18, Basement Flood Protection and Risk Reduction. The municipality has an excellent opportunity to intersect with homeowners when they have just purchased a new home, particularly when the subdivision is still in the maintenance period.

This section includes some measures that would likely apply to existing, rather than new, homeowners. They are included in this foundational document for consideration by the NSC developers, since public education programs are likely to target owners of both new and existing homes at the same time.

6.1. Access information specific to the municipality, subdivision and lot before undertaking any lot level changes

Building owners should access information specific to the municipality, subdivision and lot before undertaking any lot level changes. This measure is intended to ensure that building owners collect information that is appropriate for their specific municipality, subdivision and lot before starting any work that may affect a building's plumbing and drainage systems (e.g., building a deck or pool or increasing impervious area).

This measure applies where renovations and/or adjustments to properties (e.g., basement flood protection) are planned and implemented.

Specifically, building owners should be provided with and/or encouraged to pursue information related to:

- Ownership of the lateral/SBS, which may be owned by the building owner, municipality or a combination of both
- Whether the home is serviced with a storm drain connection
- Whether the home is serviced by a third pipe connection
- Whether an individual or shared sanitary service lateral services the home
- Whether downspouts and foundation drains are commonly connected to storm sewer systems, sanitary sewer systems, or foundation drain systems in their subdivision
- Presence of and operational information about any protective plumbing equipment that is in the residence (e.g., sump pumps or backwater valves)

Developers should provide a complete package of operations manuals for all equipment in the home related to I/I and flood risk, including sump pumps, backwater valves and other relevant items.

6.2. Collect and provide information to the municipality following flooding events

Building owners should collect and provide information to the municipality following flooding events. This measure is intended to ensure that all available information concerning flood occurrence that may be able to assist in identifying flood cause is communicated to the municipality.

The information collected by building owners/occupants following flood events may assist in assessing regions prone to high rates of I/I. The measure reflects the fact that neither insurers nor municipalities have a complete picture of flooding events, since sometimes residents report a flood to one or the other, but not both.

Lists of appropriate data to collect are available through a variety of resources, including CSA Z800-18, Basement Flood Protection and Risk Reduction.

6.3. Consider regular sanitary building drain and sanitary building sewer inspections

Building owners should be advised to consider regular sanitary building sewer inspections. This measure is intended to ensure that private-side SBSs are well maintained and not unduly contributing to infiltration and/or exposing the homeowner to flood risk associated with failed laterals.

A CCTV inspection of a private building sewer can be undertaken for about $350 (2017 dollars).[95] This is a small investment relative to the personal and societal costs of flooding that may result from failing infrastructure.

6.4. Investigate plumbing and drainage during windows of opportunity

Building owners should be encouraged to undertake plumbing and drainage investigations to assess the condition of sanitary building sewers and sanitary building drains during windows of opportunity. This measure is intended to proactively identify and address infiltration issues associated with sanitary building sewers.

Investigations should be done under the following conditions:

- Where there is high risk of I/I originating on the private side of the property line, as determined by the municipality
- During any significant renovations (e.g., renovations exceeding $100,000)[96]
- When any work is undertaken that affects the sanitary building drains and sanitary building sewers (e.g., infill development following a demolition)
- Other scenarios as determined by the municipality

6.5. Complete drainage inspections during significant renovations

The municipality should require thorough drainage inspections wherever large renovations are contemplated.[97] This measure is intended to identify defects in SBSs that may contribute to I/I entering the municipal sewer system and increase flood risk.

Thorough drainage inspections should be completed where the building owner applies for a building permit for renovations in excess of a certain amount (e.g., $100,000) for work related to sanitary building drains or sanitary building sewers.

6.6. Maintain key drainage features

Building owners should routinely maintain key drainage features. This measure is intended to proactively identify and address site drainage issues that may indirectly contribute to I/I.

This measure generally relates to ensuring that key drainage features (e.g., site grading and drainage, downspouts, sump pump discharge) remain protective against flooding and promote good drainage on the lot. This measure is intended to limit risk of water entering foundation drainage systems, which may contribute to I/I, depending on the plumbing arrangement of the building.

6.7. Complete thorough drainage inspections where there is risk of I/I occurring on the private side of the property line

The owner should complete thorough drainage inspections where there is risk of I/I occurring on the private side of the property line. This measure is intended to identify defects in SBSs that may contribute to I/I.

The measure is further meant to apply in instances where relevant stakeholders, including the municipality, believe that there is risk of I/I occurring on the private side of the property line.

6.8. Be aware of sump pump lifespan and replacement

Building owners should be made aware that sump pumps have a design life (typically 10 years or as specified by the manufacturer) depending on the application, and need to be replaced.[98] This measure is meant to reduce risk of sump pump failure, which increases risk of flooding and water entering sanitary systems via floor drains that are connected to SBSs.

A 10-year lifespan is a commonly accepted maximum lifespan for residential sump pumps. However, expected lifespan may be considerably shorter depending on operating conditions and quality of installation of the full sump system.[99]

6.9. Summary

Homeowner behaviour is an essential component of reducing I/I in sewer systems and reducing risk of flooding. Although homeowners have not traditionally taken charge of their private-side drainage and sewer pipes, this paradigm needs to shift. The advent of more severe flooding events is likely to bring these issues to the attention of homeowners.

Homeowners have already largely accepted the need to maintain a home’s roof, furnace, and smoke and carbon monoxide detectors. The need to maintain protective plumbing measures and equipment needs to be addressed as the new reality in Canada. This can be achieved by education programs delivered by municipal, provincial and federal governments.

7. Conclusion and next steps

There is a well-documented need to manage I/I in sewer infrastructure across Canada. The negative impacts of excessive I/I are well defined and include impacts to the environment, risks to public health and safety, and increased costs of managing sewer infrastructure for municipalities and households. I/I is also a major factor in basement flooding, which results in hundreds of millions of dollars in insured and uninsured losses each year in Canada.

The need to manage I/I will intensify as a number of factors have the potential to increase strain on sewer infrastructure, including greater urban development, changes in building use (e.g., more frequent use of basements as living space), and the expected impacts of climate change.

While it is widely known that older sanitary systems are prone to I/I, input from stakeholders across Canada and extensive evidence collected in Ontario have indicated that newly constructed sanitary systems exhibit excess and/or unacceptable rates of I/I. A number of factors have been identified as causal to this phenomenon, including inadequate construction practices, inadequate inspection and testing, gaps in codes and standards, jurisdictional issues and lack of education.

The goal of this project was to provide a foundation for national discussion concerning occurrence of excessive I/I in new sanitary sewer infrastructure, and to provide background information for the development of an NSC (guideline or standard). It is anticipated that developing a national guideline or standard will provide a basis for a significant increase in awareness of I/I in new construction, leading to improved practices on both the private and public sides of the property line to reduce I/I occurrence.

Measures presented in this report are preliminary and are expected to be refined as the project proceeds towards the development of an NSC; however, they are meant to indicate that the issue of I/I in new sewer infrastructure can be addressed through relatively straightforward and inexpensive measures. Many of the measures that could manage I/I in new sewers are already in use in some locations, or are meant to ensure conformance with existing codes and standards applied across Canada. More innovative methods are being tested or used in a few locations across North America.

7.1. Development of a National Standard of Canada

It is recommended that an NSC concerning I/I in new construction be developed, which may take the form of either a standard or a guideline. The development of an NSC will require ongoing consultations with all affected stakeholder groups across Canada, notably municipalities, which are typically responsible for regulation of sewer infrastructure design and construction, and the development sector, which is directly tasked with construction of the infrastructure. Further, several opportunities exist to review and potentially refine provisions contained within national and provincial building and plumbing construction codes, as well as local regulations that may be applied to govern sewer construction on the public and private sides of the property line.

7.2. Further work

This section outlines further work that has been suggested during the preparation of this document and related consultation. Much of this is likely outside the purview of an NSC at this point (e.g., further technical research is required), but this work is presented here for information.

National input: Many of the examples discussed in this document focus on the experience in Ontario, since that is where Norton's original research took place. The project's ESC, along with participants in a national stakeholder webinar and communications and comments from various stakeholders across Canada, provided additional input (see Section 3.4). Further, less formal information has been obtained by the lead author from numerous other locations across Canada via discussions and professional conference presentations, which further confirm the key concepts contained in the report. Regardless of this input, it is recommended that developers of the NSC continue to collect relevant input and consider examples from a wider geographical area.

Data collection and analysis: Collection of flow monitoring data from new subdivisions is starting to take place across Ontario. A recommendation from this project is that municipalities not only continue to collect relevant data, but also that a commonly accepted method for analyzing this data be developed. It is recommended that the technical committee involved in the development of the national standard or guideline pursue development of a set of recommendations for data collection and analysis.

Prioritization of measures: The intent of this project was to provide a comprehensive discussion of measures that, in the experience and opinion of the author team and informed by the ESC and additional external stakeholders, would mitigate risk of excessive I/I in new sanitary sewer infrastructure. It was noted, however, that some measures should be assigned a higher priority than others. For example, actions related to Section 4.1 "Conceptual/system management" may be considered a lower priority than other measures and could be assigned to an appendix rather than the main section of a national standard or guideline. Ongoing thorough review and consideration of all measures presented in this report should be incorporated into further phases of this work.

Time-of-sale requirements: Many stakeholders have noted that time-of-sale requirements, notably applied in some US jurisdictions, may show promise as a means of controlling risk of excessive I/I. Time-of-sale requirements specifically include measures such as CCTV inspections of laterals and review of the records by municipal staff, which must be done before sales processes can be completed. Measures have been effective where applied, but they have not been applied in Canada. Further investigation of this method is warranted.

General costing of I/I impacts: This report cited the cost to treat 1 L/s of I/I at $95,000 per year. This estimate was based on a treatment cost of $3.05/m^3. However, ESC members noted that treatment costs have traditionally been calculated only based on the marginal cost of the last m^3 treated. It would be useful to develop a commonly accepted method to cost the overall impacts of excessive I/I in advance of the development of an NSC.

Height of sewer infrastructure relative to groundwater: It was recognized that placement of sewer infrastructure below seasonally high GWT increases risk of infiltration. Locating building foundation in high/seasonally high groundwater areas also increases infiltration risk for both buildings and private-side sewer infrastructure. The ESC's consensus was that further study of acceptable heights of sewer infrastructure and foundations relative to groundwater is warranted. This work may include developing acceptable prescriptive separations (e.g., 0.3 m, 0.6 m, 0.75 m, plus additional freeboard/safety factor) between sewer infrastructure and seasonally high groundwater and/or acceptable alternative solutions that would limit the risk of infiltration over the lifespan of the sewer.

Review and revision of peak long-term I/I values to be used in system design: Existing long-term peak I/I values (0.10 to 0.28 L/s/ha in Ontario) used in design are badly out of date. These figures were developed when foundation drains and roof leaders were still commonly connected to sanitary sewer systems. Many stakeholders identified a need to develop modern peak long-term I/I values for design. Also, expressing this value in L/s/ha, which is how it is used in sanitary sewer design sheets, does not account for different densities used in development (modern development is frequently denser than older development). Whether peak long-term I/I design values for new construction still need to be associated with a return period (given the above) needs to be evaluated. This work is complex and will involve detailed evaluation, given how important it is. It is recommended that a research project be established to review and modernize these values.

Impact assessment: This report focused on measures that would mitigate risk of I/I and are generally acceptable practices in the sewer design and construction industry. Many of the measures outlined in this report would not necessarily add additional costs for construction and management of sewer systems, as they are already required by various codes and standards concerning public- and private-side construction in Canada. However, a full impact analysis has not yet been conducted and should be incorporated into the next phase of this project (i.e., development of national standard or guideline).

Additional specific topics that may require consideration in an impact assessment include (as identified by the author team, the ESC or based on additional stakeholder input):

- Supply of materials identified in the report. ESC participants specifically identified concerns related to availability of differential pipe sizes for private-side sanitary and storm building sewers.
- Implications associated with placement of building sewers (i.e., sanitary pipe on right, storm on left) to reduce risk of cross-connections. While this was identified by ESC members as common practice in some regions of Canada (notably Quebec), other ESC members recommended that the feasibility of the approach should be discussed with the development community.
- Costs and benefits associated with construction of sewers and manholes to watertightness standards applied for water systems in high groundwater conditions.
- Measures associated with frequency of inspection. Though several measures identified in this report included increasing the regularity of inspections, ESC members noted that limited capacity may exist for these types of measures in many jurisdictions.
- Costs and benefits of CCTV inspection of the public- and private-side laterals (note that these are required per CAN/CSA 182.11).

End notes

1 National Research Council of Canada. 2015. National Building Code of Canada 2015. Ottawa: National Research Council.

2 https://www.britannica.com/science/water-table

3 Metcalf & Eddy. 1981. Wastewater Engineering: Collection and Pumping of Wastewater. Wakefield MA: Metcalf & Eddy.

4 Metcalf & Eddy. 1981. Wastewater Engineering: Collection and Pumping of Wastewater. Wakefield MA: Metcalf & Eddy.

5 United States Environmental Protection Agency. 2018. Urban Runoff: Low Impact Development. Accessed March 2019 from https://www.epa.gov/nps/urban-runoff-low-impact-development

6 National Research Council of Canada. 2015. National Building Code of Canada 2015. Ottawa: National Research Council.

7 National Research Council of Canada. 2015. National Building Code of Canada 2015. Ottawa: National Research Council.

8 National Research Council of Canada. 2015. National Building Code of Canada 2015. Ottawa: National Research Council.

9 National Research Council of Canada. 2015. National Building Code of Canada 2015. Ottawa: National Research Council.

10 Amec Foster Wheeler and Credit Valley Conservation. 2017. National Infrastructure and Buildings Climate Change Adaptation State of Play Report. Prepared for the Infrastructure and Buildings Working Group, part of Canada's Climate Change Adaptation Platform. Available from http://www.ibwgsop.org/

11 See, for example: *Toronto Star*. 2018. Worried about local water and sewer capacity, Toronto staff move to pause condo development at Yonge-Eglinton. Accessed March 2019 from https://www.thestar.com/news/gta/2018/04/03/worried-about-local-water-and-sewer-capacity-toronto-staff-move-to-pause-condo-development-at-yonge-eglinton.html

12 Estimated at 7%/decade. Source: York Region. 2015. Inflow and Infiltration Reduction Strategy: 2015 Best in Class Update. Newmarket, ON: York Region.

13 Federation of Canadian Municipalities and National Research Council. 2003. Infiltration/Inflow Control/Reduction for Wastewater Collection Systems. A Best Practice by the National Guide to Sustainable Municipal Infrastructure. Ottawa: FCM and NRC.

Also see Hodgson, J.E., Ward, C.J.W., and Schultz, N.U. 1995. Sanitary Sewage Discharges in the City of Edmonton, Alberta. National Conference on Sanitary Sewer Overflows (SSOs), Washington, DC, April 24–26, 1995, pp. 403-413.

14 US EPA. 2014. Quick Guide to I/I.

15 Based on City of Kitchener water and sewer rates: https://www.kitchenerutilities.ca/en/ratesoffers/Water---Sewer-Rates.asp

16 See, for example:

Amec Foster Wheeler and Credit Valley Conservation. 2017. National Infrastructure and Buildings Climate Change Adaptation State of Play Report. Prepared for the Infrastructure and Buildings Working Group, part of Canada's Climate Change Adaptation Platform. Available from http://www.ibwgsop.org/

Andrey, J., Kertland, P., and Warren, F.J. 2014. Water and Transportation Infrastructure; in Canada in a Changing Climate: Sector Perspectives on Impacts and Adaptation. F.J. Warren and D.S. Lemmen (ed.). Ottawa: Government of Canada, p. 233-252.

Canadian Standards Association. 2018. CSA Z800-18: Basement Flood Protection and Risk Reduction Guideline. Toronto: Canadian Standards Association.

Canadian Standards Association. 2012. CSA PLUS 4013-12: Development, Interpretation, and Use of Rainfall Intensity-Duration-Frequency (IDF) Information: Guideline for Canadian Water Resources Practitioners. Technical Guide. Toronto: Canadian Standards Association.

Credit Valley Conservation and Zizzo Strategy. 2018. Developing a Stormwater Quality

Management Standard (QMS) in Light of a Changing Climate. Ottawa: Engineers Canada and the Standards Council of Canada.

17 Canadian Standards Association. 2012. CSA PLUS 4013-12: Development, Interpretation, and Use of Rainfall Intensity-Duration-Frequency (IDF) Information: Guideline for Canadian Water Resources Practitioners. Technical Guide. Toronto: Canadian Standards Association.

Semadeni-Davies, A., Hernebring, C., Svensson, G., and Gustasfsson, L. 2008. The impact of climate change and urbanization on drainage in Helsingborg, Sweden: Combined sewer system. *Journal of Hydrology*, 350: 100-113.

18 GENIVAR Inc. 2011. Climate Change Vulnerability Assessment of the Town of Prescott's Sanitary Sewage System. Markham, ON.

Nasrin, T., Sharma, A., and Muttil, N. 2017. Impact of short duration rainfall events on sanitary sewer network performance. *Water*, 9 (3): 225-242.

Torres, M. 2013. Infiltration and Inflow in Oslo Municipality: Assessment of I/I Volumes, Sources, and Relationship with Measurable Wastewater System's Characteristics. Master's Thesis. Norwegian University of Life Sciences.

Zhang, Z. 2007. Estimating rain derived inflow and infiltration for rainfalls of varying characteristics. *Journal of Hydraulic Engineering*, 33 (1): 98-105.

Zhang, M., Liu, Y., Cheng, X., Zhu, H., Shi, H., and Yuan, Z. 2018. Quantifying rainfall-derived inflow and infiltration in sanitary sewer systems based on conductivity monitoring. *Journal of Hydrology*, 558: 174-183.

19 Denault, C., Millar, R., and Lence, B. 2006. Assessment of possible impacts of climate change in an urban catchment. *Journal of the American Water Resources Association*, 42 (3): 685-697.

GENIVAR Inc. 2011. Climate Change Vulnerability Assessment of the Town of Prescott's Sanitary Sewage System. Markham, ON.

Metro Vancouver. 2014. Inflow and Infiltration Allowance Assessment – Integrated Liquid Waste Management Plan. Vancouver, BC.

Metro Vancouver. 2008. Vulnerability of Vancouver Sewerage Area Infrastructure to Climate Change. Vancouver, BC.

20 Semadeni-Davies, A. 2004. Urban water management versus climate change: Impacts on cold region waste water inflows. *Climatic Change*, 64: 103-126.

21 Flood, J., and Calhoon, L. 2011. Risk to coastal wastewater collection systems from sea-level rise and climate change. *Journal of Coastal Research*, 27 (4): 652-660.

22 Mikalson, D., Guo, Y., and Adams, B. 2012. Rainfall derived inflow and infiltration modeling approaches. *Journal of Water Management Modelling*, January. DOI: 10.14796/JWMM.R245-08.

23 See Amec Foster Wheeler and Credit Valley Conservation. 2017. Infrastructure and Buildings Adaptation State of Play. Prepared for the Infrastructure and Buildings Working Group, part of Canada's Adaptation Platform. Available from www.ibwgsop.org

24 Canadian Standards Association. 2018. CSA Z800-18: Basement Flood Protection and Risk Reduction. Toronto: Canadian Standards Association.

Sandink, D. 2015. Urban flooding and ground-related homes in Canada: An overview. *Journal of Flood Risk Management*, 9 (3): 208-223.

25 Institute for Catastrophic Loss Reduction. 2009. Handbook for Reducing Basement Flooding. Toronto: Institute for Catastrophic Loss Reduction. Adapted for Canadian Standards Association. 2018. Z800-18 Basement Flood Protection and Risk Reduction Guideline. Toronto: Canadian Standards Association.

26 Insurance Bureau of Canada. 2018. 2018 Facts of the Property and Casualty Insurance Industry in Canada. Toronto: Insurance Bureau of Canada.

27 Worsely, B. 2005. City of Peterborough Flood Reduction Master Plan. UMA/AECOM. Peterborough, ON: City of Peterborough.

28 Insurance Bureau of Canada. 2018. 2018 Facts of the Property and Casualty Insurance Industry in Canada. Toronto: Insurance Bureau of Canada.

29 Environment and Climate Change Canada. 2017. Engineering Climate Datasets, via Simonovic, et al. 2019. IDF_CC Tool. Accessible from https://www.idf-cc-uwo.ca/home.aspx

30 Insurance Bureau of Canada. 2018. 2018 Facts of the Property and Casualty Insurance Industry in Canada. Toronto: Insurance Bureau of Canada.

31 Environment and Climate Change Canada. 2017. Engineering Climate Datasets, via Simonovic, et al. 2019. IDF_CC Tool. Accessible from https://www.idf-cc-uwo.ca/home.aspx

32 Insurance Bureau of Canada. 2018. 2018 Facts of the Property and Casualty Insurance Industry in Canada. Toronto: Insurance Bureau of Canada.

33 Duong, J. 2016. Recovering from the Flood: Halton's Basement Flooding Mitigation Program. Presentation to ICLR Friday Forum Series, November 2016.

34 CatIQ. 2018. Catastrophe Bulletins. Toronto: CatIQ. Reproduced with permission.

35 CatIQ. 2018. Catastrophe Bulletins. Toronto: CatIQ. Reproduced with permission.

36 City of Windsor. 2017. Special Meeting of City Council. Agenda, January 23, 2017. Windsor: City of Windsor.

Town of Tecumseh. 2016. Town of Tecumseh Flooding Event. News Release, September 29, 2016.

37 CatIQ. 2018. Catastrophe Bulletins. Toronto: CatIQ. Reproduced with permission.

38 Insurance Bureau of Canada. 2018. 2018 Facts of the Property and Casualty Insurance Industry in Canada. Toronto: Insurance Bureau of Canada.

39 CatIQ. 2018. Catastrophe Bulletins. Toronto: CatIQ. Reproduced with permission.

40 CatIQ. 2018. Catastrophe Bulletins. Toronto: CatIQ. Reproduced with permission.

41 Insurance Bureau of Canada. 2019. Facts of the Property and Casualty Insurance Industry. Toronto: Insurance Bureau of Canada.

42 Catastrophe Indices and Quantification. 2019. CatIQ Database. Toronto.

Friedland, J., Cheng, H., and Peleshok, A. 2014. Water Damage Risk and Property Insurance Pricing. Prepared by KPMG. Ottawa: Canadian Institute of Actuaries.

Sandink, D., Kovacs, P., Oulahen, G., and Shrubsole, D. 2016. Public relief and insurance for residential flood losses in Canada: Current status and commentary. *Canadian Water Resources Journal/Revue canadienne des ressources hydriques*, 41 (1-2), 220-237.

43 Kesik, T. 2015. Management of Inflow and Infiltration in Urban Developments. Toronto: Institute for Catastrophic Loss Reduction.

44 Chambers, K. 2013. Weeping Tile Disconnection to Reduce the Impact of Basement Flooding in London, Ontario. Second Basement Flood Symposium, Institute for Catastrophic Loss Reduction, Toronto.

45 Garrat, C., Rutherford, S., and Macdonald, R. 2013. An Approach Towards Private Sewer Lateral Certification in Real Estate Transactions. Prepared for Metro Vancouver: Pinna Sustainability.

Metro Vancouver. 2010. Integrated Liquid Waste and Resource Management Plan. Vancouver: Metro Vancouver.

46 Water Environment Research Foundation. 2006. Methods for Cost-Effective Rehabilitation of Private Lateral Sewers. Alexandria, VA: Water Environment Research Foundation.

47 Nelson, D., Cantrell, C., Gross, J. 2005. Columbus Private Source Infiltration and Inflow Identification Pilot Program. Proceedings of the Water Environment Federation, WEFTEC 2005, Session 81 through Session 90, pp. 6845 to 6859.

48 Pawlowski, C., Rhea, L., Shuster, D., and Braden, G. 2014. Some factors affecting inflow and infiltration from residential sources in a core urban area: Case study in Columbus, Ohio, neighborhood. *Journal of Hydraulic Engineering*, 140: 105-114.

49 Canadian Standards Association. 2019. CSA Z800-18: Basement Flood Protection and Risk Reduction Guideline. Toronto: Canadian Standards Association.

50 Norton Engineering. 2017.

51 Canadian Standards Association. 2019. CSA Z800-18: Basement Flood Protection and Risk Reduction Guideline. Toronto: Canadian Standards Association.

52 Robinson, B. 2018. Building Code Regulations and Engineering Standards As They Relate to I/I in New Sanitary Sewer Systems. Kitchener: Norton Engineering Inc.

53 US EPA. 2014. Quick Guide for Estimating Infiltration and Inflow for Region 1 NPDES Annual Reporting. https://www3.epa.gov/region1/sso/pdfs/QuickGuide4EstimatingInfiltrationInflow.pdf

54 Robinson, B. 2018. Building Code Regulations and Engineering Standards As They Relate to I/I in New Sanitary Sewer Systems. Kitchener: Norton Engineering Inc.

55 Note: A building code change request was submitted for the National Building Code of Canada by ICLR in 2013 to clarify where foundation drain connections to sanitary should be permitted, with an argument that they should be restricted/prohibited in almost all scenarios.

56 Meeting, IPEX Representatives, June 2019: Cambridge.

57 IPEX Inc. 2015. Installation Guide - Municipal Systems - PVC SEWER PIPE & FITTINGS 100 mm – 1200 mm (4" – 48"). IPEX Inc.

58 Robinson, B. 2017. Inflow and Infiltration in New Subdivisions. Kitchener: Norton Engineering Inc.

59 See, for example: Kyriazis, J., Zizzo, L., and Sandink, D. 2017. Assessing Local Mandatory Measures to Reduce Flood Risk and Inflow & Infiltration in Existing Homes. Toronto: Institute for Catastrophic Loss Reduction.

60 See, for example: Kyriazis, J., Zizzo, L., and Sandink, D. 2017. Assessing Local Mandatory Measures to Reduce Flood Risk and Inflow & Infiltration in Existing Homes. Toronto: Institute for Catastrophic Loss Reduction.

61 Norton Engineering research, To be published in 2019

62 Norton Engineering research, to be published in 2019

63 Robinson, B.and Lapp, D. 2017. Role of Professional Engineer Signoff of New Infrastructure. Toronto: ES&E.

64 Norton Engineering, 2017.

65 Robinson, B. 2017. Inflow and Infiltration in New Subdivisions. Kitchener: Norton Engineering Inc.

66 Norton Engineering, 2017.

67 Norton Engineering, 2017.

68 Canadian Standards Association. 2018. CSA-Z800-18: Basement Flood Protection and Risk Reduction. Toronto: Canadian Standards Association.

69 Canadian Standards Association. 2018. CSA-Z800-18: Basement Flood Protection and Risk Reduction. Toronto: Canadian Standards Association.

Sump and Sewage Pump Manufacturers' Association. 2013. For New or Replacement Sump Pumps: Guide for Installation. Indianapolis: SSPMA.

70 BC Housing. 2017. A Builder's Guide to Site and Foundation Drainage – Best Practices for Part 9 Houses. December 2017 Draft. Victoria: BC Housing. Used with permission.

71 See:

American Society of Civil Engineers. 2013. ANSI/ASCE/EWRI 12-13 Standard Guidelines for the Design of Urban Subsurface Drainage. Reston VA: ASCE.

BNQ 3661-500/2012. 2012. Dépôts d'ocre dans les systèmes de drainage des bâtiments. PARTIE II : Méthodes d'installation proposées pour nouveaux bâtiments et bâtiments existants. Montreal: BNQ.

Canadian Standards Association. 2018. Z800-18 Basement Flood Protection and Risk Reduction Guideline. Toronto: Canadian Standards Association.

72 See, for example:

Sentence 10.5.80.40(2) of the City of Toronto Zoning By-Law 569-2013 states: "In the Residential Zone category, for a detached house or semi-detached house, and for an individual townhouse dwelling unit where an individual private driveway leads directly to the dwelling unit, the elevation of the lowest point of a vehicle entrance in a main wall of the building must be higher than the elevation of the centreline of the driveway at the point where it intersects a lot line abutting a street."

Sentence 4.1.4.(g)(i) of the City of Vaughan's Zoning By-Law 1-88 (Comprehensive Zoning By-Law) (2012) states that "all driveways shall have a positive slope away from all parts of the building or structure to the street for all single family detached dwellings, semi-detached dwellings, townhouse dwellings, and street townhouse dwellings."

Also see City of Vaughan. 2016. City of Vaughan Urban Design Guidelines for Infill Development in Established Low-Rise Residential Neighbourhoods (Draft). Vaughan: City of Vaughan.

73 Canadian Standards Association. 2018. Z800-18 Basement Flood Protection and Risk Reduction Guideline. Toronto: Canadian Standards Association.

74 Canadian Standards Association. 2018. Z800-18 Basement Flood Protection and Risk Reduction Guideline. Toronto: Canadian Standards Association.

75 Canadian Standards Association. 2018. Z800-18 Basement Flood Protection and Risk Reduction Guideline. Toronto: Canadian Standards Association.

76 BC Housing. 2017. A Builder's Guide to Site and Foundation Drainage – Best Practices for Part 9 Houses. December 2017 Draft. Victoria: BC Housing. Used with permission.

77 Norton research, to be published 2019.

78 E.g., IPEX Solvent Welding Guide, 2016

79 E.g., IPEX Solvent Welding Guide, 2016

80 Norton communication with Building Officials User Group, 2019

81 Robinson, B., Sandink, D., Parente, A., Manzon, C., Copland, T., and D'Amico, R. 2017. Unacceptable Inflow and Infiltration in New Subdivisions. Phase 1 Report. Waterloo: Norton Engineering Inc.

Robinson, B. and Sandink, D. 2017. Research shows 'unacceptable' high rates of sewer inflow, infiltration in new subdivisions. *Environmental Science and Engineering*, October 2017.

Robinson, B. et al. 2017. Project to Address Unacceptable Inflow and Infiltration (I/I) in New Subdivisions. Phase 1 Final Report (2015–2017). Norton Engineering Inc., York Region, City of London, City of Windsor, Institute for Catastrophic Loss Reduction and Region of Peel.

Robinson, B., D'Amico, R., Motala, I., Sandink, D., and Hill, C. 2016. We Need to Address I/I in New Subdivisions Immediately! WEAO 2016 Technical Conference, Niagara Falls, Ontario.

82 Norton Engineering, 2017.

83 Reported by plumbers in Ontario, Norton research.

84 Halifax Water. 2016. Design and Construction Specifications (Water, Wastewater and Stormwater Systems). Halifax: Halifax Water.

Ministry of Environment. 2008. Design Guidelines for Sewage Works 2008. Toronto: Ministry of Environment.

Ontario Provincial Standards for Roads and Public Works. 2011. 1006.020 Sewer Service Connections for Flexible Main Pipe Sewer. Toronto: Province of Ontario.

85 See:

American Society of Civil Engineers. 2013. ANSI/ASCE/EWRI 12-13 Standard Guidelines for the Design of Urban Subsurface Drainage. Reston VA: ASCE.

BC Housing. 2017. A Builder's Guide to Site and Foundation Drainage – Best Practices for Part 9 Houses. December 2017 Draft. Victoria: BC Housing. Used with permission.

Sandink, D. 2018. Part A: Basement Flood. In ICLR-Durham Region. Durham Region Climate Resilience Standard for New Houses. Whitby: Durham Region.

86 See, for example, City of Ottawa. 2018. Technical Bulletin ISTB 2018-04. Ottawa: City of Ottawa.

87 Scherer, T. 2015. Sump Pump Questions. Fargo: North Dakota State University Extension Service.

88 Sump and Sewage Pump Manufacturers' Association. 2013. For New or Replacement Sump Pumps: Guide for Installation. Indianapolis: SSPMA.

89 Sump and Sewage Pump Manufacturers' Association. 2013. For New or Replacement Sump Pumps: Guide for Installation. Indianapolis: SSPMA.

90 Sandink, D., Dale, N., Robinson, B., and Okrutney, P. 2018. Addressing Critical Information Gaps: Practical Guidance for Private Side Drainage Systems to Reduce Basement Flood Risk. Submitted to the National Research Council of Canada, December 2018.

91 Kovacs, P., Guilbault, S., and Sandink, D. 2014. Cities Adapt to Extreme Rainfall. Toronto: Institute for Catastrophic Loss Reduction.

Sandink, D. 2009. Urban flooding, homeowner hazard perceptions and climate change. *Public Sector Digest*, Winter 2009.

92 Norton research, to be published 2019

93 Sandink, D., Dale, N., Robinson, B., and Okrutney, P. 2018. Addressing Critical Information Gaps: Practical Guidance for Private Side Drainage Systems to Reduce Basement Flood Risk. Submitted to the National Research Council of Canada, December 2018.

94 Sandink, D., Dale, N., Robinson, B., and Okrutney, P. 2018. Addressing Critical Information Gaps: Practical Guidance for Private Side Drainage Systems to Reduce Basement Flood Risk. Submitted to the National Research Council of Canada, December 2018.

95 Cost cited by Bradford West Gwillimbury (Ontario), 2017.

96 See, for example:

City of Surrey. 2008. Surrey Stormwater Drainage Regulation and Charges By-law, 2008, No. 16610. Surrey: City of Surrey.

Specific clauses:

- **36. When an application for a *service connection* accompanies a building permit with the construction value greater than $100,000 or where a *parcel* is being redeveloped, the following shall apply to the *service connection* and the *building drain*.**

  (a) if the *service connection* or *building drain* is less than 30 years old, the *owner* must provide a video inspection for the City to review. The owner shall repair or replace the connection if the connection has excessive damage as determined by the *General Manager, Engineering*;

  (b) if the *service connection* or *building drain* is 30 years old or older a replacement or new service is required;

  (c) all no-corrode, asbestos cement or clay service pipes of any age or condition shall be replaced;

  (d) any shared *service connection* or *building drain* shall be replaced; and

  (e) all costs associated with the above are the responsibility of the *owner*.

City of Surrey. 2008. Surrey Sanitary Sewer Regulation and Charges By-law, 2008, No. 16611. Surrey: City of Surrey.

Specific clauses:

- **39. When an application for a *service connection* accompanies a building permit with the construction value greater than $100,000 or where a parcel is being redeveloped, the following shall apply to the *service connection* and the *building sanitary sewer*:**

  (a) if the *service connection* and *building sanitary sewer* is less than 30 years old, the *owner* must provide a video inspection and recommendation for the *City* to review. The owner shall repair or replace the connection if the *City* determines that the connection is not adequate for service or has excessive damage;

  (b) if either the service connection or the *building sanitary sewer* is 30 years old or older, a replacement or new service is required;

  (c) all no-corrode, asbestos cement or clay service pipes of any age or condition shall be replaced;

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98 Sandink, D., Dale, N., Robinson, B., and Okrutney, P. 2018. Addressing Critical Information Gaps: Practical Guidance for Private Side Drainage Systems to Reduce Basement Flood Risk. Prepared for the National Research Council of Canada.

99 Sandink, D., Dale, N., Robinson, B., and Okrutney, P. 2018. Addressing Critical Information Gaps: Practical Guidance for Private Side Drainage Systems to Reduce Basement Flood Risk. Prepared for the National Research Council of Canada.

Institute for Catastrophic Loss Reduction
Institut de prévention des sinistres catastrophiques

Toronto Office
20 Richmond Street East
Suite 210
Toronto, Ontario, Canada
M5C 2R9

416-364-8677

416-364-5889

London Office
Western University
Amit Chakma Building, Suite 4405
1151 Richmond Street
London, Ontario, Canada
N6A 5B9

519-661-3234

519-661-4273

info@iclr.org

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