Practical guidance for private-side drainage systems to reduce basement flood risk: addressing critical information gaps

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PRACTICAL GUIDANCE FOR PRIVATE-SIDE DRAINAGE SYSTEMS TO REDUCE BASEMENT FLOOD RISK

Addressing Critical Information Gaps

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Practical Guidance for Private-Side Drainage Systems to Reduce Basement Flood Risk: Addressing Critical Information Gaps

Prepared by the Institute for Catastrophic Loss Reduction with funding and oversight from NRC's Climate-Resilient Buildings and Core Public Infrastructure Initiative

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List of Abbreviations

ABS: acrylonitrile-butadiene-styrene
AHJ: authority having jurisdiction
BCBC: British Columbia Building Code 2018
BCPC: British Columbia Plumbing Code 2018
BNQ: Bureau de normalisation du Québec
CCTV: closed-circuit television
CSA: CSA Group
DR: dimension ratio
FDC: foundation drainage collector
HDPE: high-density polyethylene
HGL: hydraulic grade line
ICLR: Institute for Catastrophic Loss Reduction
I/I: inflow/infiltration
LID: low-impact development
LTF: lowest top of footing
MECP: Ministry of Environment, Conservation and Parks of Ontario
MOE: Ministry of the Environment of Ontario (former name)
NBC: National Building Code of Canada 2015
NPC: National Plumbing Code of Canada 2015
NRC: National Research Council of Canada
OBC: Ontario Building Code 2012
OPSD: Ontario Provincial Standard Drawing
OPSS: Ontario Provincial Standard Specification
PVC: polyvinyl chloride
TC: technical committee
TRCA: Toronto and Region Conservation Authority

1. Introduction

1.1. Background and Purpose

This guide is intended to provide a basis for the development of guidance on foundation drainage systems, sump pump systems, backwater protection for foundation drainage systems, and private-side sanitary sewer connections (also referred to as "sanitary building sewers"), as these components of private-side drainage systems are used to mitigate basement flood risk for new and existing National Building Code of Canada (NBC) Part 9 residential buildings.[1] The recommendations in this guide are meant to complement the measures for basement flood protection outlined in CSA Z800-18, "Guideline on Basement Flood Protection and Risk Reduction."[2]

This guide originated from discussions about foundation drainage and sump pump standards and guidelines in Canada that were held amongst members of the Technical Committee on Basement Flood Protection who were involved in the development of Clause 6 of CSA Z800-18 (which is related to technical recommendations for flood protection). Specifically, it was noted that there is limited national guidance that is widely accepted and applied on foundation drainage and sump pump systems, which are critical components of private-side drainage systems. Another important driving force and source of information for this guide was discussion amongst members of the Basement Flood Technical Committee involved in the development of the draft standard entitled "Durham Region Climate Resilience Standard for New Houses" (referred to as the "Durham Standard (2018)"; see Box 1a).[3]

This guide is meant to (a) help begin the process of filling gaps in information related to the protection of homes from basement flooding, and (b) provide information to assist in the implementation of the measures for private-side drainage and flood protection outlined in CSA Z800-18.

This guide does not, in its current form, provide guidance for regions of northern Canada that may be vulnerable to changes in permafrost conditions. Rather, this guide focuses largely on urban areas of southern Canada that have experienced repeated basement flood events and where local authorities have developed guidance on topics relevant to this guide.

Box 1a: "Durham Region Climate Resilience Standard for New Houses" (Durham Standard (2018))

In fall 2017, the Institute for Catastrophic Loss Reduction (ICLR) carried out work on behalf of the Region of Durham, Ontario, to develop a draft municipal standard intended to increase the resilience of new homes complying with Part 9 of the Ontario Building Code (OBC). This project was initiated as part of the Region's Community Climate Change Adaptation Plan.

The Durham Standard (2018) was developed to reduce the risks associated with short-duration, high-intensity rain events (i.e., risk of urban or basement flooding), extreme wind or tornados, and extreme heat. Its development was supported by technical committees focused on each of these hazards.

Contact D. Sandink (dsandink@iclr.org) for more information.

1.2. Content

This guide focuses on the topics of foundation drainage systems, sump pump systems and backwater protection, and sanitary building sewers. Each of these topics is covered in one of the following sections of the guide. Each section includes:

- a list of draft recommendations;
- observations on common practices and guidelines for the design and installation of relevant systems and components; and
- a list of knowledge gaps and research and data needs.

The draft recommendations are meant to address issues discussed in the observations. The recommendations are intended to promote discussion and are not considered final at this stage. They are meant as general guidelines that may be considered applicable to NBC Part 9 residential buildings and serve to complement the measures presented in CSA Z800-18. Other resources, including industry professionals, should be consulted for high-risk or uncommon drainage and flood risk scenarios.

Section 2 of this guide provides a discussion of foundation drainage systems, which draws significantly on two documents produced for the Canadian context: "Builder Guide to Site and Foundation Drainage – Best Practices for Part 9 Buildings in British Columbia" (Horizon Engineering (2020)),[4] and BNQ 3661-500/2012, "Dépôts d'ocre dans les systèmes de drainage des bâtiments" (available in French only).[5] Although BNQ 3661-500/2012 is meant specifically for areas exposed to iron ochre, this standard provides detail with respect to best practices for the design of foundation drainage systems in the Canadian context, with specific emphasis on facilitating system inspection and maintenance. Additional resources are referenced in Section 2 as necessary.

Improper functioning and failure of foundation drainage systems can occur in both older buildings and in relatively new construction. Spot or full excavations around building foundations to access, maintain and repair foundation drainage systems result in considerable costs for homeowners. The methods outlined in existing guidance documents and standards may be applied to facilitate access to these systems for maintenance and repair, which could significantly reduce the associated costs for homeowners and improve system performance and lifespan.

However, conflicting technical guidance exists with respect to best practices for the design of foundation drainage systems, and inconsistent design practices are used across Canada. Some of these inconsistent design practices are the result of inconsistencies in the interpretation of construction code provisions governing the design and installation of foundation drainage systems, including provisions related to providing access or cleanouts. Additional issues related to foundation drainage systems include inconsistent guidance with respect to the location of these systems relative to groundwater levels, a need to ensure that private-side features designed to promote the infiltration of surface water into the ground do not unnecessarily increase the loads on these systems, and uncertainty with respect to the lifespan of these systems under various operating conditions. The need to consider these issues is exacerbated by the increased use of basements as living space.

Section 3 of this guide covers sump pump system design (for pumped foundation drainage systems) and methods applied to protect foundation drainage systems from backwater. The section largely relies on widely available, though varied, standards and on design drawings produced by municipalities across Canada.

Sump pump system failure is a major cause of basement flood damage and insured loss. This failure may be caused by mechanical failure of sump pumps, overwhelming of systems due to high rates of foundation drainage flow into sump pits, power failure, inadequate site grading and drainage, or inadequate maintenance, among other factors. Forensic engineering investigations of failed sump pump systems have revealed a number of basic causes of sump pump failure, including the lack of backup power and the failure of simple, inexpensive sump pump components.

Aside from basic provisions in national and provincial construction codes, there exists limited consistent, authoritative guidance on sump pump system design and installation for the Canadian context. Municipalities across Canada have developed location-specific guidance on sump pump system design, with varied approaches to discharge pipes, connection of discharge pipes via downpipes to building sewer connections, temporary or emergency drainage of sump pump systems into building sewer connections (including sanitary sewer connections), etc.

The discharge options for foundation drainage systems depend on site conditions, including slope, proximity to ravines, lot size and carrying capacity for sump pump discharge, capacity of storm systems, and the existence of foundation drainage collector (FDC) systems. Backwater valves may be applied to protect gravity-drained foundation drainage systems from backwater; however, there is limited guidance with respect to the installation of backwater valves for this application. Furthermore, professionals concerned with the municipal side of the property line may express a preference for the use of sump pumps to provide a hydraulic break between foundation drainage systems and municipal systems, while those concerned with building design and construction tend to avoid the use of pumps and prefer gravity drainage wherever possible. A similar observation has been made about sanitary sewer backwater protection, regarding the use of sewage ejectors for basement sanitary drainage.

When backwater valves are used to protect gravity-drained foundation drainage systems, additional means of discharging foundation drainage may be required. For example, if backwater valves will be closed for extended periods of time, sump pump systems should be provided to discharge foundation drainage. Limited guidance is available for the design of gravity-drained foundation drainage systems that include both backwater valves and sump pump systems.

Section 4 of this guide covers sanitary building sewers. This section relies on municipal and provincial standards for sanitary sewer connections, which typically include prescriptive provisions that are more stringent than those of provincial construction codes for sanitary building sewers, but apply only on the public side of the property line.

Construction code provisions governing sanitary building sewers differ from the provisions of standards commonly applied on the municipal side of the property line (e.g., design and construction standards for municipal-side sanitary service connections or "stubs"). These standards specify more stringent requirements for pipe material, jointing, grade, bedding, embedment, backfill and compaction. They may also specify means to reduce the risk of water backflow through pipe trenches. In general, because soil conditions are not expected to differ between the municipal side and the private side within a subdivision, standards for municipal-side sanitary service connections may also be adopted for private-side sanitary building sewers.

> **Note:** The recommendations that are highlighted in grey are considered to be of higher priority or certainty.

2. Foundation Drainage Systems

2.1. Recommendations

2.1.1. Site Grading and Drainage

- Site grading and drainage practices should be applied to reduce the accumulation of surface water near the building's foundation. Refer to CSA Z800-18 for additional detail on site grading and drainage.
- Site grading and drainage should comply with the requirements set out by the authority having jurisdiction (AHJ).

2.1.2. Backfill

- Free-draining materials should be used for foundation excavation backfill.
- Where possible, clear gravel with a gradation of 12.7 mm to 25 mm (1/2 in. to 1 in.) should be used for backfill material placed against foundation walls.[4] Preferably, clean, well-graded sand backfill (maximum 8% silt content) may be used for backfill against foundation walls.[4]
- Both rough and final grades should slope away from the building foundation (2% grade where appropriate, as approved by the local AHJ).[4]
- Backfill should be capped with an impermeable surface as described in CSA Z800-18.

2.1.3. Downspout Discharge

- Downspout discharge should generally comply with CSA Z800-18, as approved by the AHJ.
- Where downspouts are made to drain to a municipal receiving system (e.g., storm sewer, downspout collector):
  - Downspout drainage should be managed by a separate sewer connection (e.g., one installed high enough to allow for gravity drainage, but deep enough to provide frost protection).
  - Where downspout collection pipes are fastened to the foundation wall, they should be adequately fastened (e.g., according to the specifications in Box 2a[6,A]) to reduce the risk of dislocation during backfill, cracking,

Box 2a: City of Windsor Specifications for Collection Pipes Anchored to Foundation Walls

- Use 3/4 in. wide 20 gauge galvanized steel straps.
- Use UCAN 1/4 in. × 1-1/4 in. nail drive fasteners (or equivalent).
- Straps with 1 in. wide polyvinyl chloride (PVC) saddles and anchors should be placed on the pipe.
- Saddles not required for black acrylonitrile-butadiene-styrene (ABS) Schedule #40.
- Support spacing:
  - Maximum spacing of straps is 16 in. for depths of up to 4 ft.
  - Maximum spacing of straps is 12 in. for depths of 4 ft. to a maximum depth of 6 ft.
- At least one strap required at all horizontal fittings.*
- Vertical piping must be supported to prevent lateral movement (including downspout downpipes, cleanouts).

*Fittings, notably couplings, are considered the weakest point in the piping system.

[A] Personal communication between Barbara Robinson and Morris Harding, Chief Building Official, Town of Lakeshore, Ontario, November 2017: "[…] currently we ask for a min. 12 in. o.c. strapping, with anchors that [are] pre-drilled into the concrete wall. We are now considering not accepting strapping anchored to the wall, we are looking into construction of a p.t. wood wall or resting on the undisturbed soil adjacent to the foundation."

failed joints and other issues causing downspout discharge to leak from pipes and enter the backfill zone.[B]

2.1.4. Grading of Excavations

- Building excavations should be graded in a manner that promotes drainage away from the building foundation and foundation drainage system.[4]

2.1.5. Utility Trenches

- Care should be taken to ensure that water does not collect near the foundation via utility trenches[4] (for further information, see Section 4.1.4.).

2.1.6. Gravel Bedding Beneath Floor Slabs

- A layer of clear gravel at least 100 mm to 150 mm (4 in. to 6 in.) thick should be provided as an under-slab drainage layer.[4]
- This layer should be at least 50 mm (2 in.) thick on top of footings.[4]

2.1.7. Weepholes

- Weepholes should be incorporated into foundation footings where necessary to assist in the drainage of water accumulated in bedding beneath basement floor slabs.[4]

2.1.8. Materials for Reducing the Risk of Blockage

- Rigid pipe (e.g., PVC pipe with dimension ratio (DR) 28) should be used for foundation drainage systems.[4,5,C]
- Fittings used at corners should not restrict inspection and maintenance procedures (e.g., two 45° fittings should be used at corners).[4,5]
- Clear gravel bedding that is sufficient to provide suitable foundation drainage on its own should be installed and graded.[4]
- Perforated drainage pipe should be installed.[4,D] Pipe that is perforated for the purposes of foundation drainage should:
    - meet the requirements of BNQ 3624-130, "Unplasticized Poly(Vinyl Chloride) [PVC-U] Pipe and Fittings – Pipes of 150 mm in Diameter or Smaller," or CAN/CSA-B182.1, "Plastic Drain and Sewer Pipe and Pipe Fittings,"[5]
    - be smooth inside and outside,[5]
    - be solid-walled,[5]
    - have a diameter of 100 mm (4 in.) (see Figure 2a),[5]
    - have perforations that are round with a diameter of 15 mm ± 2 mm (see Figure 2b),[5] and
    - have perforations that are free of burrs that may restrict the passage of liquid.[5]
- Clear gravel should cover the perforated drainage pipe.[4]

[B] Reviewer comment (Nov. 2018): "Proper jointing of pipe sections might also prove beneficial in the reduction of exfiltration."

[C] BNQ 3661-500/2012 notes:

> According to the most recent studies carried out on construction sites and in laboratories, ringed flexible drains should be avoided when the land to be constructed presents a risk of clogging by ocher deposits. Although this type of product has experienced recent improvements, particular with respect to the dimensions of its openings, its annelings and its slit-shaped orifices, favour the accumulation of ferruginous water and restrict the flow of water.
> [As translated and reproduced in the Durham Standard (2018).]

[D] This recommendation is more stringent than the NBC foundation drainage provisions, which do not require the use of foundation drainage pipes (i.e., the provisions permit the use of gravel alone or gravel and pipe).

Figure 2a: Perforated Foundation Drainage Pipe (see Figure 2b) Installed Inside Foundation Footings in Accordance with BNQ 3661-500/2012[5,E]

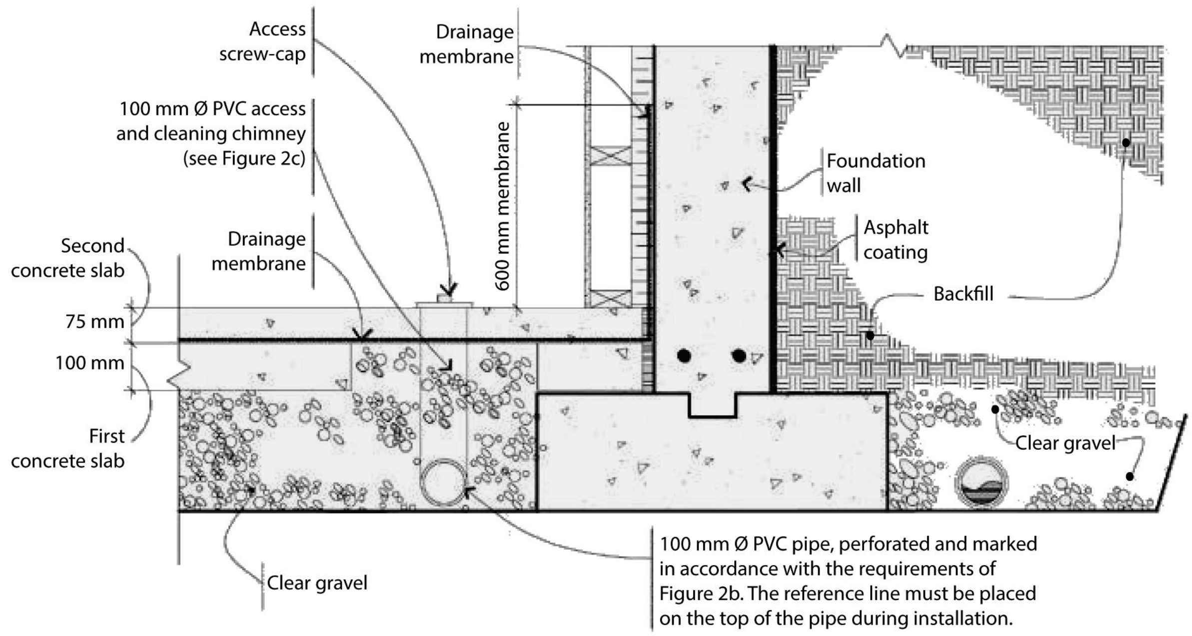
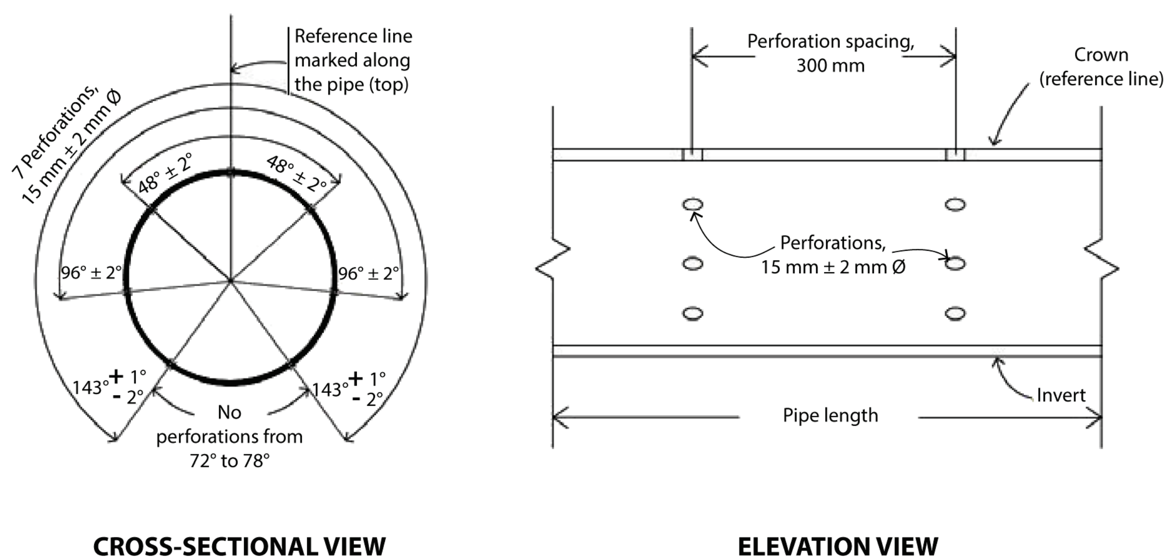


Figure 2b: Perforation of Drainage Pipe (see Figure 2a) in Accordance with BNQ 3661-500/2012[5,E]



[E] Translation of original BNQ figure provided by NRC.

2.1.9. Clear Gravel Layer and Filter Cloth

- At least 150 mm (6 in.) of clear gravel should surround the top and sides of the foundation drainage pipe.[4]
- Preferably, 250 mm to 300 mm (10 in. to 12 in.) of clear gravel should be placed on top of the foundation drain pipe.[7]
- The gravel should have a particle size of 20 mm to 40 mm.[5,F]
- The gravel on top of the pipe should slope away from the foundation wall.[5]
- Placement of clear gravel beneath the foundation drainage pipe is dependent on site conditions.[4]
- Where present, the clear gravel layer beneath the foundation drainage pipe should be suitably compacted.[4]
- Foundation drainage pipes should not be wrapped with filter cloth.[5,G]
- To minimize soil migration into the foundation drainage system, the clear gravel layer that surrounds the foundation drainage pipe should be wrapped with filter cloth.[7]

2.1.10. Inspection and Maintenance

- Inspections of foundation drainage systems should be conducted as frequently as operating conditions require and at least on a yearly basis.[4]

2.1.11. Cleanouts

- Cleanouts should be provided at appropriate intervals and locations to allow for inspection and maintenance (e.g., at opposite corners of buildings with square or rectangular footprints).[3,4,5,H]
- Cleanouts should be connected to foundation drainage pipes using wye and 45° fittings (see Figure 2c).[5]
- Cleanouts should remain accessible.[4,I]
- Cleanouts should be provided with threaded cleanout caps.
- Cleanouts should be supported to prevent lateral movement.
- Pipes that connect foundation drainage systems to interior sump pits, where present, should be accessible for inspection and maintenance.[5]

[F] BNQ 3661-500/2012 notes that, for buildings with a risk of pipe blockage by iron ochre, the gravel should not contain shale or organic material.

[G] BNQ 3661-500/2012 notes:

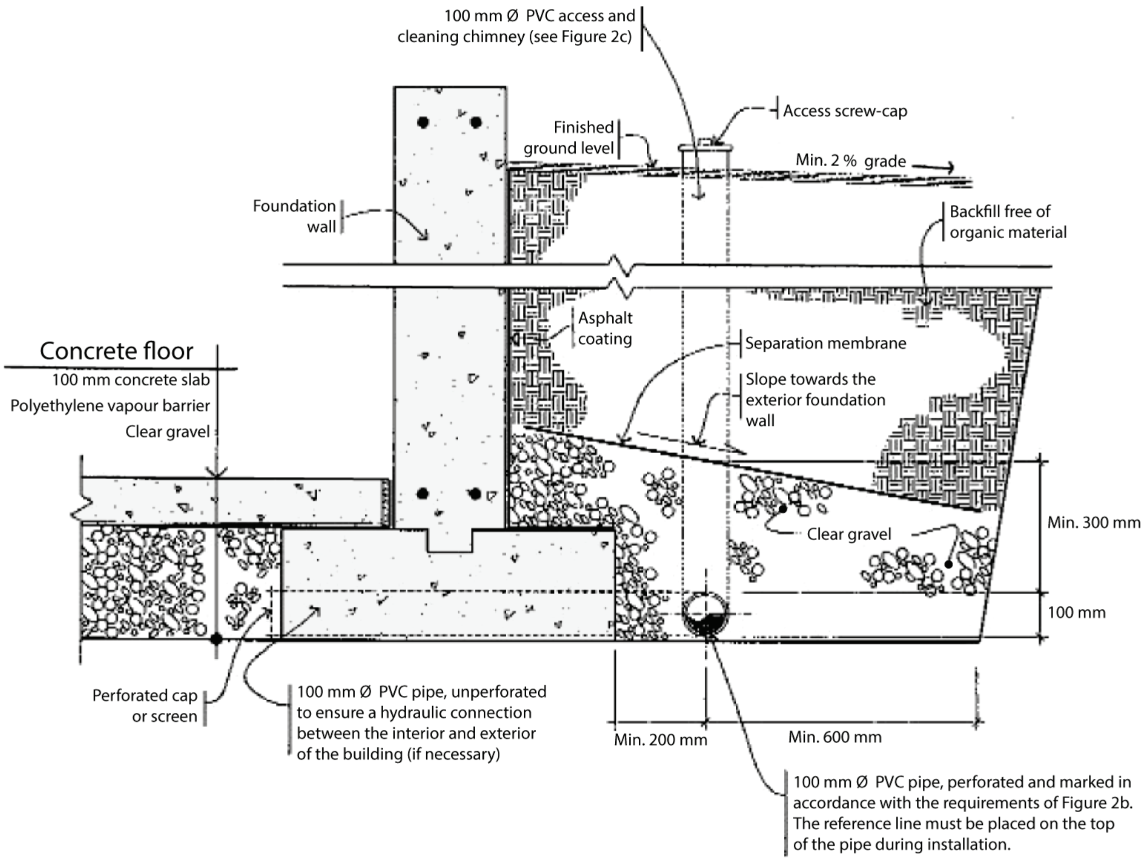
> The many studies conducted to date (Henry W. Ford, S. Gameda, D. R. Cullimore) on the use of a geotextile filter (membrane) around foundation drains demonstrate that there is a direct link between external clogging and the use of a sheath around the drains. Therefore, the use these geotextile filters is not recommended when a potential for ocher deposits is present.

[H] BNQ 3661-500/2012 notes:

> These chimneys consist of two series of 100 mm [4 in.] diameter PVC unperforated vertical hoses connected to the drain with elbows and installed at the opposite sides of the building. They terminate at the surface of the ground, where their extremity is provided with a screw-cap. These [chimneys] provide two functions:
>
> - Insert a camera to see the inside of the drain to determine if periodic maintenance is required.
> - allow access to the drain for cleaning with pressurized water.
>
> So that runoff water does not provide additional water to the foundation drain, it is preferable that the top layer of the soil be made of impermeable backfill material (such as clay) and set with a slope of 2%, in order to remove the water from the foundation wall. In addition, the downspouts of the gutters can not be connected to or oriented towards the foundation drain; they will end as far as possible from the foundation wall.
>
> [As translated and reproduced in the Durham Standard (2018).]

[I] Reviewer comment (Apr. 2018): “Ensure that access chimneys are not used as downpipes, resulting in the connection of downspouts to foundation drainage systems. This has been identified as an issue in some instances in Quebec.”

Figure 2c: Installation of Cleanouts ("Access and Cleaning Chimneys") in Accordance with BNQ 3661-500/2012[5,J,K]



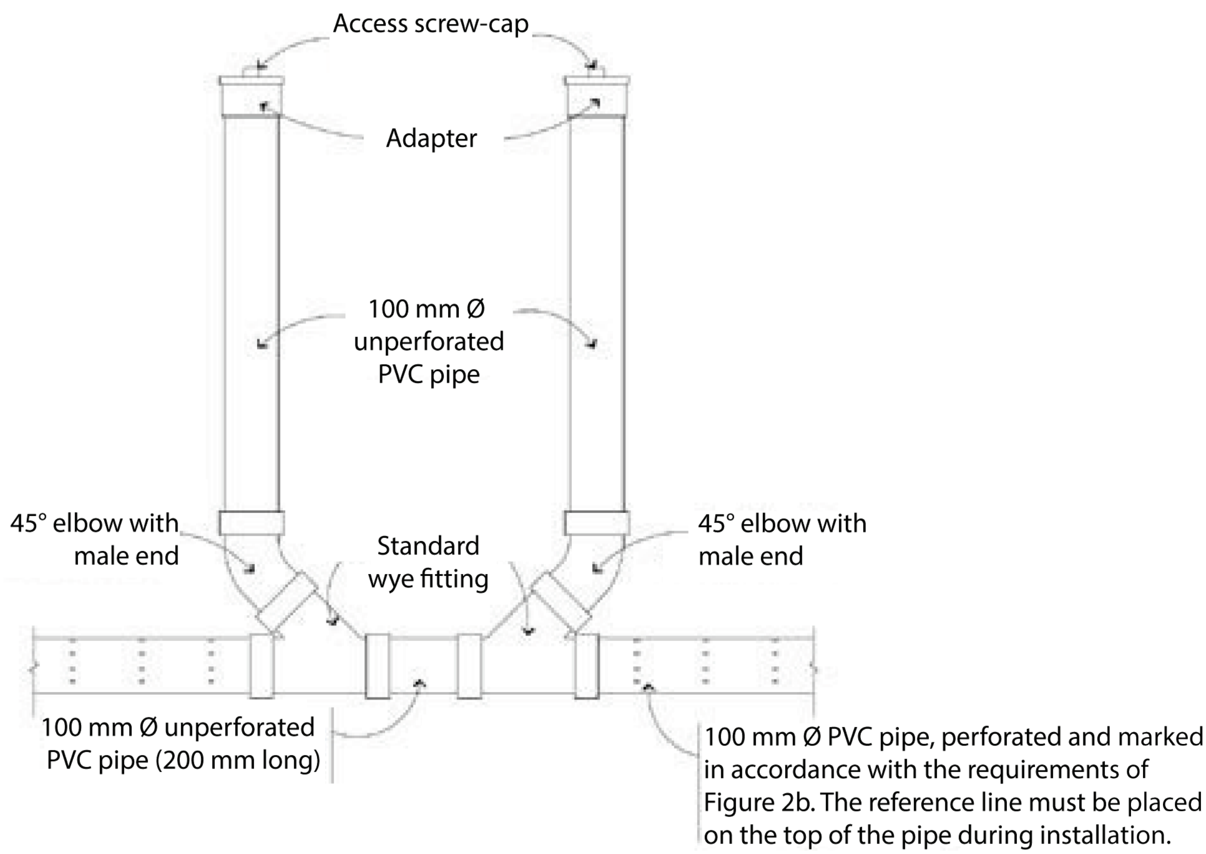
[J] Translation of original BNQ figure provided by NRC.

[K] Note that BNQ 3661-500/2012 largely addresses concerns related to iron ochre. The above recommendations are intended to facilitate access to foundation drainage systems for the purpose of inspection and maintenance. BNQ 3661-500/2012 provides options to meet these recommendations, regardless of the potential cause of system blockage.

In reference to external access chimneys, BNQ 3661-500/2012 states (Annex A, page 19):

> In spite of all the precautions and the methods applied, the installation of a drainage system in a soil favorable to the clogging of drains always carries a certain risk. In order to prevent this risk, the installation of access or cleaning chimneys connected to the foundation drain is essential.
>
> [As translated and reproduced in the Durham Standard (2018).]

Figure 2c: Installation of Cleanouts ("Access and Cleaning Chimneys") in Accordance with BNQ 3661-500/2012 (Continued)



2.1.12. Interior Foundation Drainage Systems

- Refer to Section 9 of BNQ 3661-500/2012 for guidance on the installation of interior foundation drainage systems.[5]

2.1.13. Separation from Water Tables

- Foundation drainage systems should not be relied upon to prevent the groundwater flooding associated with continually or periodically high groundwater levels.

2.1.14. Separation from Infiltration Features

- Infiltration features, such as infiltration fields and low-impact development (LID) features that are designed to promote the infiltration of stormwater, should be separated from building foundations.[4]

2.2. Observations

The failure of foundation drainage systems is of concern because of the significant costs associated with accessing, repairing and replacing these systems in existing homes. According to the contractors who perform system remediation that were surveyed for this guide, the replacement of a failed foundation drainage system may cost $100 to $300 per foot on average (see Table 2a in Section 2.2.5.).

It is noted that foundation drainage issues occur in both existing and new buildings. In citing the reason for developing a comprehensive guide on foundation drainage for buildings complying with Part 9 of the British Columbia Building Code[8] (BCBC), Horizon Engineering (2020) states:[4]

> Initiation of this document was driven by a common experience of various warranty providers encountering foundation drainage and leakage problems with building projects, many of which may have been avoided had best practices been incorporated into the design and construction.

It is further noted that well-functioning foundation drainage systems provide multiple benefits related to housing performance and livability. Horizon Engineering (2020) states that "where there is ingress of moisture to the below-grade area of a building, damage and mould often result, and remediation is usually iterative, expensive, and often frustrating for the owner/occupant and the contractor in charge of the repair."[4] A trend toward more, and deeper, finished basements has been observed as the availability of high-quality developable land has decreased and as land values have increased in BC's Lower Mainland.[4] Horizon Engineering (2020) further states: "This, in combination with climate change and an increase in storm event intensity, frequency and duration, means that proper drainage is becoming more important in order to protect the investments of homeowners."[4]

Figure 2d: Foundation Drainage Pipe Blockage

Several questions related to foundation drainage systems were identified during TC discussions and consultations with contractors during the development of CSA Z800-18 and the Durham Standard (2018), including:

- Can foundation drainage systems be designed to limit the risk of blockage by fine soil particles over the expected system lifespan in various soil and site drainage conditions?
- What inspection and maintenance methods are available for these systems to reduce the risk of blockage by fine soil particles and other debris? What inspection schedules and methods for flushing or cleaning partially or fully blocked systems should be considered?
- Are there reasonable means of ensuring that these systems are accessible for inspection and maintenance?

- Should multiple drainage points be provided for the discharge of foundation drainage water to sumps or stormwater connections to avoid system failure if there is a blockage (see Figure 2d)?
- What are the expected lifespans of these systems under varied operational scenarios?

Horizon Engineering (2020) indicates that certain basic BCBC and Vancouver Building By-law requirements related to foundation drainage system design are considered starting points for minimum requirements, but are not "best practice."[4]

It should be noted that the foundation drainage provisions in Part 9 of the BCBC are largely the same as those provided in Part 9 of the NBC (see Box 2b).[1,8]

Box 2b: NBC 2015 and BCBC 2018 Sentence 9.14.2.1.(1), Foundation Wall Drainage

1) Unless it can be shown to be unnecessary, the bottom of every exterior *foundation* wall shall be drained by drainage tile or pipe laid around the exterior of the *foundation* in conformance with Subsection 9.14.3. or by a layer of gravel or crushed *rock* in conformance with Subsection 9.14.4.

Box 2c: NBC 2015 and BCBC 2018 Foundation Drainage Options

Option 1:
Drainage Tile and Pipe: Drainage pipe or tile laid on undisturbed or well-compacted soil with the top and sides covered by at least 15 cm (6 in.) of clear gravel (Subsection 9.14.3.*).
See Figure 2e.

Option 2:
Granular Drainage Layer: A minimum 12.5 cm (5 in.) thick layer of clear gravel beneath the footing, extending 30 cm (12 in.) beyond the outside edge of the footing (Subsection 9.14.4.**).
See Figure 2f.

*Aside from the removal of the reference to CAN/CGSB-34.22, Subsection 9.14.3. of the BCBC 2018 remains consistent with Subsection 9.14.3. of the BCBC 2012.
**Subsection 9.14.4. of the BCBC 2018 remains consistent with Subsection 9.14.4. of the BCBC 2012.

Figures 2e and 2f illustrate Horizon Engineering (2020)'s interpretation of two foundation drainage options presented in the BCBC and NBC (see Box 2c).[4]

Swinton & Kesik (2008) note that Option 1 is the most commonly applied option.[9] Horizon Engineering (2020) further states:[4]

> the BCBC Part 9 minimum drainage systems […] may achieve moderate performance, but a better solution is desired where reliable long-term drainage is needed, including where interflow groundwater flows may be significant. Among other potential long-term performance concerns, the "code minimum" requirements may not provide:
> - enough drainage capacity,
> - access for maintenance, and
> - protection from potential clogging.

Figure 2e: NBC and BCBC Foundation Drainage Option 1 (adapted by ICLR from Horizon Engineering (2020))[4]

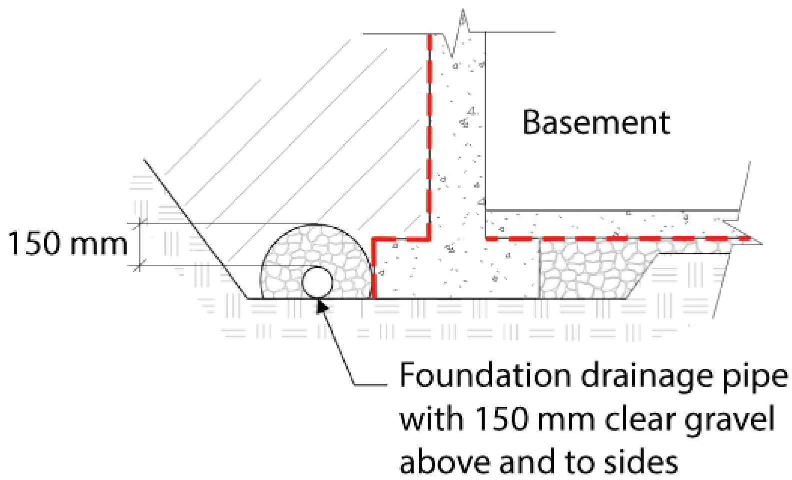
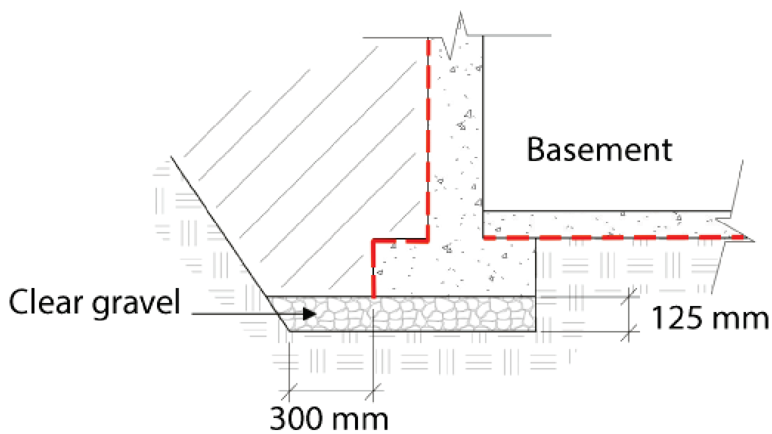


Figure 2f: NBC and BCBC Foundation Drainage Option 2 (adapted by ICLR from Horizon Engineering (2020))[4]



2.2.1. Site Grading and Drainage, Backfill, Downspout Discharge

Site grading and drainage, including practices related to backfill, backfill capping and downspout discharge, are considered the first line of defence in keeping precipitation and surface water away from foundations and foundation drainage systems.[4,10] According to "Moisture-Resistant Homes" by the US Department of Housing and Urban Development (HUD (2006)), "proper backfill practices and grading will ensure that a foundation remains dry to a greater degree than all other recommendations in [the Basement Foundation Construction] section of [their] guide."[11]

With respect to the relationship between surface and subsurface water, surface drainage features, and foundation drainage systems, ANSI/ASCE/EWRI 12-13, "Standard Guidelines for the Design of Urban Subsurface Drainage," states:[12]

> Surface water sources that can contribute to groundwater consist primarily of reservoirs, ponds, canals, open drainage ditches, and rainfall. Often the subsurface drainage requirement is a direct result of seepage from one or more of these sources […] For example, the focused drainage of roof runoff onto flat ground surfaces immediately adjacent to building foundation walls is a common cause of basement flooding. The settlement of disturbed soils adjacent to building foundations over time can exacerbate this condition. Another common problem involves preferential groundwater flow paths created when the pervious bedding and backfill of utility trenches create flow pathways from ponds to areas where this water can cause problems. The designer of subsurface drainage facilities should investigate any probable surface water sources and, if appropriate, incorporate surface drainage improvements into the design.

BNQ 3661-500/2012 further states:[5,L]

> So that runoff water does not provide additional water to the foundation drain, it is preferable that the top layer of the soil be made of impermeable backfill material (such as clay) and set with a slope of 2%, in order to remove the water from the foundation wall. In addition, the downspouts of the gutters cannot be connected to or oriented towards the foundation drain; they will end as far as possible from the foundation wall.

Impermeable backfill capping has been recommended elsewhere.[2,3,11]

CSA Z800-18 provides guidance related to site grading and drainage, including backfill capping and downspout drainage. Horizon Engineering (2020), however, provides additional guidance related to backfill materials, which has been incorporated into the recommendations in Section 2.1.2.

HUD (2006) recommends that backfill be placed in 6 in. to 8 in. thick lifts and tamped or compacted with light construction equipment to prevent settlement, which could result in water collecting near foundations and percolating into foundation drainage systems (or leaky foundation walls).[11] The compaction of backfill was discussed during the development of the basement flood recommendations for the Durham Standard (2018). Because of the potential for damage to utilities and services surrounding or penetrating foundation walls and the limited capacity of local AHJs to enforce compaction requirements, it was decided to leave such requirements out of the Standard.

[L] As translated and reproduced in the Durham Standard (2018).

2.2.2. Grading of Excavations, Utility Trenches

The recommendations in Section 2.1.4. include the suggestion from Horizon Engineering (2020) that excavations for building foundations be appropriately graded to promote drainage away from the building foundation and foundation drainage system.

With respect to the grading of excavations and utility trenches, and particularly the potential for water to migrate through utility trenches and enter foundation drainage systems, Horizon Engineering (2020) states:[4]

> It can be helpful to imagine that water flows along the path of least resistance whether this is down a slope, through free draining materials, pipes, utility trenches, poorly compacted fills, pockets of debris with a high void ratio, buried decomposing organics (such as logs), or into openings in a below-grade wall. For this reason, it is important to consider the overall site and construction layout when designing a drainage system.

ANSI/ASCE/EWRI 12-13 further highlights the risks associated with utility trench flow paths.[12] Trench plugs or dams can be utilized to limit these risks.[13] Additional guidance related to the grading of, and protection from backflow through, utility trenches is covered in detail in Section 4 of this guide.

2.2.3. Gravel Bedding Beneath Floor Slabs

The importance of placing a layer of clear gravel at least 100 mm to 150 mm thick beneath floor slabs is emphasized by Horizon Engineering (2020). Specifically, the guide states that "the success of a perimeter foundation drainage system relies on a suitable underslab drainage layer." Horizon Engineering (2020) further states:[4]

> Best practice is to provide at least a 100 mm (4") to 150 mm (6") thick layer of compacted clear gravel below any interior slab-on-grade with minimum 50 mm (2") on top of footings. This layer provides a capillary break and acts as a drainage layer. […] The underslab gravel should be compacted to reduce potential settlement that could manifest as cracks in the slab-on-grade.

2.2.4. Materials for Reducing the Risk of Blockage

The blockage of foundation drainage systems by fine soil particles was identified as a concern in TC discussions during the development of the Durham Standard (2018) and CSA Z800-18. It has been noted that materials commonly used across Canada for foundation drainage systems are not ideal for this application because of their vulnerability to blockage by fine soils. 100 mm diameter perforated "Big-O" pipe, a corrugated high-density polyethylene (HDPE) pipe is an example of such a material. Existing best practice guidance in Canada suggests that smooth-walled, rigid pipe (e.g., PVC pipe) should be used for foundation drainage applications.[4,5,M]

With respect to drain envelopes, ANSI/ASCE/EWRI 12-13 states that envelope materials are placed around subsurface drains to prevent excessive movement of soil particles into the drain, to provide material in the immediate vicinity of the drain that is more permeable than the surrounding soil, to provide bedding for the drain, and to stabilize the soil in which the drain is being placed.[12] Measures proposed by the Basement Flood TC for the Durham Standard (2018) to manage long-term blockages of foundation drainage systems include increasing the thickness of the granular layer above the foundation drainage pipe from 150 mm to 250 mm or 300 mm and exploring new products that could reduce the risk of blockage over the lifespan of the systems.

[M] Reviewer comment (Nov. 2018): "Use of smooth wall pipe in conjunction with proper placement/ numbers of cleanouts would increase effectiveness of cleaning. [Consider looking into] access to extract materials being cleaned from weeper and/or lateral, to prevent blockage of gravity lateral or municipal infrastructure."

Geotextile filters (e.g., socks) are applied for the purpose of managing soil migration into foundation drainage systems.[9] Although the placement of geotextile socks over drainage pipes is one of the more common methods for reducing the risk of foundation drainage system blockage, the Basement Flood TC for the Durham Standard (2018) noted that geotextile socks are vulnerable to blockage and should not be used. ANSI/ASCE/EWRI 12-13 confirms that pore blockages in geotextile fabrics are difficult to remediate:[12]

> […] geotextiles may be used as coverings and liners in several construction applications. In drainage applications, geotextiles serve as filters that pass water and colloidal fines while restricting soil migration. Extra care should be taken in the design of systems utilizing geotextiles to prevent pore blockage by migrating fines. Fabric failures due to pore blockage are extremely difficult to remedy.

Reviewers suggested that rigid pipe facilitates cleaning and camera inspections. However, practical experience indicates that Big-O drainage pipe is effective in most instances and that migration of fine soils can be controlled through the application of geotextile socks. Proper design and installation by a professional with relevant local knowledge is also considered helpful to improve the performance of the foundation drainage system. Nevertheless, as discussed above, guidance documents may advise against application of geotextile socks on foundation drainage pipe.

The Basement Flood TC for the Durham Standard (2018) proposed laying geotextile fabric filter on top of the granular layer before adding backfill, rather than wrapping the geotextile filter around the foundation drainage pipe. Further, to mitigate soil migration into the systems, Horizon Engineering (2020) recommends the following:[4]

> Place at least 15 cm (6") of clear crushed gravel beneath and surrounding the perforated perimeter drainage pipe so that underlying soil is separated from the pipe to minimize soil migration into the system. Without this gravel layer, as in Option (a), fine-grained soil could seal the perforations on the bottom of the pipe. Wrap the clear gravel with a layer of filter cloth or use a ***granular filter*** to minimize soil migration into the system.

2.2.5. Inspection and Maintenance

The need to incorporate methods for inspecting and maintaining foundation drainage systems was discussed during TC meetings for CSA Z800-18 and the Durham Standard (2018). Recommendations for incorporating a means to inspect and maintain these systems were incorporated into both of the documents. The need for maintenance of foundation drainage systems is discussed in the literature as well.[4,10] Contractors involved in foundation drainage system repair were surveyed to identify inspection and maintenance methods; input was also received from TC members.

In March 2018, eight contractors working in basement flood remediation and foundation drainage maintenance and repair responded to a number of key questions about foundation inspection, maintenance, and repair posed by ICLR staff. These interviews add dimension to the initial consultation with contractors discussed above.

The highlights of the contractors’ responses are summarized in Table 2a. Because most of the contractors contacted for this guide requested anonymity, contractor names are not included in the table. Six of the eight contractors were located in southern Ontario, one was located in Saskatchewan, and one was located in southern Manitoba.

As summarized in Table 2a, interviewees indicated that blockages of foundation drainage systems by soil and roots, as well as poor initial installations, are the primary causes of system failure. General "degradation" of the systems was also identified as a cause of failure, as was the clogging of foundation drainage pipes with shingles and leaves in situations where downspouts were directed to foundation drainage pipe. When prompted to provide opinions on the most important causes of system failure, some contractors identified the failure of sump pump systems as one of the most important causes and mentioned the need for sump pump backup systems.

Full excavation was identified as a means of accessing foundation drainage systems for replacement in situations where the systems cannot be maintained or repaired. Excavation at key points in the system (e.g., at opposite corners of the foundation or at the location of the blockages) was further identified as a means of accessing the systems. Sump pits were identified as access points, and it was reported that it may be possible to perform spot repairs from the inside of buildings in some circumstances. A contractor working mainly in southern Ontario reported that the vast majority of failures of foundation drainage systems are caused by clogging with soil and that excavation is the most common means of accessing systems for repair or replacement, as cleanouts are rarely incorporated in the systems.[N]

High-pressure flushing, sometimes in combination with vacuum removal of debris, was identified as a method for maintaining foundation drainage pipes. CCTV cameras were identified as means for performing inspections, and augurs and cutters were identified as means for clearing root blockages. Annual and biannual maintenance regimes were recommended by some interviewees. It was also reported that the use of non-directional fittings (e.g., T-fittings rather than wyes) makes camera inspection difficult in foundation drainage systems.[O]

The estimated cost of replacing a foundation drainage system in an existing home ranged from $100 to $300 per foot, and from $5,000 to $30,000 in total, depending on the site conditions and building characteristics. Several interviewees reported that it was difficult to estimate an "average" cost for foundation drainage repair and replacement, as the value varies drastically depending on the soil type at the building site, the depth, accessibility and condition of the foundation drainage system, and the size of the building, among other factors.[P] It was noted that excavation significantly adds to the cost of maintaining or replacing a foundation drainage system.[Q] A southern Ontario contractor reported that the rough cost of cleaning a clogged system by using a combination of high-pressure flushing, vacuuming and CCTV inspection was $1,300,[R] assuming the cleaning operation was relatively simple and the drainage pipes were in relatively good condition. A southern Ontario contractor who suggested that annual maintenance should be performed on foundation drainage systems indicated that, on average, this maintenance would cost $170 per foot.[S]

Some of the contractors considered the cost of the installation of cleanouts for foundation drainage systems to be low. For example, one contractor reported that the labour and material costs associated with installing cleanouts during foundation drainage pipe replacement are low enough to not warrant an additional charge.[T] It was further reported, however, that it is rare for customers to request that

[N] Contractor 4.
[O] Contractor 5.
[P] Contractors 2, 3, 4.
[Q] Contractor 4.
[R] Contractor 5.
[S] Contractor 2.
[T] Contractor 3.

cleanouts be installed.[U]

The installation of cleanouts and the incorporation of means to prevent the infiltration of tree roots were identified as methods to improve foundation drainage systems. It was noted that, where cleanouts are installed, they may facilitate flushing and CCTV inspections, but may not facilitate vacuum removal of debris with vacuum trucks.[V] Several contractors highlighted the importance of installation quality, indicating that existing foundation drainage systems would likely operate adequately as designed provided they were properly installed by experienced contractors.

Additional methods to improve the design and construction of foundation drainage systems include the following: installing backwater valves, using the proper amount of clear stone around drainage pipes, using directional fittings, using appropriate backfill materials, and securing foundation drainage pipes to prevent shifting during backfill.

Some contractors reported that improper installation, including improper grading and insufficient clear stone, was a frequent occurrence in newer subdivisions.[W] Blockages caused by soil, roots, sediment, etc., although common, can be exacerbated by inappropriate grading of weeping tiles.[X] A regional issue was identified by one contractor. Specifically, a contractor working in southern Manitoba noted that soil expansion may affect water flow in the foundation drainage system, causing backup and potentially crushing foundation drainage pipes.[Y] Additionally, geotextile filter socks were recommended by one contractor, despite the advice from other sources that these not be used (see Section 2.2.4.).[Z]

Table 2a: Contractor Responses from March 2018 Interviews

Question	Response	Contractor(s)
Primary observed causes of foundation drainage system failure	Blockage by soil (e.g., clay, sand), roots	1, 2, 4, 6, 8
	Poor initial installation (e.g., improper backfill practices, crushed pipes, insufficient clear stone, improper base for foundation drainage pipe, improper grading)	3, 4, 6, 7, 8
	Degradation over time, collapse (notably for clay weeping tiles)	4, 5
	Clogging with shingle debris, leaves, etc. (when downspouts are directed to foundation drains)	5
Access existing foundation drainage systems	Full excavation, replacement of clogged system, or full replacement when flushing is ineffective or when initial installation was poor	1, 3, 4, 6
	Excavation at key points (for maintenance)	3, 5, 7, 8
	Access via sump pit	7
	Spot repairs from inside the buildings may be possible under specific circumstances	3

[U] Contractors 3, 4.
[V] Contractor 5.
[W] Contractors 3, 4.
[X] Contractor 8.
[Y] Contractor 8.
[Z] Contractor 5.

Question	Response	Contractor(s)
Inspection, maintenance, repair methods	High-pressure flushing, sometimes in combination with vacuum removal of debris	2, 5, 6
	CCTV (to perform inspections, identify location of blockages, etc.)	2, 5
	Electric augers (for clearing tree roots)	2
	Specialized adapters to cut through roots, built-up material	2
	Annual or biannual maintenance (to reduce the likelihood of blockage by roots, soil)	2, 8
Estimated cost of foundation drainage system replacement	$120 to $200 per foot[AA]	1
	$150 to $300 per foot (the largest cost is excavation; an average house would require excavation of 120 to 150 ft.)	6
	$100 per foot	7
	$5,000 to $30,000 (underpinning, where necessary, may add $25,000)	8
	Difficult to estimate	2, 3, 4
Recommendations for foundation drainage system improvement, maintenance approaches	Install cleanouts	1, 4
	Exercise caution when planting near foundation drainage systems; incorporate means to prevent the infiltration of tree roots	5, 8
	Install backwater valves to prevent system damage; perform regular maintenance on backwater valves	2
	Use proper amount of clear stone around drainage pipes	4
	Provide backup power for sump pump systems	4
	Use directional fittings	5
	Ensure that system is installed by an experienced contractor	6
	Use appropriate materials for backfill (backfill materials should have low silt content; backfill should not be heavy enough to crush foundation drainage pipe)	6
	Use filter cloths	6
	“Trench” drainage pipes into the soil, rather than laying them on top of soil	8
	Secure drainage pipes to prevent shifting during backfill	8

[AA] According to the contractors, most customers choose to replace the entire system rather than sections of the system.

With respect to access to and maintenance of foundation drainage pipes, BNQ 3661-500/2012 states:[5,BB]

> A pressurized water wash will ensure the durability of the building's storm drainage system. These [chimneys] consist of two series of 100 mm [4 "] diameter PVC unperforated vertical hoses connected to the drain with elbows and installed at the opposite sides of the building. They terminate at the surface of the ground, where their extremity is provided with a screw-cap. These [chimneys] provide two functions:
>
> - Insert a camera to see the inside of the drain to determine if periodic maintenance is required.
> - allow access to the drain for cleaning with pressurized water.

Figure 2c illustrates the installation of cleanouts (referred to as "access and cleaning chimneys") in accordance with BNQ 3661-500/2012 (see Section 2.1.11.).

As the result of an identified need to facilitate the inspection and maintenance of foundation drainage systems, the Durham Standard (2018) specifically recommends the incorporation of a means of accessing these systems (see Table 2b). Because there is a lack of generalized guidance on cleanouts for foundation drainage systems, this recommendation is performance-oriented; however, the installation of cleanouts in accordance with BNQ 3661-500/2012 is referenced as an option for following the recommendation.

It should be noted that BNQ 3661-500/2012, as discussed in Section 2.1.8., requires the use of smooth-walled, rigid pipes in combination with two 45° fittings at corners to facilitate inspection and maintenance.[5] A member of the Basement Flood TC for the Durham Standard (2018) argued that the installation of cleanouts in accordance with BNQ 3661-500/2012 may not facilitate CCTV inspection of foundation drainage systems that use Big-O pipe instead of smooth-walled, rigid pipes. However, foundation drainage contractors have indicated that Big-O pipe does facilitate CCTV inspection and maintenance, as long as the pipe is not clogged. Whether the cleanout installation described in BNQ 3661-500/2012 would facilitate CCTV inspections for Big-O foundation drainage pipe remains unverified.

[BB] As translated and reproduced in the Durham Standard (2018).

Table 2b: Durham Standard (2018) Recommendation on Accessing Foundation Drainage Systems[3]

#	Recommendation	Purpose	Notes

6.	Incorporate means of accessing foundation drainage systems to facilitate inspection and maintenance (e.g., access and cleaning chimneys).	• Foundation drainage systems are prone to blockage with fine soil particles over their lifecycles.
		• The cost of replacing and repairing foundation drainage systems is extremely high, necessitating measures to limit risk of blockage and failure over the lifecycle of the system.
		• Providing access to these systems will allow for inspection and increases viability of maintenance over their lifecycles.
			• Provision of access to foundation drainage systems to allow inspection and maintenance to extend the useful life of foundation drainage systems.
			• Maintenance (e.g., flushing) often requires excavation of key locations around foundation wall to access foundation drainage system and to remove flushed debris. Excavation adds to the cost and complexity of maintaining foundation drainage systems.
			[…]
			• Potential options that may be considered to achieve this provision include:
			  ○ [Providing access to foundation drainage system via cleanouts that are incorporated into backwater valves (applicable to gravity-drained foundation drainage systems).]
			  ○ Provision of "access and cleaning chimneys" as per BNQ 3661-500/2012.*
			  ○ Alternative means of increasing accessibility of foundation drainage systems as appropriate and approved by the authority having jurisdiction.
			• Application of methods to reduce the service requirement of foundation drainage systems, including use of materials that are less likely to become blocked, is also encouraged. For example, smooth-walled, rigid, perforated PVC pipe may be considered less vulnerable to blockage, when compared to ringed, flexible pipe that is commonly used for foundation drainage applications.** Rigid, smooth walled pipes may also increase ease of access for closed circuit television (CCTV) inspections.

*Note that BNQ 3661-500/2012 largely addresses concerns related to iron ochre. Regardless of the cause of foundation drainage blockage, it is the intent of the standard presented here to increase access to foundation drainage systems for the purposes of inspection and maintenance. BNQ 3661-500/2012 provides options to meet this provision.

In reference to external access chimneys, BNQ 3661-500/2012 further states (Annex A, page 19):

> "In spite of all the precautions and the methods applied, the installation of a drainage system in a soil favorable to the clogging of drains always carries a certain risk. In order to prevent this risk, the installation of access or cleaning chimneys connected to the foundation drain is essential."
>
> "A pressurized water wash will ensure the durability of the building's storm drainage system. These chimneys consist of two series of 100 mm [4 "] diameter PVC unperforated vertical hoses connected to the drain with elbows and installed at the opposite sides of the building. They terminate at the surface of the ground, where their extremity is provided with a screw-cap. These [chimneys] provide two functions:
>
> - Insert a camera to see the inside of the drain to determine if periodic maintenance is required.
> - allow access to the drain for cleaning with pressurized water.
>
> So that runoff water does not provide additional water to the foundation drain, it is preferable that the top layer of the soil be made of impermeable backfill material (such as clay) and set with a slope of 2%, in order to remove the water from the foundation wall. In addition, the downspouts of the gutters can not be connected to or oriented towards the foundation drain; they will end as far as possible from the foundation wall."

**BNQ 3661-500/2012 further states that (page 18):

> "According to the most recent studies carried out on construction sites and in laboratories, ringed flexible drains should be avoided when the land to be constructed presents a risk of clogging by ocher deposits. Although this type of product has experienced recent improvements, particularly with respect to the dimensions of its openings, its annelings and its slit-shaped orifices, favor the accumulation of ferruginous water and restrict the flow of water. Thus, the development of bacteria which occurs inside the drain and which results in the accumulation of consistent deposits (clogging) reduces the hydraulic capacity of the drain (flow)."
>
> "The rigid drain with a smooth wall prevents clogging by ocher deposits. Its smooth inner wall favors a free flow of ferruginous water and, unlike the ringed drain, does not allow bacteria to proliferate there. Its circular openings allow groundwater to be captured from the water table and effectively routed to the municipal storm sewer system."

Article 5.2.3.1 of BNQ 3661-500/2012 provides specifications for smooth-walled foundation drainage pipe:

> 5.2.3 Perforated pipes
>
> Where perforated pipes are used in the works described in this Part, they shall comply with the following requirements.
>
> 5.2.3.1 Prior to perforation, the hoses shall meet the following requirements:
>
> - they must comply with the requirements of NQ 3624-130 or CSA B182.1;
> - they must have smooth inner and outer walls;
> - they must be solid-walled, the pipes with hollow walls not being accepted for the works described in this part;
> - they must have a nominal diameter of 100 mm.
>
> 5.2.3.2 The hoses shall be perforated and shall have round holes with a diameter of 15 mm ± 2 mm as required in Figure 1. The holes shall be free of burrs which may restrict the flow of liquid. The sockets must not be drilled. The marking line illustrated in FIG. 1 corresponds to the marking line of the pipe.
>
> NOTE - At the time of publication of this Part, the requirements of NQ 3624-130 do not permit the manufacture of perforated pipes. CSA B182.1 does not permit the manufacture of pipes having an area of opening per meter as large as that required in Figure 1. Fittings must not be drilled.
>
> "Mounting with 45 ° elbows makes inspection and cleaning devices easier to run through the pipe."

BNQ 3661-500/2012 contains further provisions related to aggregates, backfill composition and drainage membranes suitable for foundation drainage systems exposed to risk associated with iron ochre.

Members of the Basement Flood TC for the Durham Standard (2018) proposed alternative methods for accessing foundation drainage systems, including the use of two 90° fittings as outlets to direct foundation drainage discharge into a sump pit. This approach allows foundation drainage systems to be accessed with a CCTV scope via the two outlets in the sump pit, each of which provides access to half of the system (see Figure 2g). It was noted that this is a relatively informal method of accessing foundation drainage systems and so was not referenced in the Durham Standard (2018). Another alternative identified by the Basement Flood TC was to access gravity-drained foundation drainage systems via backwater valve cleanouts.

Figure 2g: Access Approach Using Two Outlets in a Sump Pit[CC]

Given the variety of access methods and the lack of guidance on specific access options, Basement Flood TC for the Durham Standard (2018) settled on the generic recommendation that means of access to foundation drainage systems to facilitate inspection and maintenance should be provided in new home construction (see Table 2b). A similarly worded recommendation was incorporated into the draft version of CSA Z800-18. The application of these recommendations will likely necessitate more specific guidance, perhaps in a form similar to that of BNQ 3661-500/2012. A reviewer of an early version of this guide highlighted the importance of installing cleanouts properly in locations where they will not be damaged:[DD]

> Cleanouts on the weeping system are likely a good idea but if not properly installed or if damaged in the field they can be another source of infiltration. There was a practice in a couple of municipalities where I have worked to put cleanouts on the sanitary PDC [private drain connection] at the property line. These can easily have the caps broken by surface activities and can have problems right at installation (especially if they are deep as it is hard to compact around the vertical pipe). Locations for installation have to be well thought out to avoid these issues.

2.2.5.1. Code Provisions for Foundation Drainage Systems

Horizon Engineering (2020) discusses whether cleanouts for foundation drainage systems should be required. Table 2c compares the provisions of the National Plumbing Code of Canada (NPC), the British Columbia Plumbing Code (BCPC), and the Ontario Building Code (OBC) related to requirements for cleanouts, as well as the Horizon Engineering (2020) comments on the BCPC provisions.[4,14,15,16] The discussion below highlights how the interpretation of the provisions listed in Table 2c may affect local requirements with respect to the incorporation of cleanouts into foundation drainage systems.

The provisions related to cleanouts for storm and sanitary drainage systems in the BCPC, OBC and NPC have similar wordings.[14,15,16] Furthermore, a review of definitions of key terms, including “storm drainage system,” “drainage system,” “storm water” (or “storm sewage” in the OBC), and “subsoil drainage pipe” (see Table 2d), suggests that cleanouts are likely not required for foundation drainage systems. Although NPC Sentence 2.4.7.1.(1) states that “storm drainage systems shall be provided with cleanouts that will permit cleaning of the entire system,” the NPC definition of “storm drainage system” references the definition for “drainage system,” which explicitly excludes “subsoil drainage pipes.” Also, though included as guidance and not part of the Code, NPC Figure A-1.4.1.2.(1)-F does not show foundation drainage pipes. The same analysis applies to the BCPC. In the OBC, “foundation drain pipes”

[CC] Reviewer comment (Nov. 2018): “You could use this in conjunction with a gravity discharge with a backwater valve, a sump pump with discharge to surface for backup, and additional cleanouts at strategic points around the building perimeter. This would provide a place to flush material to and remove with a [vacuum] truck. Expense and complexity of design and maintenance might make it unpopular.”

[DD] Reviewer comment (Nov. 2018).

are explicitly included in the definition of "subsoil drainage pipe" and are, therefore, excluded from the definition of "drainage systems."

Table 2c: Comparison of NPC 2015, OBC 2012 and BCPC 2018 Provisions Related to Cleanouts for Foundation Drainage Systems, and Horizon Engineering (2020) Comments on the BCPC Provisions

Canada	Ontario	British Columbia	
NPC 2015[14]	**OBC 2012**[16]	**BCPC 2018**[15,EE]	**Horizon Engineering (2020) Comments**[4]
2.4.7.1. Cleanouts for Drainage Systems 1) *Sanitary drainage systems* and *storm drainage systems* shall be provided with *cleanouts* that will permit cleaning of the entire system.	**7.4.7.1. Cleanouts for Drainage Systems** (1) Every *sanitary drainage system* and *storm drainage system* shall be provided with *cleanouts* that will permit cleaning of the entire system.	**2.4.7.1. Cleanouts for Drainage Systems** 1) *Sanitary drainage systems* and *storm drainage systems* shall be provided with *cleanouts* that will permit cleaning of the entire system.	Provide cleanouts regularly to allow for access and maintenance of the entire system, and ensure that cleanouts are not buried or otherwise covered which would inhibit access. Capped system cleanouts are an essential part of a long-life drainage system as they allow for easy access to clean out the perimeter drains by a maintenance contractor. Caps should be threaded. Ensure that sumps are large enough and equipped with ladder rungs to allow person access to the sump base for the purpose of future maintenance.
Per Table 2.4.7.2.: For 3 in. and 4 in. drainage pipes: • minimum size of cleanout: 3 in. • maximum cleanout spacing (one-way rodding): 15 m • maximum cleanout spacing (two-way rodding): 30 m	**7.4.7.2. Size and Spacing of Cleanouts** (1) Except as provided in Sentences (2) and (3), on drainage piping of 4 in. *size* and smaller, the minimum *size cleanout* opening shall be the same *size* as the drainage pipe […] and the maximum spacing between *cleanouts* on horizontal pipe shall be, […] (b) in the case of a horizontal *sanitary drainage pipe*, or *storm drainage pipe*, other than a *waste pipe* from a sink, 15 m, and (c) in the case of a horizontal *sanitary drainage pipe* or *storm drainage pipe* larger than 4 in. *size*, 30 m. […] (4) *Cleanouts* that allow rodding in one direction only shall be installed to permit rodding in the direction of flow.	Per Table 2.4.7.2.: For 3 in. and 4 in. drainage pipes: • minimum size of cleanout: 3 in. • maximum spacing of cleanouts, one-way rodding: 15 m • maximum spacing of cleanouts, two-way rodding: 30 m	

[EE] In the BCPC 2012, Table 2.4.7.2. indicates that the minimum size of cleanouts for 3- and 4-in. drainage pipes is the same size as the drainage pipe. The BCPC 2018 provisions listed in Table 2c are otherwise unchanged from the BCPC 2012.

Canada	Ontario	British Columbia	
NPC 2015[14]	**OBC 2012**[16]	**BCPC 2018**[15, EE]	**Horizon Engineering (2020) Comments**[4]
2.4.7.4. Location of Cleanouts 1) *Cleanouts* and access covers shall be located so that their openings are readily accessible for drain cleaning purposes.	**7.4.7.4. Location of Cleanouts** (1) *Cleanouts* and access covers shall be located so that the openings are readily *accessible* for drain cleaning purposes.	**2.4.7.4. Location of Cleanouts** 1) *Cleanouts* and access covers shall be located so that their openings are readily accessible for drain cleaning purposes.	

Table 2d: Comparison of NPC 2015, OBC 2012 and BCPC 2018 Definitions Related to Storm Drainage Systems (emphasis added)

Term	NPC 2015[14]	OBC 2012[16]	BCPC 2018[15, FF]
Storm drainage system	*Storm drainage system* means a *drainage system* that conveys *storm water*.	*Storm drainage system* means a *drainage system* that conveys *storm sewage*.	*Storm drainage system* means a *drainage system* that conveys *storm water*.
Drainage system	*Drainage system* means an assembly of pipes, fittings, *fixtures*, *traps* and appurtenances that is used to convey *sewage, clear-water waste* or *storm water* to a public sewer or a *private sewage disposal system*, **but does not include *subsoil drainage pipes*.** (See Figure A-1.4.1.2.(1)-F in Note A-1.4.1.2.(1).)	*Drainage system* means an assembly of pipes, fittings, *fixtures* and appurtenances on a property that is used to convey *sewage* and *clear water waste* to a main sewer or a *private sewage disposal system*, and includes a *private sewer*, **but does not include *subsoil drainage piping*.**	*Drainage system* means an assembly of pipes, fittings, *fixtures*, *traps* and appurtenances that is used to convey *sewage*, *clear-water waste* or *storm water* to a public sewer or a *private sewage disposal system*, **but does not include *subsoil drainage pipes*.** (See Figure A-1.4.1.2.(1)-F in Note A-1.4.1.2.(1).)
Storm water (storm sewage in the OBC)	*Storm water* means water that is discharged from a surface as a result of rainfall or snowfall.	*Storm sewage* means water that is discharged from a surface as a result of rainfall, snow melt or snowfall.	*Storm water* means water that is discharged from a surface as a result of rainfall or snowfall.
Subsoil drainage pipe	*Subsoil drainage pipe* means a pipe that is installed underground to intercept and convey subsurface water.	*Subsoil drainage pipe* means a pipe that is installed underground to intercept and convey subsurface water, **and includes foundation drain pipes.**	*Subsoil drainage pipe* means a pipe that is installed underground to intercept and convey subsurface water.

[FF] The BCPC 2018 definitions listed in Table 2d are unchanged from the BCPC 2012.

2.2.6. Reducing the Load on Foundation Drainage Systems – Separation from Water Tables

An understanding of water table levels and drainage characteristics of soils is considered fundamental to the protection of basements from flooding associated with groundwater.[10] Specifically, separating building foundations and foundation drainage systems from seasonal high water tables may be a method to reduce loads on foundation drainage systems. The seasonal high water table may be defined as the "highest water table conditions that would be observed during a year with normal amounts of precipitation."[17,GG]

Table 2e lists the footing heights required in several jurisdictions to separate buildings from high water tables.[17] Foundation drainage systems should be high enough above the seasonal high water table level to be required only during "atypical" conditions, such as major storm events or unusually high groundwater conditions.[18]

Reflecting the need to limit reliance on sump pump systems to protect homes from seasonal high water tables, the Durham Standard (2018) recommends that foundation drainage systems not be relied upon to prevent flooding associated with continually or seasonal high water tables (see Table 2f).

Table 2e: Examples of Requirements for the Height of Footings relative to the Groundwater Table[19]

Jurisdiction	Requirement
City of Cambridge, Ontario	Base of footings 0.75 m above the water table.
City of Barrie, Ontario	Foundation drains 0.5 m higher than water table, or as high as practical.
Town of Wasaga Beach, Ontario	Underside of the footing elevation minimum 0.3 m above seasonal high water table.
City of Ottawa, Ontario	Development where sump pumps are proposed shall ensure that each underside of footing is at least 0.3 m above the seasonal high water table.[13]
Eau Claire County, Wisconsin	0.3 m separation between the basement and the seasonal high water table.

Methods for the collection of data on groundwater levels need to be defined, and the responsibility for carrying out this data collection needs to be assigned. Groundwater assessments should consider all site-specific factors that might affect the selection of an appropriate height of footings above the water table.[HH]

[GG] Reviewers of an early draft of this guide indicated that a clear definition of "seasonally high groundwater table" would be helpful. Note that recent technical guidance offered by the City of Ottawa states:

> The estimation of the seasonal high water table shall be completed during spring freshet conditions. Although long term static water table levels may be lower post-development, the pre-development seasonal high water table will be considered as representative of transient conditions that may occur post-development at sites of this nature with poorly drained soils (e.g., clay sites), such as during the spring freshet or higher intensity or sustained storm events.
> (City of Ottawa (2018). Technical Bulletin ISTB 2018-04. Ottawa: City of Ottawa.)

[HH] Reviewer comment (Nov. 2018): "Specific guidance with respect to defining methods for site-specific assessment of groundwater levels may be required."

Table 2f: Durham Standard (2018) Recommendation on Limiting Reliance on Foundation Drainage Systems for Groundwater Flood Prevention[3]

#	Recommendation	Purpose	Notes
17.	Foundation drainage systems should not be relied upon to prevent groundwater flooding associated with continually or periodically high groundwater levels.	• Continual reliance of sump pumps in high groundwater areas increases risk of basement flooding associated with sump pump failure and/or overwhelming of sump pump systems. • Groundwater related infiltration flood issues are extremely difficult to manage post-construction. • Part 9 residential buildings should not be assumed to be able to withstand hydrostatic pressure, buoyancy forces associated with groundwater or overland flooding, unless they have been specifically designed for these purposes.	• The recommendation applies for constant and/or seasonally high groundwater levels. • OBC 9.14.6.1. Surface Drainage sentence (1) states that "the *building* shall be located or the *building* site graded so that water will not accumulate at or near the *building* and will not adversely affect adjacent properties." This sentence does not necessarily address basement flood risk associated with groundwater. • The Ontario Provincial Policy Statement 3.1.1 states that "development shall generally be directed to areas outside of … hazardous lands adjacent to river, stream and small inland lake systems which are impacted by flooding hazards," which does not specifically address basement flood risks associated with groundwater. • The Stormwater Planning and Design Manual (MOE, 2003) includes a provision that basement floor elevations be set above groundwater levels.* • Basement flood elevations should be located above continually or periodically (seasonally) high groundwater levels. • Sites exposed to continually or periodically high groundwater levels may be considered unsuitable for basement construction.

*[Ontario] Ministry of Environment. 2003. Stormwater Planning and Design Manual. Toronto: Ministry of Environment. See: https://www.ontario.ca/document/stormwater-management-planning-and-design-manual/stormwater-management-plan-and-swmp-design

2.2.7. Separation from Infiltration Features

The City of Ottawa's Planning Committee Report #56 states that LID features that may result in increased infiltration of surface water or precipitation into the subsurface should be separated from building foundations to prevent the overloading of foundation drainage systems and sump pits.[18] A similar statement appears in the Durham Standard (2018): "The need to ensure that LID features are hydraulically disconnected from basements, structures, and the suite of drainage infrastructure servicing individual homes (e.g., foundation drainage systems) was further highlighted by Technical Committee members […]."[3]

A draft provincial stormwater management guideline, focused on the application of LID in Ontario, regards "rainwater as a resource which is to be managed as close to the source area as possible (i.e. onsite) using approaches which focus on mimicking the natural water balance and preventing rapid, excessive runoff responses associated with urbanization."[20] Several guidelines are available that promote the use of LID or infiltration features on private properties. The guide entitled "Greening your Grounds: A Homeowners Guide to Stormwater Landscaping Projects," by the Toronto and Region Conservation Authority (TRCA), recommends a 3 m separation between buildings and rain gardens: "To prevent water from getting into foundations and causing basement flooding, rain gardens should always be set at least three metres away from your home, garage and any neighbouring properties."[21]

2.3. Knowledge Gaps, and Research and Data Needs

Judging from the inconsistent responses from contractors involved in the maintenance and repair of foundation drainage systems, comprehensive guidance on foundation drainage system access, inspection, maintenance and repair is needed. Related questions include:

- How can foundation drainage systems be designed to be both accessible and cost-effective? A specific issue identified is whether inspection cameras can be used in systems where cleanouts are combined with perforated, flexible "Big-O" pipe?
- What are the long-term performance implications for foundation drainage systems associated with the use of rooting, cutting, etc. to remove blockages? Are foundation drainage pipes likely to be damaged by these maintenance methods?
- Should multiple drainage points be provided for foundation drainage discharge to sumps or storm connections to avoid system failure if there is a blockage in one location?
- What inspection and maintenance methods are available for foundation drainage systems to reduce the risk of blockage by fine soil particles and other debris? What inspection schedules and methods for flushing or cleaning partially or fully blocked systems should be considered?
- What are the expected lifespans of foundation drainage systems under various operational scenarios?

Plumbing or building code provisions in some jurisdictions may be interpreted as requiring cleanouts for foundation drainage systems. Related questions include:

- Which provincial or territorial codes are interpreted as requiring cleanouts in foundation drainage systems?
- What methods are being applied for this purpose in new and existing homes?

Questions related to the use of infiltration features:

- What is the effect of increasing use of infiltration or LID features on the loads placed on foundation drainage systems?

- Has the increasing use of infiltration features resulted in increased stress on foundation drainage systems and related systems (e.g., sump pumps)?

A consistent finding throughout this guide is that the failure or inadequate performance of private-side drainage features is often related to poor installation, rather than inadequate construction guidance. Related questions include:

- How can AHJs ensure that critical drainage features, specifically those that are expensive to inspect, maintain and repair, are installed according to the best available construction guidance? What is the overall failure rate of foundation drainage systems?
- Are failure rates increasing (e.g., poor installation is more common in newer subdivisions, as reported by contractors)?

The urgency of addressing the above questions is exacerbated by the expected impacts of climate change.

3. Sump Pump Systems and Backwater Protection

3.1. Recommendations

3.1.1. Sump Pits

- Sump pits should be designed to ensure optimal pump operating conditions by:[II]
  - reducing frequency of pump on/off cycles,
  - ensuring consistent, adequate depth of water in the pit based on pump requirements,[22,JJ] and
  - providing storage to protect basements from flooding in the event of a pump failure for an adequate period of time, as determined by the AHJ (e.g., the pit should be capable of containing foundation drainage water for a period of at least 1 hour during peak flow conditions).
- Sump pits should be located as close as possible to the exterior wall (maximum 1.2 m from wall) on the side of the building that facilitates positive drainage.[23,24,KK]
- Sump pit walls and bottoms should be constructed of concrete, polyethylene, polypropylene, fiberglass or other suitable material, as approved by the AHJ.[25]
- Sump pit bottoms should be solid and should provide permanent support for the pump.[24]
- Sump pits should be placed on an even, compacted surface.[23]
- Sump pit covers should be:
  - sealed,[25,LL]
  - capable of supporting the occupancy floor load,[25] and
  - fastened in a manner acceptable to the AHJ.[25]
- The outside perimeter of the sump pit should be filled with clean washed rock (19 mm to 25 mm) to facilitate good drainage (for metal and plastic sump pits).[23]

3.1.2. Sump Pit Inlet Pipes

- Sump pit inlet pipes should be 100 mm (4 in.), and sump pits should be fitted with an opening to accept a pipe of that size.[23]
- Where present, connections between the foundation drainage system and the sump pit should be sloped in a manner that directs water to the sump pit.[5]
- The existing sump pit should be replaced with a deeper pit if necessary to achieve an appropriate slope for the inlet pipe.[5]
- The invert of the sump pit inlet pipe should be located above the centreline of the height of the sump pit.[23]

[II] Note the following prescriptive provisions for sump pit sizing:
- City of Winnipeg (2001). "Sump Pits and Pumps." Winnipeg Building By-Law No. 4555/87. Winnipeg: City of Winnipeg: Recommends that the pit be capable of containing foundation drainage water for a period of at least 1 h, and that pits have a minimum floor area of 0.46 m^2 and a minimum depth of 0.8 m.
- City of Lethbridge (1994). "Sump Design Criteria." Lethbridge: City of Lethbridge: "Sump pits are to be a minimum of 750 mm (30") deep, and 0.25 m^2 in area."
- Sump and Sewage Pump Manufacturers' Association (SSPMA) (2013). "For New or Replacement Sump Pumps: Guide for Installation." Indianapolis: SSPMA: Recommends sump pit diameters of 18 in. to 24 in. depending on flow conditions.

[JJ] As reported by Friend, D. and Petersen, D. (2005). "Sizing Up a Sump Pump." University of Illinois Extension College of Agriculture, Consumer and Environmental Sciences: "Most pumps depend on having water in the pump at all times to lubricate and cool pump seals. So make sure the float switch is positioned to prevent the pump from running dry."

[KK] Note that SSPMA (2013) recommends that pits be placed 6 in. away from walls.

[LL] NBC Sentence 9.25.3.3.(7): "Where access hatches and sump pit covers are installed through assemblies constructed with an *air barrier system*, they shall be weatherstripped around their perimeters to prevent air leakage."

- The water level in the sump pit should be maintained below the invert of the weeping tile or inlet pipe that is discharging water into the sump pit.[25]

3.1.3. Sump Pumps

- Sump pumps should:
  - be of the centrifugal impeller type,[25]
  - be of the submersible[25] or column type,[23]
  - be designed for up to 10 on/off cycles per hour,[25]
  - be rated for continuous duty[25] and at least 0.19 kW,[25]
  - have a minimum service factor of 1.10,[25] and
  - be capable of passing objects (e.g., stones) up to 10 mm (0.4 in.) in size.[26]
- Suppliers and manufacturers of sump pumps should be consulted to estimate the expected lifespan of the sump pumps. Where this information is unavailable, the following may be considered:
  - Sump pumps should be expected to have a lifespan of no more than 10 years.
  - The expected lifespan may be considerably shorter depending on the operating conditions and the quality of the installation of the full sump pump system.[MM]
  - Sump pumps should comply with CSA 22.2 No. 108:14, "Liquid Pumps," and CAN/CSA-E60335-2-41:13, "Household and similar electrical appliances – Safety – Part 2-41: Particular requirements for pumps."[2]

3.1.3.1. Capacity

- The sump pump capacity should:
  - be determined on a case-by-case basis and should account for the flow of water into the sump pit and the total dynamic head (see Section 3.2.2.1.),[22] and
  - be large enough to manage expected flow into sump pits without being too large, as over-powered pumps may cycle frequently, resulting in an increased risk of premature failure and the stressing of system components (e.g., check valves and discharge pipes).[22]
- In new homes, where information related to the flow of water into the sump pit is not available, the following guidelines related to sump pump capacity may be considered:
  - For homes built on sandy soil, plan for a system capacity of 53 L/min (14 gal./min) for every 93 m^2 (1 000 $ft.^2$) of home.[22]
  - For homes built on clay soil, plan for a system capacity of 30.3 L/min (8 gal./min) for every 93 m^2 (1 000 $ft.^2$) of home.[22]

3.1.3.2. Installation

- Sump pits and pumps should be easily accessible to allow for inspection and maintenance.[18,24,NN]
- Sump pumps should be installed such that inlets are located at least 30 mm (1 1/8 in.) above the bottom of the sump pit.[25]
- Sump pumps should be connected to an electrical circuit that does not supply other outlets or electrical equipment, in compliance with local electrical safety authority requirements and as approved by the AHJ.[23,25,27,OO]
- Sump pumps should be located in sump pits such that the pump housing will not come into contact with the side of the pit.[24]

[MM] One indicator of pump lifespan may be the lifespan of its microswitch. For example, with a microswitch design life of 50 000 cycles, a pump performance of 10 cycles per hour would result in the microswitch exceeding its lifespan after approximately 208 days (see Section 3.2.3.4.).

[NN] The need for homeowners to maintain sump pumps was further highlighted by City of Ottawa (2017).

[OO] "The sump pump should be connected to an electrical circuit that supplies no other outlet or equipment."

3.1.4. Sump Pump Float Switch

- There should be no interference with the float switch:[28]
  - The sump pump should be located in the sump pit such that the float will not come into contact with the side of the pit.[24]
  - Power cords and related obstructions should not be draped over the float switch.[24]
- Floats should be located such that they are able to operate freely over the lifespan of the pump.

3.1.5. Sump Pump Discharge Pipes and Check Valves

- See CSA Z800-18 for common sump pump discharge options.
- Surface flows from sump pump discharge pipes should not cross property lines.[PP]
- Where drainage across property lines is necessary, and where possible, drainage across property lines should be spread to encourage sheet flows and reduce concentrated, erosive flows.[29]
- Discharge pipe size should be equal to or larger than the discharge size of the pump.[24]
- Discharge pipes should have a minimum diameter of 30 mm (1 1/8 in.).[23,25,QQ]
- Discharge pipes should be as short as possible with a minimum number of turns.[24]
- Discharge pipes should be located so as not to create hazards[25] within the home (e.g., a tripping hazard or a hazard associated with leakage onto electrical equipment and other utilities).
- Discharge pipes should be adequately secured to the foundation wall.[23]
- Discharge pipes from pumped sumps should be equipped with a union, a check valve and a shut-off valve installed in that sequence in the direction of discharge.[23,24,25,26,30,RR,SS]
- A relief hole of 3.17 mm to 4.57 mm (1/8 in. to 3/16 in.) in diameter should be drilled in the discharge pipe. This hole should be located below the floor line between the pump discharge and the check valve, and should drain into the sump pit.[24]
- When the pump cycles frequently, the check valve and discharge pipe should be regularly inspected for wear and fatigue.[TT]
- Components in discharge pipes requiring periodic maintenance or replacement (e.g., check valves) should be easily accessible and removable (e.g., not glued in place).[31]
- Discharge pipes located outside a building should be adequately graded or otherwise protected against freezing and frost.[25]

3.1.6. Backup Systems and Alarms

- Sump pump systems may be supplied with a backup sump pump with a backup power supply, set to engage in the event of a power outage or mechanical failure of the primary pump.[3,UU]

[PP] Where possible, surface flows should be kept 1 m inside property lines.

[QQ] The City of Lethbridge requires a minimum diameter of 32 mm.

[RR] See also NPC Sentence 2.4.6.3.(6): "The discharge pipe from every pumped sump shall be equipped with a union, a *backwater valve* and a shut-off valve installed in that sequence in the direction of discharge."

[SS] This measure remains in this guide to ensure that the code wording is consistently interpreted. Specifically, OBC Sentence 7.4.6.3.(8) states:

> The discharge pipe from every pumped *storm sewage* sump shall be equipped with,
> (a) a union and a *check valve* installed in that sequence in the direction of discharge and pumped to above grade level, or
> (b) a union, a *check valve* and a shut-off valve installed in that sequence in the direction of discharge.

The definition of "storm sewage" in the OBC is as follows: "*Storm sewage* means water that is discharged from a surface as a result of rainfall, snow melt or snowfall." Thus, there may be a need to revisit the code wording in some jurisdictions to clarify that check valves are required for sump pumps servicing foundation drainage systems.

[TT] Input from NRC reviewer (March 22, 2018).

[UU] Reviewers of an earlier draft commented that the backup pump may be considered an unnecessary redundancy in most circumstances. This provision has been reworded to indicate that backup pumps "may" be incorporated. The application of backup pumps may depend on the risk tolerance of the homeowner, builder, AHJ, etc.

- See CSA Z800-18 for general recommendations on backup power for sump pumps. Primary and backup pumps should be powered by their own dedicated electrical circuit.
- Backup pump batteries should:
  - be deep-cycle batteries (e.g., marine batteries),[32]
  - have the highest ampere-hour rating recommended by the manufacturer of the backup pump,[32] upon approval by the local AHJ,
  - have their voltage checked every six months, and
  - be tested for both static voltage and voltage under load.[32]
- Chargers for backup pump batteries should:
  - be located off of the basement floor (e.g., 90 cm to 120 cm above the floor) to reduce the risk of damage in the event of a basement flood,[32]
  - be located in a dry environment,[32] and
  - be easily accessible for regular testing, maintenance and replacement.[32]
- Depending on risk tolerance, foundation drainage flow conditions, and direction provided by the AHJ, a generator should be used to supply both the primary sump pump and the backup pump battery charger.[32]
  - Alternatively, a rough-in should be provided to allow for the installation of an external generator or an auxiliary power supply by homeowners at a later date.[3]
- Primary and backup pumps may use the same discharge pipe.[32]
  - When they discharge via the same pipe as the primary pump, backup pumps should be supplied with their own check valve.[32]
- Sump pump systems should be supplied with a failure alarm to notify homeowners of primary pump failure and high water conditions in the sump pit.[3,24]

3.1.7. Backwater Valves for Gravity-Drained Foundation Drainage Systems[VV]

- Backwater valves should be used to protect gravity-drained foundation drainage systems against sewer backwater.[3,32]
- Provision should be made for foundation drainage discharge in the event that storm system surcharge closes the backwater valve (i.e., sump system draining to the surface of the lot).[3]
  - Sump systems used in combination with backwater valves should be installed in consultation with the local AHJ.
- Backwater valves used in this application may be normally open or normally closed.
- The following standards should be consulted when selecting storm and sanitary backwater valves:
  - ASME A112.14.1-2003, "Backwater Valves"[33]
  - ANSI/CAN/UL/ULC 1201:2016, "Sensor Operated Backwater Prevention Systems"[34]
  - CAN/CSA B1800-15, "Thermoplastic Nonpressure Piping Compendium"[35]
- Devices and technologies used to protect foundation drainage systems against sewer backwater should be accessible for routine maintenance and inspection.[3]

3.1.8. Foundation Drainage Systems Where Drainage is Pumped to a Municipal Storm or Foundation Drainage Collector (FDC) System

- A sump pump, sump pit, and backup system should be installed in accordance with the above recommendations (see Sections 3.1.1. to 3.1.6.).
- The sump pump discharge pipe should be made to loop over the foundation wall.

[VV] See NPC Article 2.4.6.4. and CSA Z800-18 Clause 6.9.1.(b) for additional information on acceptable backwater protection measures.

  - Alternatively, the highest point of the sump pump discharge pipe should be well above the probable high (e.g., 100-year) hydraulic grade line (HGL) in the receiving system.
- The discharge pipe should be made to drain into an external downpipe that is connected to a municipal storm or FDC system.
- A separate discharge to surface should be included to allow for sump pump discharge when the receiving system is surcharged, blocked or otherwise unable to receive sump pump discharge.

3.1.9. Foundation Drainage Systems Where Drainage is Pumped to the Surface

- Where a connection to a municipal storm or FDC system is not provided, see CSA Z800-18 for recommendations on sump pump discharge to surface. Additionally:
  - Discharge to surface is subject to approval by AHJ.
  - The carrying capacity of the lot, which may include factors related to slope and drainage, soil type, groundwater conditions, etc., should be considered when discharging sump pumps to the surface of the lot.

3.1.10. Documentation for Homeowners[3]

- Guidance should be provided for any basement flood protection system of the building that requires maintenance for effective operation, including:[ww]
  - foundation drainage systems,
  - sump pump systems, and
  - other systems as necessary.
- Homeowners should be provided with basement floor plans that identify the location of critical basement flood protection equipment, including:
  - sump pits,
  - backwater valves (storm or sanitary), and
  - other equipment as necessary.
- Labelling should be provided for basement flood protection equipment to facilitate easy identification of:
  - backwater valves (storm or sanitary),
  - check valves (e.g., on sump pump discharge lines),
  - sump pits,
  - primary sump pumps,
  - backup sump pumps,
  - sump pump backup power supplies (including batteries and battery chargers),
  - sump pump discharge lines, and
  - other equipment as necessary or as required by the AHJ.

[ww] See, for example, City of Ottawa (2018). Technical Bulletin ISTB 2018-04. Ottawa: City of Ottawa, which states:

> The maintenance and operation of the sump pump system (including back-up power and backwater valve) and eavestrough discharge is the responsibility of the homeowner. These conditions shall be included in the purchase and sale agreement and registered on title […] all equipment must be clearly labeled and a floor plan showing the system must be provided by the home builder to the purchaser.

3.2. Observations

CSA Z800-18 provides general provisions related to sump pump systems, including provisions for backup power options and alarms, discharge options, sewer backwater protection, protection of discharge pipes against frost and freezing, sump pit covers, sump pit overflow (where approved by the local AHJ), discharge point location relative to foundation walls, and ensuring that sump pump discharge does not create hazards in yards, neighbouring properties or public right-of-ways.[2] Furthermore, CSA Z800-18 discourages the use of exterior sump pump systems (i.e., systems where the sump pit is located outside the building), and does not permit the use of water-powered backup sump pumps.[2] CSA Z800-18 also outlines common foundation drainage discharge options and recommendations with respect to the protection of foundation drainage systems from sewer backwater.[2]

With respect to the selection, design and capacity of sump pumps, electrical supplies for sump pumps (e.g., dedicated circuits), and the expected lifespan of sump pump systems, CSA Z800-18 refers users to generalized information and/or the local AHJ.[2] Similarly, the NBC provides relatively generalized, high-level minimum requirements for sump pump systems (see Box 3a).[1]

Box 3a: NBC 2015 Part 9 Sump Pit and Pump Provisions

9.14.5.2. Sump Pits

1) Where a sump pit is provided it shall be
- a) not less than 750 mm deep,
- b) not less than 0.25 m^2 in area, and
- c) provided with a cover.

2) Covers for sump pits shall be designed
- a) to resist removal by children, and
- b) to be airtight in accordance with Sentence 9.25.3.3.(7).

3) Where gravity drainage is not practical, an automatic sump pump shall be provided to discharge the water from the sump pit described in Sentence (1) into a sewer, drainage ditch or dry well.

9.25.3.3. Continuity of the Air Barrier System

[…]

7) Where access hatches and sump pit covers are installed through assemblies constructed with an *air barrier system*, they shall be weatherstripped around their perimeters to prevent air leakage.

While municipalities across Canada have developed detailed requirements related to foundation drainage discharge, protection of foundation drainage systems from backwater, and sump pits and pumps, limited standard guidance is available at the national level for sump pump system design and sewer backwater protection for foundation drainage discharge connections. It is further noted that specific details on sump pump systems and foundation drainage discharge requirements vary at the local level.

Sump pump systems have the potential to be relatively complex, depending on local requirements and site conditions. Furthermore, it is recognized in several documents produced by the sump pump manufacturing industry, as well as in foundation drainage design guidelines, that sump pump systems – even when installed according to best available practices – are vulnerable to failure. Causes of sump pump system failure include:

- mechanical failure of sump pumps (see Section 3.2.3.),
- failure of sump pumps due to power outages,
- overwhelming of sump pumps or pits due to high foundation drainage discharge rates,
- improperly installed sump pump systems, where floats are not able to move freely, and
- freezing of sump pump discharge lines.

The intent of the draft recommendations presented above is to begin to fill gaps in the CSA Z800-18 guidelines with respect to sump pits and pumps, such that more consistent standards with respect to sump pump system design can be applied in Canada.

3.2.1. Discharge Options for Foundation Drainage

Table 3a summarizes three common discharge options for foundation drainage: gravity drainage to a municipal receiving system (storm or FDC system), pumped discharge to the surface of the lot, and pumped discharge to a municipal receiving system. The third option involves a "looped" or "gooseneck" approach in which a discharge pipe that is raised to reduce the risk of backwater from the receiving system entering the discharge pipe (i.e., raised over the foundation wall or above the 100-year HGL of the receiving system).

The discharge options for foundation drainage depend on specific site conditions, including slope, proximity to ravines, lot size and carrying capacity for sump pump discharge, capacity of storm systems, and the existence of FDCs. It should be noted that preference for a specific discharge option for foundation drainage is not expressed in CSA Z800-18 or the Durham Standard (2018); however, both of these documents indicate that foundation drainage systems should be protected from backwater.

Table 3a: Comparison of Common Foundation Drainage Discharge Options – Gravity Drainage, Pumped to Surface, and Pumped to Municipal Receiving System[3]

Option	Benefits	Drawbacks
Gravity Drainage: Gravity drainage to storm or FDC system	• Reduces reliance on sump pump systems. • Does not depend on carrying capacity of lots (based on lot size, soil conditions, slope, etc.).	• Protection from backwater requires installation of backwater valve(s). • Provisions must be made for foundation drainage discharge in the event of valve closure (e.g., overflow to sump pit, discharge to surface). Sump pump systems require inspection, maintenance and backup power. • Foundation drain connections to storm and FDC systems increase load during periods when these systems are stressed (e.g., during extreme rainfall events), increasing risk of water not effectively draining from foundation drainage systems and risk of backwater. • A storm or FDC service lateral must be provided, requiring maintenance and exposing the building to potential issues associated with poor construction or installation of laterals.
Pumped to Surface: Drainage to sump, discharge via sump pump to surface of the lot	• Provides passive hydraulic break from municipal storm or FDC system.[XX] • Protects foundation drainage system from sewer backwater. • Does not require installation of storm	• Relies on sump pumps for foundation drainage discharge, which require inspection and maintenance. • Power requirements for sump pumps (e.g., increased energy use, energy costs, failure during power outages where backup power systems are not in place or inadequately maintained). • Requires backup power systems, alarms for sump

[XX] Reviewer comment (Nov. 2018): "The FDC system should not be able to receive overland flows as it is dedicated to weeping tiles only. It could, however, be prone to inflow from areas of surface flooding via the maintenance hole covers."

Option	Benefits	Drawbacks
	private drain or FDC connection, provided no other gravity interconnection exists. • May serve to attenuate flow of foundation drainage to municipal storm systems.	pumps, potentially backup sump pump system depending on risk tolerance of user. • Drainage to lots may be limited based on carrying or conveyance capacity (based on lot size, soil conditions, grading, etc.). • Improper discharge practices (e.g., discharging too close to foundation wall, recirculation of foundation drainage discharge) may exacerbate flood hazards, risk of premature sump pump failure due to pump over-cycling.
Pumped to Municipal Receiving System: Drainage to sump, discharge via sump pump to external downpipe that is connected to storm or FDC system (looped or gooseneck approach)	• When outlets are installed well above probable HGL in FDC or storm systems, this approach provides passive hydraulic break from municipal storm or FDC systems. • Provides protection of foundation drainage system from sewer backwater. • Does not depend on carrying capacity of lots (based on lot size, soil conditions, grading, etc.) to manage foundation drainage discharge.	• Relies on sump pumps for foundation drainage discharge, which require inspection and maintenance. • Power requirements for sump pumps (e.g., increased energy use, energy costs, failure during power outages where backup power systems are not in place or inadequately maintained). • Failure to appropriately install and protect downpipes and storm connections during backfilling may result in disconnection or cracking of pipes, exacerbating flood hazards associated with recirculation of foundation drainage discharge. • Requires backup power systems, alarms for sump pumps, potentially backup sump pump system depending on risk tolerance of user. • A storm or FDC service lateral must be provided, requiring maintenance and exposing the building to potential issues associated with poor construction or installation of laterals.

3.2.1.1. Risks Associated with Pumped Discharge Options

Practice guides and documents produced by local AHJs highlight the inherent risks associated with using sump pump systems for foundation drainage discharge. For example, Horizon Engineering (2020) makes the following observations related to sump pump systems used to discharge foundation drainage:[4]

- Where possible, the need for a pumped system should be eliminated through site selection and/or building design.
- In some residential buildings, the requirement for a pumped system may be eliminated by raising the basement floor slab by only a few inches.

With respect to the risk of failure of sump pump systems, a similar observation is made in *Best Practice Guidance – Type-C Waterproofing Systems (BS 8102:2009)* by the Property Care Association (2015):[36]

> It should be remembered that the sump pump is a mechanical device and as such will fail eventually. It is therefore good practice to consider the service life of a pump and plan to replace the unit long before the pump fails.

Reflecting the risks associated with pumped foundation drainage systems, the “Sewer Design Guidelines” by the City of Ottawa (referred to as “City of Ottawa (2012) Guidelines”) include the following:[37]

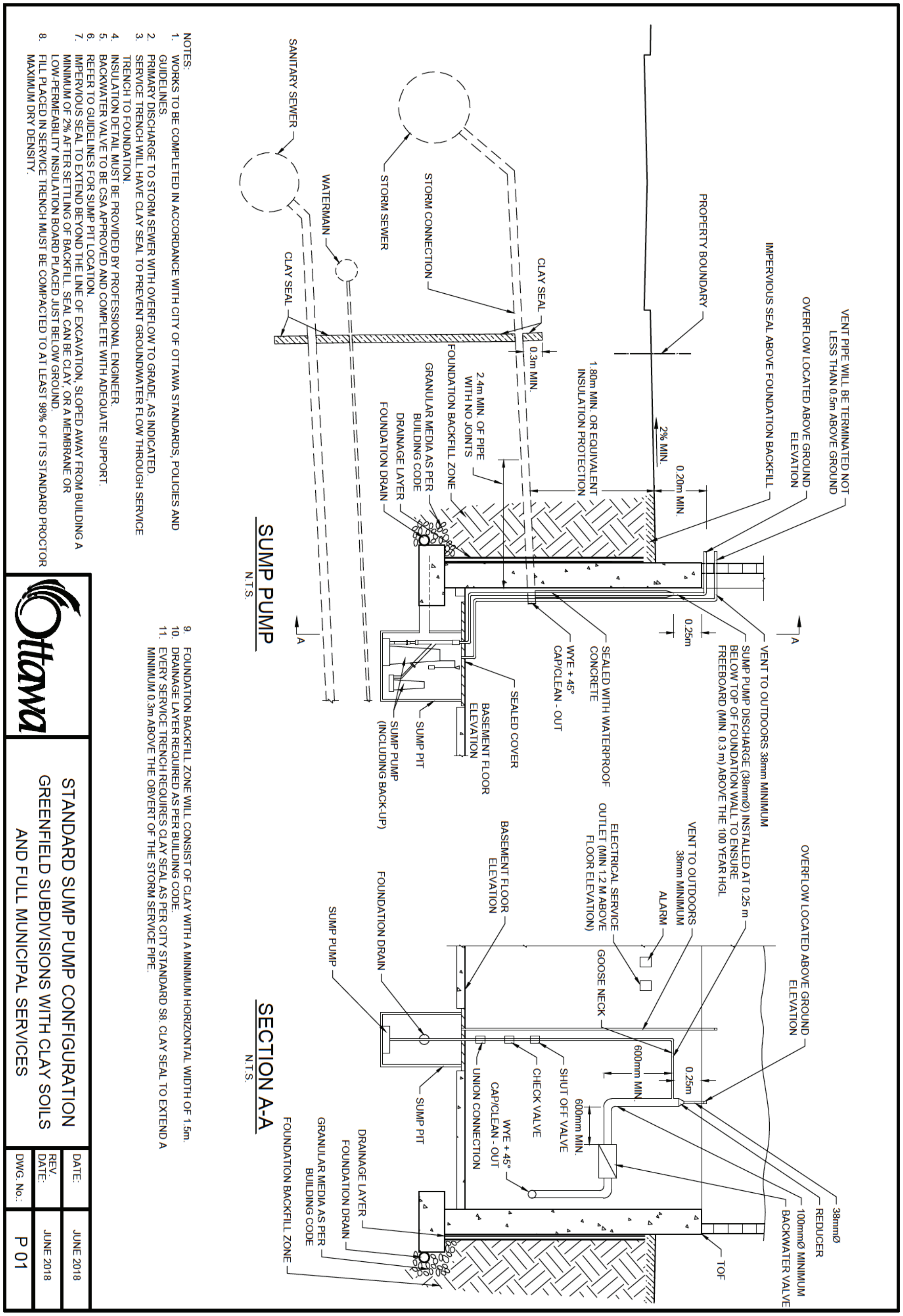
- All basement foundation drains should drain by gravity to a storm sewer,
- Basements should be located above the 100-year HGL of the storm sewer, and
- Exceptions (use of sumps) may be considered if proponent demonstrates justification in terms of implementation feasibility and economics, as well as engineering, environmental, operational, reliability, risk and maintenance issues.

The City of Ottawa (2012) Guidelines allow the use of sump pump systems for foundation drainage discharge, provided construction meets recently introduced criteria for sump pumped foundation drainage systems.[37] The criteria include provisions for sump pumps and pits, discharge pipes, backwater protection (backwater valves), backup power supplies, and failure alarms, which correspond to many of the best practices identified in this guide and in CSA Z800-18. The criteria further include provisions for:

- the use of impervious caps for backfill zones (extending 1.5 m from the drainage layer on all sides of the foundation) (see Figure 3a),
- the use of clay seals to manage the risk of groundwater flow through service trenches to the foundation (see Figure 3a),
- the use of backwater valves for foundation drainage system protection (see Figure 3a),
- the completion of hydrogeological assessments to identify the pre-development high water table and an understanding of transient events that may affect groundwater (e.g., spring thaw, high intensity storms), and
- the completion of assessments of groundwater ingress for long-term conditions and transient events to support the setting of elevations for the underside of footings.

To assist homeowners in the maintenance of sump pump systems, the criteria state that “all equipment must be clearly labeled and a floor plan showing the system must be provided by the home builder to the purchaser.”[13]

Figure 3a: Criteria for Sump Pumped Foundation Drainage Systems, City of Ottawa[37]



The risks associated with the use of sump pump systems for foundation drainage discharge have been considered significant enough to warrant indemnification of builders and municipalities where these systems are present. For example, a report submitted to the City of Ottawa on sump pump system design advises that homebuilders should "include [a] clause during sale stating that the homeowner accepts responsibility for maintenance and operation of the sump system" and that the "purchaser should also be provided with information on the use and maintenance of the system." The report makes the following observations related to use of sump pump systems for foundation drainage discharge:[17]

- "It is noted however that the potential rate of ingress of groundwater to foundation drains is a function both of the elevation of the water table, and the permeability of the surrounding soils, with the concerns noted […] where relatively higher permeability soils occur."
- "Gravity drainage applied where there are robust stormwater management systems in place, such as those designed for 100 year storm events. Gravity drainage would not be appropriate where systems can not handle this level of flow, as the risk of surcharging would be greater."

3.2.1.2. Alternatives to Pumped to Surface Discharge Option

The increasing density of new developments (where a large portion of each lot is covered by the building footprint and impermeable surfaces) results in inadequate space to drain sump pump discharge. Issues with the carrying capacities of lots are intensified as homeowners add impervious surfaces, including patios, pools, decks, etc. For example, the Town of Collingwood, Ontario has routinely received complaints about wet conditions in yards caused by sump pump discharge (see Figure 3b). It is suspected that, to avoid the wet conditions, many homeowners in affected Collingwood subdivisions (approximately 50%) have been redirecting sump pump discharge pipes to connect with sanitary sewer connections in basements.[38] To limit the potential for cross-connections, houses in new subdivisions are being provided with storm sewer service, and sump pump discharge is made to enter the storm sewer. As presented in Table 3g in Section 3.2.4.1., several other jurisdictions in Canada are applying a similar approach.

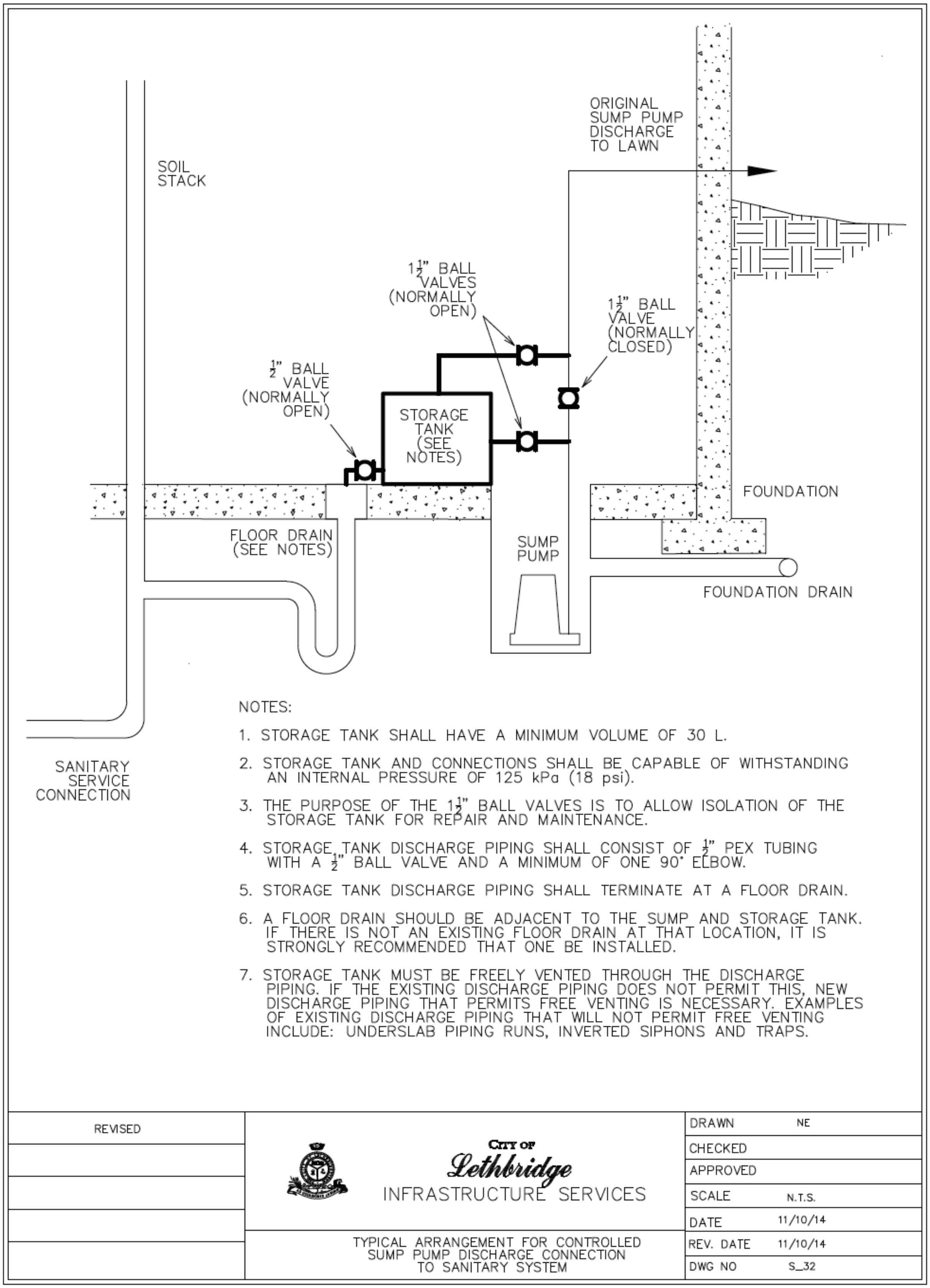
Figure 3b: Saturated Yard Resulting from Sump Pump Discharge (Collingwood, Ontario)[39]

The City of Lethbridge permits the connection of sump pump systems to sanitary sewer systems through "controlled discharge connections," which allow controlled discharge to floor drains for properties that experience issues with sump pump discharge (e.g., negative impacts on neighbouring properties, ponding, icing). The City of Lethbridge describes the controlled discharge option as follows (see Figure 3c):[40]

> A controlled discharge connection is an authorized connection from the sump pump to the sanitary sewer system via a basement floor drain. It includes a small storage tank intended to allow a limited amount of water into the floor drain. During wet weather events, the controlled discharge is designed to move surplus water to your yard. This mitigates frequent or year-round sump pump discharge to your yard or adjacent property.

This option is consistent with an accepted approach in Alberta that allows sump pumps to discharge to sanitary sewers under specific circumstances. A similar approach would likely not be permitted in other regions of Canada (e.g., Ontario, where local sewer use by-laws typically prohibit direct or indirect foundation drainage to sanitary systems).

Figure 3c: Controlled Discharge Option, City of Lethbridge[40]



3.2.2. Sump Pump Systems

3.2.2.1. Sump Pump System Sizing, Capacity, and Cycling

The appropriate sizing of sump pump systems is an important aspect of good system design. With respect to sump pit size, the City of Moncton states: "If [the] sump pit is incorrectly sized, it will affect the operation of the pump. The pump is most efficient when it is working at its optimal flow rate, based on the capacity of the pit."[26] Related recommendations include the following:

- Pumps should be sized with greater pumping capacity and head than is required.
- "Sump pumps should be rated for continuous duty."[17]
- "Sump pump should be CSA approved and designed for up to 10 start/stop cycles per hour."[17]

In the context of flood abatement pumps, ANSI/FM Approvals 2501-2014 requires a pump to be capable of 336 h of continuous operation at its rated capacity.[41] ANSI/FM Approvals 2501-2014 further requires that no excessive wear or damage be exhibited after 1 000 cycles of flood abatement pump switches.

Horizon Engineering (2020) suggests the following:[4]

- The sump pump system should be sized for site-specific groundwater volumes (perched, interflow and/or ambient), including seasonal fluctuations and considering the hydraulic conductivities of the surrounding soil (refer to geotechnical, civil engineers for design guidance).
- Sump volumes should be large enough to allow for some storage of water and the proper operation of float switches, to reduce the risk of a pump "burning out."

Code inspection staff of the City of Winnipeg indicated that the sump pit depth requirements in the City's By-law 4555/87 were likely developed to ensure that sump pits had the volume necessary to contain discharge from extreme rainfall events (based on intensity-duration-frequency curves). However, the intensities of the events used to develop these requirements were not readily available. The sizing requirements were also developed to contain discharge during potential power outages.

The potential rate of groundwater flow into the foundation drain is a function of the elevation of the water table and the permeability of the surrounding soils. Sump pumps in clay soils should cycle less frequently than those in sandy soils because the clay soils are less permeable.[18] Rainwater or surface water that percolates through the backfill zone and enters the foundation drainage system is an important component of the load placed on the system.[4]

As reported by Friend and Peterson (2005), two critical pieces of information for the sizing of sump pumps are system capacity and total dynamic head (static head + friction head).[22] Sump pumps should have adequate capacity to draw water out of a sump pit faster than water flows into the pit. Friend and Peterson (2005) provide guidelines for determining the necessary capacity for a sump pump system, which include guidance on selecting the size of the sump pit, determining the flow rate into the pit, and determining the static head and friction head (which can then be used to determine the total dynamic head).[22]

3.2.2.2. Sump Pump Discharge

The appropriate method of sump pump discharge will largely depend on site-specific characteristics (e.g., lot grading and carrying capacity, soil type, existence of permeable discharge points). Regardless of the discharge method, however, measures should be applied to ensure that sump pump discharge does not re-enter the foundation drainage system via the backfill zone (see Table 3b). Ensuring that sump pump discharge does not create nuisance issues for neighbouring properties is also necessary. For example, the City of Winnipeg includes provisions for sump pump discharge points in its lot grading by-law. The by-law stipulates that sump pump discharge points must be identified on site plans for lot grading approvals and that property owners are responsible for the maintenance of discharge pipes and splash pads, as follows:[42]

> <u>Maintenance of Roof Downspouts, Sump Pump Discharge Pipe and Splash Pads</u>
> (3) The Owner shall be responsible to ensure that roof downspouts, sump pump discharge pipe and splash pads or their approved equivalent are maintained so as to meet the requirements set forth in subsections 5(9) and 5(10) of this By-law.

Table 3b: Durham Standard (2018) Recommendation on Avoiding Recycling of Foundation Drainage via Sump Pump Discharge[3]

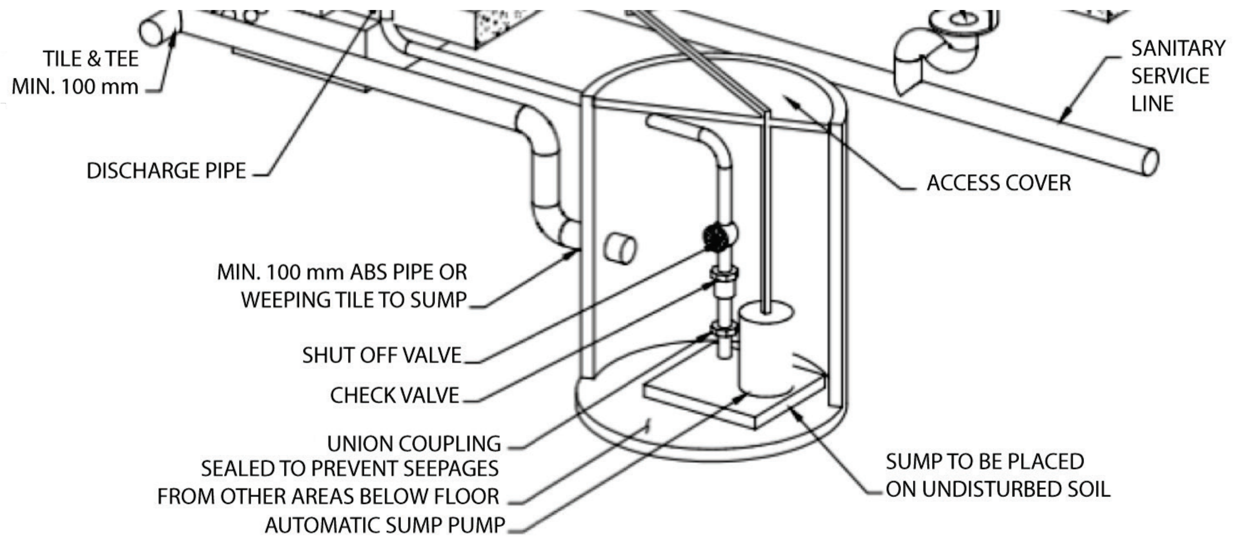
#	Recommendation	Purpose	Notes
19.	When sump pumps are used to discharge foundation drainage to the surface of the lot: Sump pump discharge should be directed to appropriate drainage infrastructure and should drain at a sufficient distance from foundation walls to reduce risk of foundation drain discharge recycling.	• Applies when sump pumps are used to discharge foundation drainage to the surface of the lot. • When sump pump discharge points are too close to foundation walls, there is increased risk of water recycling into the foundation drainage system (i.e., water that has been pumped percolates into foundation drainage via backfill zone). • Drainage to appropriate infrastructure reduces municipal and private sidewalk, walkway, driveway etc. icing risk. • Reduces the likelihood that sump pump discharge will negatively affect neighbouring properties.	• Sump pump discharge and drainage not covered by the OBC. • Sump pump discharge should be directed to drainage swales or other conveyance infrastructure or discharge points, as approved by the local municipality. • Sump pump should be made to discharge to permeable surface (e.g., lawns)* or other approved discharge and conveyance infrastructure (e.g., green infrastructure, LID). • Where possible, extend sump pump discharge points to minimum 1.8 m from foundation walls. • Where site/drainage conditions do not permit 1.8 m extensions, ensure that discharge points are beyond the line of excavation and backfill. • Municipalities in Durham Region may assess sump pump discharge as part of lot grading approvals. • Selection, design and construction of appropriate lot-scale/private-side LID features will depend on lot-level factors related to soil, slope, availability of drainage outlets, expected discharge rates from sump pumps, etc. See: Sustainable Technologies Evaluation Program (STEP). 2018. *Low Impact Development Stormwater Management Planning and Design Guide* for appropriate lot-scale/ private-side LID features that may be used to manage sump pump discharge drainage.**

			• Provision should be made to ensure that sump pump discharge is safely conveyed away from buildings/ properties in the event of LID system failure.

*City of Oshawa Engineering Design Criteria Manual Section 5: Lot Grading, subsection 5.7 states: "roof water leaders discharged to the surface shall be directed to front and rear yard permeable areas only and not to the side yard swale."
**At the time of writing, these materials under review. Materials will be available from the following webpage in 2018: https://wiki.sustainabletechnologies.ca/index.php?title=Special:CiteThisPage&page=Main_Page&id=5893
2010 versions of the guidance documents are available from https://www.creditvalleyca.ca/low-impact-development/low-impact-development-stormwater-management-planning-design-guide/

Several design drawings provided by municipalities include requirements for union couplings, check valves and shut off valves in sump pump discharge lines (see Figure 3d). These fittings are arranged in the direction of flow, as stipulated in NPC Sentence 2.4.6.3.(6) and illustrated in NPC Figure A-2.4.6.3.[14] While guidance on these fittings is included in the NPC, it is important to ensure that these fittings are incorporated when existing homes are retrofitted with sump pumps.

Figure 3d: Sump Pump System Detail, City of Regina[30]



The incorporation of an air relief hole in the discharge pipe may be recommended when a check valve is not attached to the pump itself. Specifically, guidance provided by the University of Illinois Extension (2008) states:[43]

> When installing a sump pump, it is usually recommended that a check valve be installed. This valve prevents water left in the outlet pipe from flowing back into the basin. Some valves can be attached to the sump pump itself, while others are placed farther up the outlet pipe. If the valve is not attached to the pump, it is recommended that a 1/8-inch air relief hole be drilled into the outlet pipe, between the valve and the pump. This hole prevents a condition called an air lock, where the pump will attempt to work but cannot pump water. Be sure the air relief hole is placed so that any water that comes out of the hole will remain in the drainage basin.

Similarly, the Sump and Sewage Pump Manufacturers Association (2013) provides the following additional recommendation:[24]

> Use of a check valve is recommended to prevent backflow of water into the sump. A relief hole (1/8" or 3/16" diameter) should be drilled in the discharge pipe. This hole should be located below the floor line between the pump discharge and the check valve. Unless such a relief hole is provided, a bottom intake pump could "air lock" and will not pump water even though it will run.

3.2.2.3. Protection from Freezing

Sump pump discharge pipes should be protected against freezing.[44] Freezing of exterior discharge pipes for sump pumps increases the risk of sump pump failure due to pump burn-out resulting from deadheading caused by build-up of ice in discharge lines.[3]

Figure 3e: Freeze Protection for Sump Pump System (Edmonton, Alberta)

It is generally acknowledged that properly sloped and drained discharge pipes are not typically vulnerable to freezing.[3] However, in some jurisdictions (notably in Alberta), provision is made for temporary drainage of sump pump systems into building sewer connections, including sanitary sewer connections, during periods when there is risk of the pipe freezing. Figure 3e shows an example of this approach, as applied in Edmonton, Alberta.[45] In Figure 3e, a series of valves allow a homeowner to discharge a sump pump system into a sanitary sewer connection during the winter months. Note that this arrangement may be prohibited by local sewer-use by-laws in some jurisdictions (e.g., Ontario). Other jurisdictions, notably the majority of Ontario municipalities, have by-laws that prohibit the discharge of foundation drainage to sanitary sewers at all times. It is important to consider the risk of freezing in a gooseneck configuration where the discharge pipe exits the exterior wall. An additional option may include placing the full gooseneck discharge pipe inside the basement, rather than directing the discharge pipe to an exterior downpipe.[46]

3.2.2.4. Backup Power and Alarm Systems

Sump pits that are large enough for two pumps (i.e., primary and backup pumps) are recommended. Alarm systems to notify homeowners of high water levels in sump pits and of potential failure of sump pump systems are also often recommended as basic system components.[24,36] With respect to backup power for pumped foundation drainage discharge systems, the Property Care Association (2015) states:[36]

> Battery backup pump systems are typically included to protect in the event of a power cut, with additional mechanical pumps being added to provide further redundancy or additional capacity as necessary. Such systems should include high level alarms to forewarn in the event of a problem, which may alert via local audible alarm or, where required, remote telemetric phone call.

With respect to backup, auxiliary-powered pumps, the following has been noted:[17]

- "Emergency backup pumps with DC electric motors powered from batteries – typically installed in the sump pit with the main AC powered pump and set to switch on at higher water level …"
- "Batteries for these applications typically 12 volt deep cycle or long-life batteries."

- “Backup systems of this nature are available as package systems that include the pump, batteries, an alarm to alert that it has been activated and controllers for automatic recharging.”

With respect to backup power options, Scherer and Hellevang in “Electric Backup Sump Pumps for Houses” (referred to as “Scherer and Hellevang (2015)”) provide the following observations and recommendations:[32]

- Typical backup sump pumps have a 12 V electric motors powered by battery connected to a trickle charger.
- The backup and primary sump pumps may discharge via the same discharge pipe.
- Backup sump pumps should be supplied with their own check valve.
- Primary and backup sump pump inlets may be located at the same level or at different levels, but the float switch for the backup sump pump should be positioned to trigger at a higher water level than the switch for the primary sump pump.
- Backup sump pumps may help to pump water out of the sump pit when the primary sump pump becomes overwhelmed.
- The charger for the backup sump pump is typically located 3 ft. to 4 ft. above the basement floor to protect it in the event of a basement flood.
- The battery for the backup sump pump is typically located in a plastic container on the basement floor.
- The charger and battery should be located in a dry environment.
- The charger and battery should be easily accessible for maintenance.

Scherer and Hellevang (2015) provide additional detail on the selection of batteries for backup systems (e.g., deep-cycle batteries, preferably, gel cell or absorbed glass mat batteries, are recommended), as well as on maintenance practices for batteries, including guidance on how to test battery voltage. Where there is a risk of prolonged power outages, the authors recommend the use of generators to power primary sump pumps and backup pump battery chargers.[32]

The testing of backup battery systems under various scenarios by Scherer and Hellevang (2015) provides an indication of their efficacy.[32] For example, a “worst case scenario” test of a 40 Ah battery under continuous sump pump operation (with a vertical lift of 10 ft., a 2 in. diameter discharge pipe, and a flow rate of 14 gal./min) indicated that the battery would provide adequate discharge of water (such that water would not start entering the home via the sump pit) for 4 h. Under the same scenario, a 120 Ah battery would provide adequate discharge for 11 h. An additional test of a 75 Ah battery with a flow rate into the sump pit of 1.5 gal./min, which resulted in the backup pump operating for 30 s every 4 min, indicated that the battery would provide for 60 h of pump operation.[32]

Table 3c outlines basic recommendations provided in the Durham Standard (2018) for sump pump backup and alarm systems that may be applied in lower risk scenarios. A backup sump pump with a backup power supply, set to engage in the event of failure of the primary electrical pump, is recommended. An alarm system set to trigger when the primary pump fails, such that the alarm sounds while the backup pump is operational, is also recommended.[3]

Table 3c: Durham Standard (2018) Recommendation on Sump Pump Backup and Alarm Systems[3]

#	Recommendation	Purpose	Notes
9.	Sump pump systems should be supplied with: a) A backup sump pump with backup power supply, set to engage in the event of a power interruption or mechanical failure of the primary pump. *And* b) A failure alarm to notify homeowners that the primary pump has failed.	• Sump pump failure is a major cause of flood damage during extreme rainfall/urban flood events. • Backup power/pumps help to address flood risk associated with sump failure due to mechanical failure and power supply interruption. • Alarms provide notification to homeowners that the primary pump has failed, and that action should be taken to ensure that there is not prolonged reliance on secondary/backup pumps.	• Backup power for sump pumps is not covered by the OBC. • Pump failure alarms are not covered by the OBC. • Sump systems should be serviced by a primary (electric) sump pump, and a backup pump provided with backup power and an alarm system to notify occupant of failure of primary pump. • The secondary pump float should be set to engage pump at higher water level than primary pump. • The failure alarm should be set to engage when the primary pump fails. • Alarm systems may be provided as part of backup power systems. • Generators may also be used as backup power systems for sumps. • Due to installation, water use, and potable water backflow concerns, it is recommended that water powered backup pumps not be used.*

*Technical committee members recommended that water-powered backup sump pumps not be used due to concerns related to water consumption and risk of backflow into potable water systems.
Note that the City of London's basement flood protection subsidy program specifically excludes funding for water-powered backup sump pumps (https://www.london.ca/residents/Sewers-Flooding/Basement-Flooding-Prevention/Pages/Sump-Pump-Grant-Program.aspx).

Horizon Engineering (2020) provided the following "best practices" concerning design of sump pump systems for pumped foundation drainage:[4]

> [...] single-pump operation by a "primary" pump should be sufficient to manage design flows generated by the 10-year storm event, with a "secondary"/back-up pump provided in case flows are in excess of this or the "primary" pump fails.
>
> The "primary" and "secondary" pumps should be wired to alternate such that both pumps are required to operate on a regular basis to minimize the risk of the backup pump seizing from lack of use.
>
> The pumps should be connected to an automatically triggered back-up power supply and a high water alarm.

Further, Horizon Engineering (2020) recommended use of a hard-wired, automatic natural gas generator or power bank as a best practice for sump pump system backup.[4] While appropriate in high-risk circumstances, the cost of automatic generators would preclude wide-scale application. A related recommendation provided in the Durham Standard (2018) is that new homes be provided with generator connection rough-ins to facilitate the installation of generators (automatic or otherwise) at a later date by homeowners (see Table 3d). This recommendation was offered as an "enhanced" protection, or second-tier, provision, while backup power (e.g., from batteries) was considered a basic provision for homes serviced by sump pump systems.[3]

Table 3d: Durham Standard (2018) Recommendation on Generator Rough-ins[3]

#	Recommendation	Purpose	Notes
18.	Provide rough-ins to allow for installation of external generators/auxiliary power supply at a later date by homeowners.	• Generators provide power for key home utilities (e.g., fridges, freezers, HVAC, sump pumps) during power outages. • Rough-ins will serve to reduce the cost of installation of generators at a later date.	• Generator rough-ins not required by OBC. • Generator rough-ins are meant to reduce the cost to homeowners associated with the installation of generators at a later date.

While they acknowledged that water-powered sump pumps may provide a flood mitigation benefit from a strictly private-side perspective (because the pump will continue to run in the event of a power failure), TCs for CSA Z800-18 and the Durham Standard (2018) argued that the use of these pumps should not be encouraged because they create a backflow/cross-connection risk for the potable water system. Furthermore, while these pumps are typically marketed as backup pumps only, they may consume significant amounts of potable water if primary sump pumps fail and are not promptly repaired.

CSA Z800-18 and Dillon Consulting (2017) identify the risk of cross-connections when water-powered sump pumps are applied as backup pumps. In jurisdictions where these pumps are permitted (e.g., the Town of the Blue Mountains), the installation of certified backflow-prevention devices is required, as is regular inspection of the backflow valves.[17] Reviewers of an early draft of this guide highlighted additional impacts of water-powered sump pumps, including the excessive use and waste of potable water. This excessive use of potable water may occur during critical periods, such as major disaster events and power failures, which would compound the challenges associated with maintaining water pressure in the municipal system.

3.2.2.5. Maintenance and Replacement

As discussed above, sump pumps have limited lifespans and require inspection and maintenance, as do other mechanical systems.[10] With respect to the maintenance of sump pump systems for foundation drainage, individual elements of sump pump systems should be inspected and maintained. Examples of components that require regular testing and maintenance include:[4,22]

- pumps,
- floats (e.g., to ensure that float movement is not restricted),
- check valves,
- backwater valves,[41, YY]
- electrical systems,

[YY] ANSI/FM Approvals 2510-2014 highlights the importance of ensuring that backwater valves are designed so that components can be maintained or replaced as necessary.

- discharge pipes,
- backup generators, and
- backup pumps, batteries, and battery chargers.[32]

The pump system as a whole should be tested, maintained and replaced as necessary.[4]

Furthermore, with respect to pump lifespan and maintenance, the Property Care Association (2015) Report makes the following recommendations:[36]

- "In circumstances where pumps are running for long periods of time, or where the system is subject to silting or the depositing of free lime, service intervals may be [relatively short]. The design specialist has the responsibility for any guarantee issued on the system – that the waterproofing system is fit for purpose. They *must* instigate a MAINTENANCE REGIME for setting service intervals. Commonly this involves a service contract with a pump service engineer as most contractors do not service their own systems."
- "Maintenance of the pump unit will vary according to the type of pump configuration installed. Information relating to the servicing of individual pumps and configurations should be provided by the manufacturer."
- "Consideration should be given to the operation of the main and back up pumps and the condition of any batteries and switchgear should be established. Seals, washers and valves may require inspection and replacement."
- "Alarms and any back-up switches that are fitted should be inspected and tested."
- "It can be extremely difficult to estimate how long a pump might last so it is important to seek advice from the supplier of the pump when estimating service life."

The report also lists the following factors related to sump pump maintenance:

- the number of sumps and pumps associated with the system,
- how hard the pumps are working (larger pumps may be required), and
- the service life of pumps and batteries.

Because of the risk of failure of sump pump systems, additional information should be provided to homeowners to warn them of the risks associated with a lack of maintenance. For example, as part of the development of a policy to allow the use of sump pump systems for foundation drainage in new developments where gravity connections are not feasible, the City of Ottawa (2012) Guidelines state:[18]

> Given the increased maintenance and operation responsibilities for homeowners, purchasers will be provided with information on the use and maintenance of the sump pump system. In addition, conditions will be included as part of planning approvals, such as within subdivision agreements, to require that prospective purchasers be notified with respect to the sump pump system through the purchase and sale agreement to ensure purchasers are aware of these responsibilities. These notices would also be registered on title.

3.2.3. Forensic Investigations of Sump Pump Failure

The firm Mitigateway has investigated numerous insurance claims where a sump pump failure has led to basement flooding and property damage; the majority were residential insurance claims made in Ontario. Mitigateway has reviewed over 100 failed sump pump claims, of which 60 were reviewed and documented in great detail as the damage caused was comparatively high. The 60 sump pumps were disassembled, inspected and thoroughly tested. For the purposes of this guide, records of these 60 failed sump pumps were reviewed in detail (see Tables 3e and 3f); the findings are summarized below.

The following discussion provides background information that may be considered in the development of general sump pump system design recommendations for the Canadian context.

Table 3e: Records of Failed Pumps Reviewed by Mitigateway

Total Number of Sump Failures	60
Number of Pump Brands	14
Number of Pump Models	30
Average Pump Age	3 years
Age of Oldest Pump	10 years
Age of Youngest Pump	6 months

Table 3f: Factors Associated with Sump Pump Failure and Impact on Sump Pump Failure

Factor	Impact on Sump Pump Failure
Pump brand	Likely unimportant
Pump age	All pumps in the dataset failed before the age of 10 years. Average was 3 years.
Pump cycle frequency	Identified as a common contributor to pump failure. Pump cycle frequency (on/off) contributed to microswitch failure, starter capacitor failure and float switch failure.
Check valve	Several installations were lacking check valves, and this installation deficiency increased the number of pump cycles to which the sump pump was exposed.
Microswitch	Microswitches were most often rated for 50 000 cycles. Microswitches were identified as a common contributor to pump failure, often having surpassed their lifespan and/or containing manufacturing defects.
Pump size	Size of failed pumps was not correlated with the size of a home or with geographical area. Pump installers likely chose the pump size arbitrarily based on what was available to them at the time.
Sump float	Identified as a common contributor to pump failure and subsequent property damage. For submersible pumps, when the float fails with the switch in the “on” position, the pump may overheat. When floats fail with the switch in the “off” position, the pump will fail to turn on. Pedestal pumps (not submerged in water) may overheat if a float switch remains in the “on” position. This may cause pump failure and, if not caught in time, a fire.

Factor	Impact on Sump Pump Failure
Shaft motor seal	Deterioration results in water infiltration into the pump motor, resulting in electrical failure. It was difficult to determine if shaft seal deteriorated from overuse or a manufacturing defect, both options seemed likely.
Pump motor start capacitor	Deterioration results in failure of pump to start.
Debris caught in pump impeller	Results in failure of pump to start.

3.2.3.1. Pump Brands and Models

The failed pumps consisted of 14 different brands and approximately 30 different models. There was no one brand that represented more than 16% of the failures. Although 16% may seem high, labelling the specific brand of pump representing this percentage of the failures as problematic is difficult without knowing the total number of pumps of that brand produced and the percentage of the pump marketplace held by the brand. As such, it is possible that the brand was a dominant brand within North America and that its percentage of the failures was simply in line with the brand's market share.

In general, there was no correlation between pump make or model and the likelihood of failure.

3.2.3.2. Pump Age at Time of Failure

The average age of a sump pump at the time of failure was 3 years. The age of the oldest pump at the time of failure was 10 years, and that of the youngest was 6 months. Given the spread of pump age at the time of failure, the impact of pump installation and use appeared to contribute more to failure than the overall age and design.

3.2.3.3. Pump Lifespan

While reviewing the manuals for many of the failed pumps, it was noted that sump pump manufacturers do not provide general lifespans for their equipment. This may be because it is nearly impossible for them to predict the conditions in which their pumps will be used and because their pumps do not come with a "cycle counter" that could be used by the homeowner to determine when pump replacement is required (similar the odometer in a car which can be used to determine when service is required).

3.2.3.4. Pump Cycles and Microswitches

Sump pump float switch assemblies generally include a microswitch. It was observed that microswitch manufacturers (generally not the same companies as the sump pump manufacturers) do not manufacture their switches specifically for sump pumps. These generic microswitches are used in many applications ranging from small appliances to large-scale machinery. The microswitch manufacturers provide a general "operating cycles" classification for their switches, which assumes a certain current draw and force to actuate the microswitch. The exact classification varies from one manufacturer to another and varies based on the type of testing standard applied to achieve the cycle count.

It was noted that, most often, the float microswitches were rated for 50 000 cycles by their manufacturers.

This finding demonstrates the lifespan problem. If, on average, a sump pump turns on once per day, a microswitch that is rated for 50 000 cycles will theoretically work for approximately 140 years. However, if the sump pump turns on every 20 min, it will cycle 26 280 times per year, and the microswitch will exceed its rating in just 2 years.

Site visits were made for some of the investigations, allowing for observation of the sump pump as installed in the residence. In several cases, it was noted that the pump would cycle every few minutes. At the extreme, it was noted that a pump was cycling every 45 s. At 45 s per cycle, the pump would cycle 525 600 times per year, more than 10 times the microswitch rating.

Several installations were identified where the pump microswitch lifespan would be exceeded in less than 3 years, and at least one was identified where the microswitch lifespan would be exceeded within a few months.

It was further noted that the type of foundation drainage and the design/installation of the sump pit were the largest contributing factors to the number of cycles a sump pump will complete.

3.2.3.5. Installation

It was not possible to visit all homes in which the sump pumps failed. However, the following installation deficiencies were identified during the performed site visits:

- lack of check valve, causing an unnecessary increase in sump pump operational frequency,
- sump pit used to drain washing machine discharge water, causing corrosion and deterioration of sump pump components from exposure to chemicals,
- sump pump float installed too close to a wall, causing float to become lodged against the wall and fail to operate,
- sump pump installed and operated without a backup, and
- sump pump powered by an electrical socket that was not a dedicated circuit. High current draw on a circuit from unrelated equipment could cause a circuit breaker to trip and prevent a sump pump (connected to the same tripped circuit) from operating.

It was noted that the sump pumps were installed in a similar manner in almost every home. However, the sump pump motor size varied between 1/3 horsepower (HP) and 3/4 HP. There was no correlation between the pump size and the property size, or groundwater level. It appeared that, in most installations, the pump size had been arbitrarily selected. The pump size was most likely determined by the sizes of pumps available for convenient purchase at the time of installation.

3.2.3.6. Pump Size

Failed sump pump motor sizes varied between 1/3 HP and 3/4 HP. For a typical basement height of 10 ft., these pumps would pump between 5 000 L/h and 16 000 L/h. The total quantity of pumped water would vary significantly from manufacturer to manufacturer and model to model. It was further noted that two different manufacturers producing pumps of the same horsepower rated the pumps as having very different capacities. There appeared to be no standard test used to compare pump capacity.

In all installations investigated, pump capacity was not an issue. We found that the sump pumps, even those with low capacity, were generally large enough to remove water from the sump pit if installed correctly.

3.2.3.7. Summary of Failure Causes

The most common factor contributing to sump pump failure was failure of the sump pump float. When the float failed in the “off” position, it prevented the pump from turning on. When the float failed in the “on” position, it caused the pump to overheat. Once overheated, the pump seals failed, water infiltrated the submersible motor, and the pump ceased to operate. In several instances when a pump overheated, a fire occurred.

It was noted that some floats contained manufacturing defects, while others had been in operation far longer than their rated lifespan. A focus on adequate design, manufacturing and installation of floats and float microswitches would likely be beneficial in preventing sump pump failures.

Other common factors contributing to sump pump failure included:

- deterioration of the shaft motor seal, causing water infiltration into the pump motor and electrical failure (it was unclear if this deterioration occurred due to a manufacturing defect or the number of cycles the pump had sustained),
- deterioration of the pump motor start capacitor, and
- debris caught in the pump impeller.

3.2.3.8. Most Significant Finding: Need for Backup Pumps

The pumps investigated had a wide range of failure modes, pump sizes, installation deficiencies, and manufacturing defects. Focusing on any one of those factors would prevent only one type of failure.

In 95% of the property damage investigations, only a single sump pump was used to protect the basement (i.e., a backup sump pump was not installed). Upon failure of the single sump pump, whether because of inadequate installation, a float switch malfunction, a motor start capacitor failure, or a shaft motor seal failure, the basement would flood during a rain event.

In the few cases where a backup pump was installed, it was either not installed correctly, or its backup power was insufficient because the battery was either undersized or not adequately maintained.

Had a functioning backup pump been present in cases where the primary sump pump failed, property damage would have been avoided.

3.2.4. Backwater Protection

CSA Z800-18 makes the following recommendations on backwater protection for foundation drainage systems that are connected to storm private drain connections:[2]

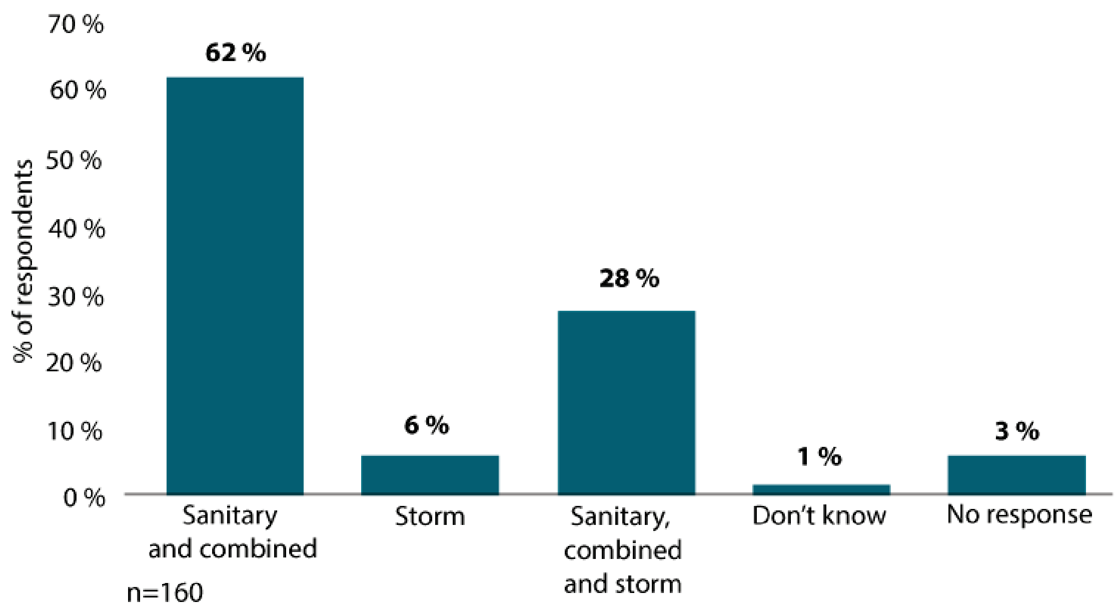
> **6.9 Sewer backwater protection**
> **6.9.1 General**
> [...]
> d) Foundation drainage systems that discharge into [public] underground sanitary, storm and/or third pipe systems should be connected in such a manner that water/sewage cannot backup into the foundation drainage system;
> e) In the case of gravity drainage from weeping tiles/foundation drain to [municipal] stormwater or third pipe systems, and where these connections are protected from backwater through installation of backwater valves:
> i) a sump pit/pump system must be supplied to provide foundation drainage discharge when the valve is closed; and
> ii) sump systems should be equipped with appropriate pump backup systems […]

The protection of gravity-drained foundation drainage systems from backwater can be relatively complex, as the approach may require both a backwater valve and a sump pump system to manage foundation drainage in the event of sewer system surcharge. Limited standardized guidance exists on backwater valve selection and on the design of gravity-drained foundation drainage systems that effectively and efficiently limit backwater risk.

It should be noted that NPC Article 2.4.6.4., Protection from Backflow, might be considered to apply only when foundation drainage systems (subsoil drainage pipes) are connected to sanitary sewer systems. A 2012 survey that generated responses from 160 Canadian municipalities and local authorities responsible for provincial plumbing code implementation revealed uncertainty in the interpretation of NPC Article 2.4.6.4. with respect to its application to storm sewer connections. Specifically, the majority of respondents indicated that NPC Article 2.4.6.4. applied only to sanitary or combined sewer connections, rather than all types of connections (see Figure 3f).[47]

Note that limited work has been completed to date to characterize the specific impacts and hazards associated with storm sewers backing up into foundation drainage systems. The ICLR is currently developing a project with the School of Engineering at the University of Guelph to develop a physical model to characterize the flood vulnerabilities associated with foundation drainage systems.

Figure 3f: Presumed Application of NPC Article 2.4.6.4. to Sanitary, Combined and Storm Sewer Connections



3.2.4.1. Backwater Protection Methods for Foundation Drainage Systems

A variety of methods may be applied to manage the risk of backwater in foundation drainage systems. Such methods include the implementation of minimum foundation drain, foundation footing or basement flood elevations above high HGLs in receiving systems with a freeboard (e.g., storm or FDC systems),[ZZ] the use of sump pump systems (which include looped or gooseneck discharge pipes,

[ZZ] See, for example:

- City of Oshawa: "underside of the footing elevation shall be designed such that it is located at minimum 0.60 metres above the 100-year hydraulic grade line elevation at the point of the foundation drain connection to the storm sewer" (for Type II Systems connected to storm sewers). City of Oshawa. "Design Requirements for the Construction of Storm Sewer and Foundation Drain Collector Systems." Oshawa: City of Oshawa. Section 4.2.1.

discharge to the surface, etc.), and the application of backwater valves to foundation drainage systems. Table 3g provides examples of the approaches of local AHJs to foundation drainage discharge. As reported by Dillon Consulting (2017), the discharge preferences presented in Table 3g were likely factors of "[the] robustness of the overall downstream receiving stormwater management systems in place in these areas" and "how commonly constraints occur such as restrictions due to storm sewer elevations higher than foundation drains."[17]

Table 3g: Preferred Approach to Foundation Drainage Discharge in Certain Jurisdictions[17]

Preferred Approach to Foundation Drainage Discharge	Jurisdictions
Direct gravity connection to storm or FDC system	Calgary, Newmarket, Oakville, Ottawa
Discharge to storm sewer via sump pump	Barrie, Cambridge, Edmonton, London, St. Catharines, Windsor
Discharge to surface via sump pump	Toronto, Winnipeg

For gravity-drained foundation drainage systems, backwater protection may be provided through the installation of a backwater valve. If this approach is used, provision should be made for foundation drainage discharge in the event that storm system surcharge closes the backwater valve (e.g., by installing a sump pump system draining to the surface of the lot). For pumped foundation drainage systems with looped or gooseneck discharge pipes that do not extend over the foundation wall, the installation of a backwater valve may be required to protect against backwater.

Despite requirements that foundation drainage systems be elevated above high HGLs in receiving systems, a backwater valve may be placed on the discharge line (i.e., building drain or sewer) to further protect the system from backwater. For example, with respect to the protection of basements from flooding associated with the surcharge of storm systems, the City of Ottawa (2012) Guidelines state:[37,AAA]

> **5.7.5 Service Connection Hydraulics**
> Foundation drains should not surcharge. In the design of new storm sewer systems, the underside of footing elevation must be a minimum of 0.3 m above the 100-year HGL. In these cases, both the HGL and the top of footing elevation must be shown on the storm sewer profile drawings. For older developments, the use of a sump pump, in addition to a backwater valve, may be required to protect the homes from high groundwater hydrostatic pressures around the foundation wall during extended surcharge periods.

- The City of Calgary requires that, "where storm sewer surcharge conditions may occur, the lowest top of footing (LTF) elevation must be a minimum of 0.30 m above the HGL for the 1:100 year event or stipulated design event," a requirement that applies to retrofit and re-development as well as new subdivisions. City of Calgary (2011). "Stormwater Management and Design Manual." Calgary: City of Calgary.

[AAA] Part 5.1.4 of the Guidelines states:

> All new storm sewers in Greenfield developments are to be designed based on the principles of dual drainage. The following shall be considered when designing a storm sewer system in Greenfield developments:
> […] In general, storm sewers must be designed to convey design flows when flowing full with the hydraulic grade line (HGL) at or below the crown of the pipe. In some instances, however, the HGL may be elevated due to boundary conditions. The maximum hydraulic grade line elevation for the minor system under these circumstances is 0.3 m below the underside of footings for the 1-in-100-year event.
> New sewers must incorporate inlet control measures to prevent surcharge and thereby prevent basement floodings for events up to a 100 year return frequency. Backwater valves will provide additional basement protection from storm sewer backups during these rare events […].

5.7.7 Storm Backwater Valves

Storm backwater valves […] are required on all foundation drain systems connecting to storm or combined sewer systems to minimize backup of stormwater. Backwater valves are to be located inside the building at a location that will allow for ease of access and maintenance.

Figure 3g illustrates the recommended installation configuration of sump pump systems in existing single-family dwellings in the City of Winnipeg. The system includes a backwater valve on the discharge pipe for sewer backwater protection. Foundation drainage normally drains by gravity via a catch basin into the municipal sewer system. When the backwater valve is activated, water is diverted to a sump pit and pumped to the surface of the lot.

Figure 3g: Sump Pump System in Existing Single-Family Dwelling, City of Winnipeg[48]

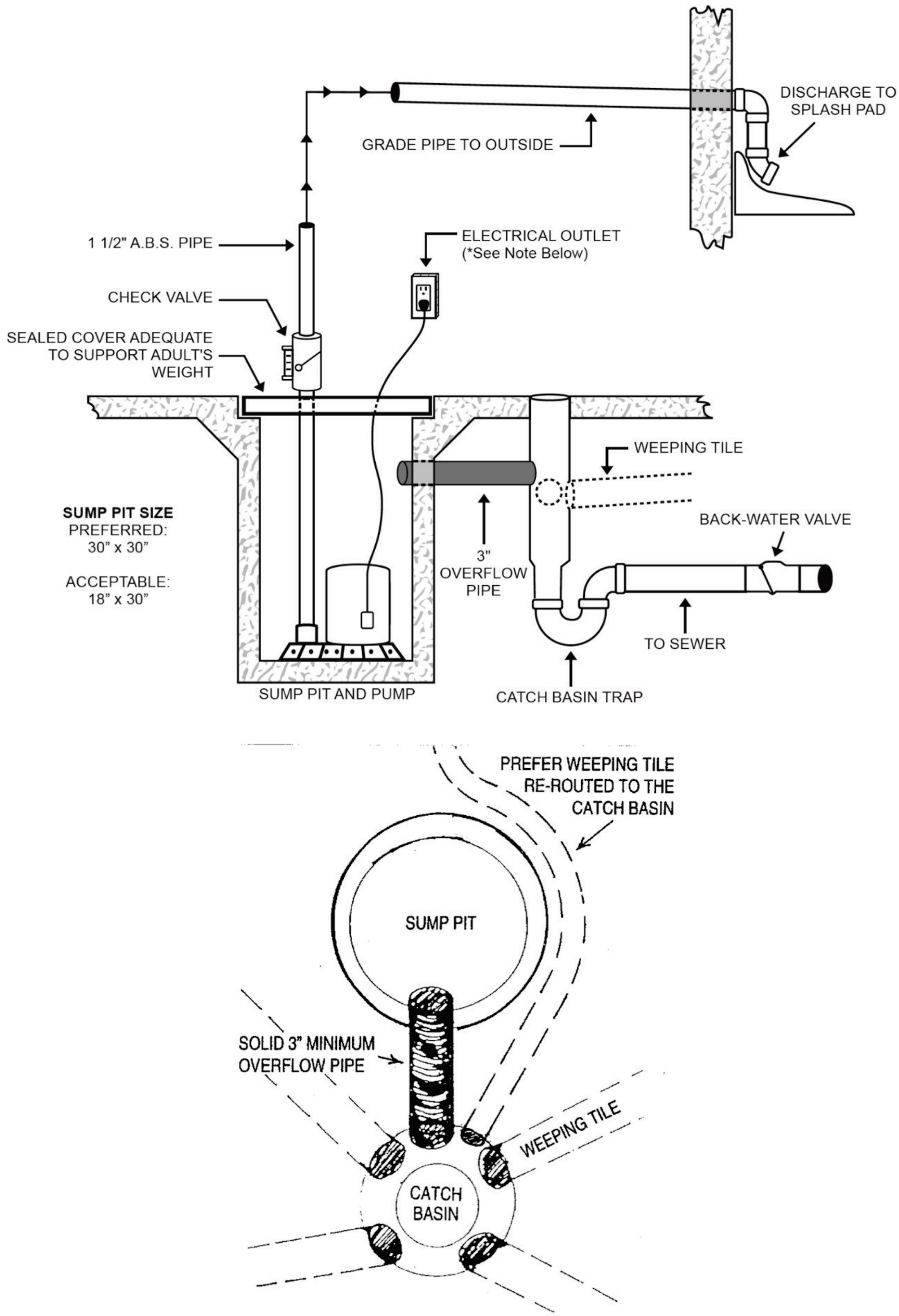
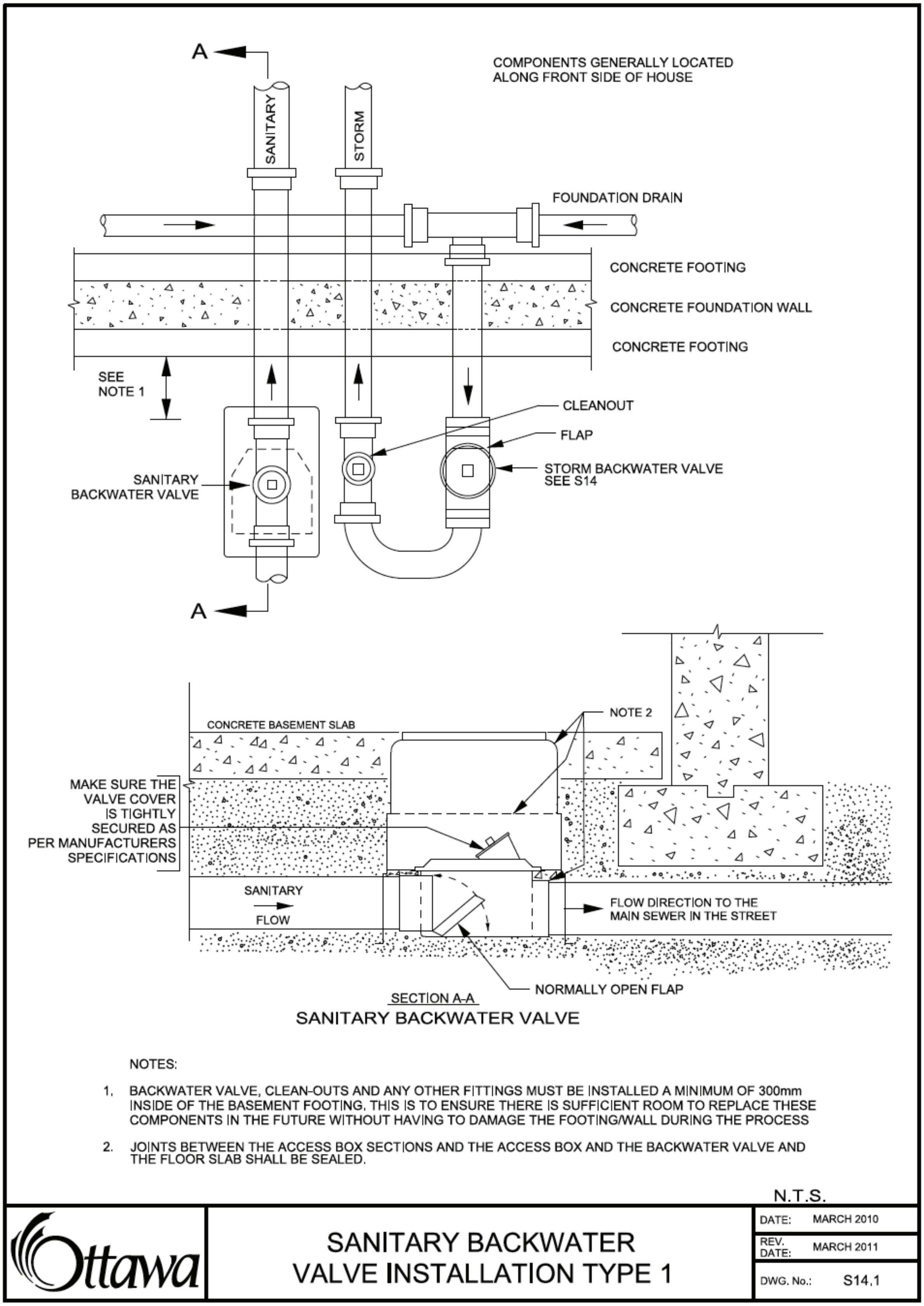


Figure 3h shows an example of a system including a storm connection backwater valve and a sump pit, as installed in Ottawa, Ontario. The system is markedly different than that recommended by the City of Winnipeg, which includes a catch basin system and trap. The system installed in Ottawa includes a wye connection that directs water to the sump pit during a surcharge event.

Figure 3h: Sump Pit and Backwater Valve Combination (Ottawa, Ontario)[49]

A further example of backwater protection for gravity-drained foundation drainage systems is illustrated in Figure 3i. In this example, the foundation drainage system is protected by a backwater valve that is normally closed, and no sump pit is provided.

Figure 3i: Backwater Valve Installation, City of Ottawa[50]



A requirement for backwater protection for sump pump discharge connections to municipal receiving systems is in line with existing urban drainage design standards. For example, ANSI/ASCE/EWRI 12-13, "Standard Guidelines for the Design of Urban Subsurface Drainage," states that the "potential flooding or drainage system backflow effects should be adequately considered."[12] The importance of accounting for the risk of backwater is also noted elsewhere.[10]

Figure 3j illustrates an example of a system with sump pump discharge and backwater protection in a municipality in southern Ontario. In this example, foundation drainage is normally pumped to a municipal receiving system. In the event of a surcharge or blockage of the receiving system, a check valve placed downstream of an auxiliary outlet is activated, forcing sump pump discharge to the surface of the lot. However, there is a lack of detail with respect to sump pit and sump pump design in the figure.

Figures 3k and 3l provide additional illustrations of goose-neck sump pump discharge. Figure 3k includes an air-gap to protect the system from backflow, and to reduce risk of sump failure should a surcharge occur.

Figure 3j: Sump Pump Discharge and Backwater Protection, Southern Ontario Municipality

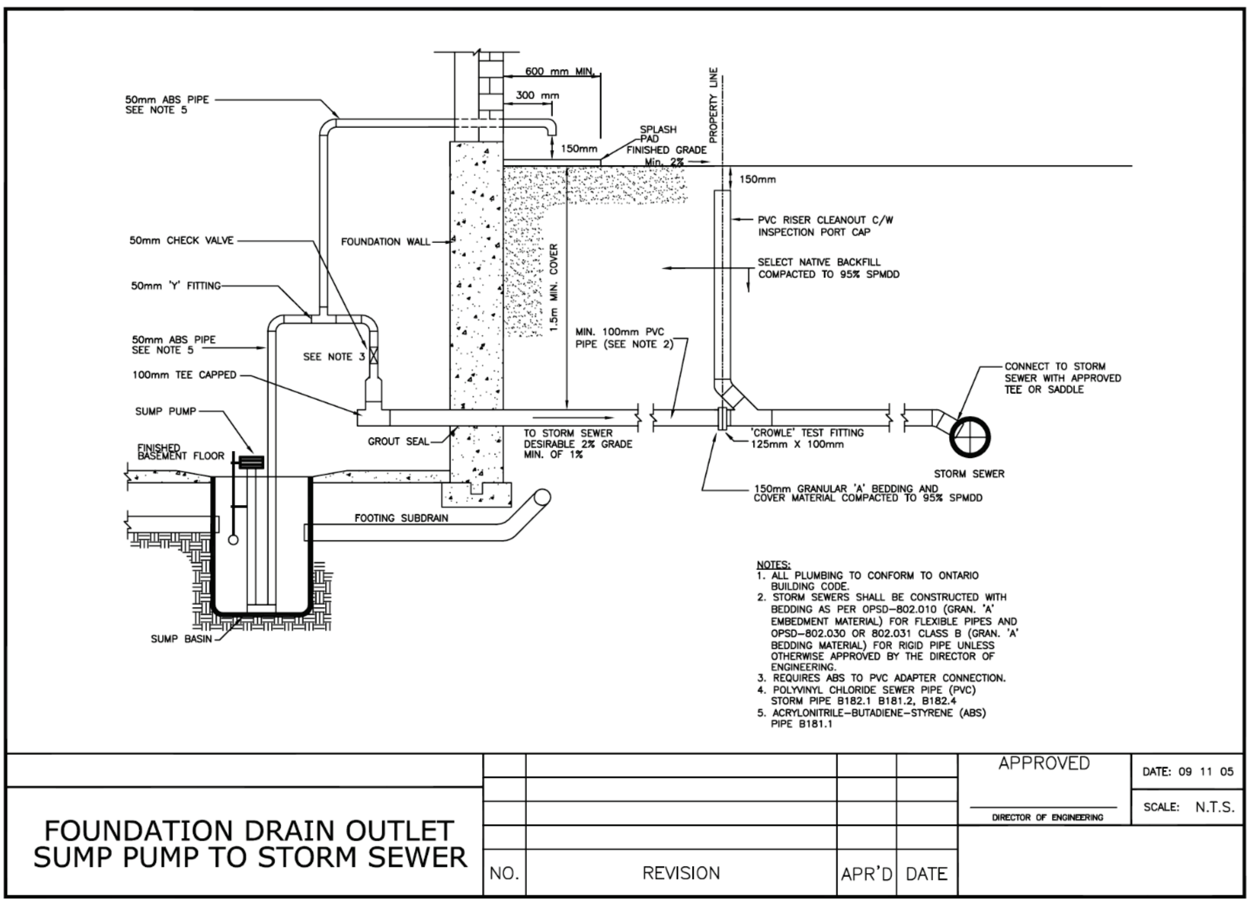


Figure 3k: Gooseneck Discharge to Storm Sewer Connection, Town of Innisfil[51]

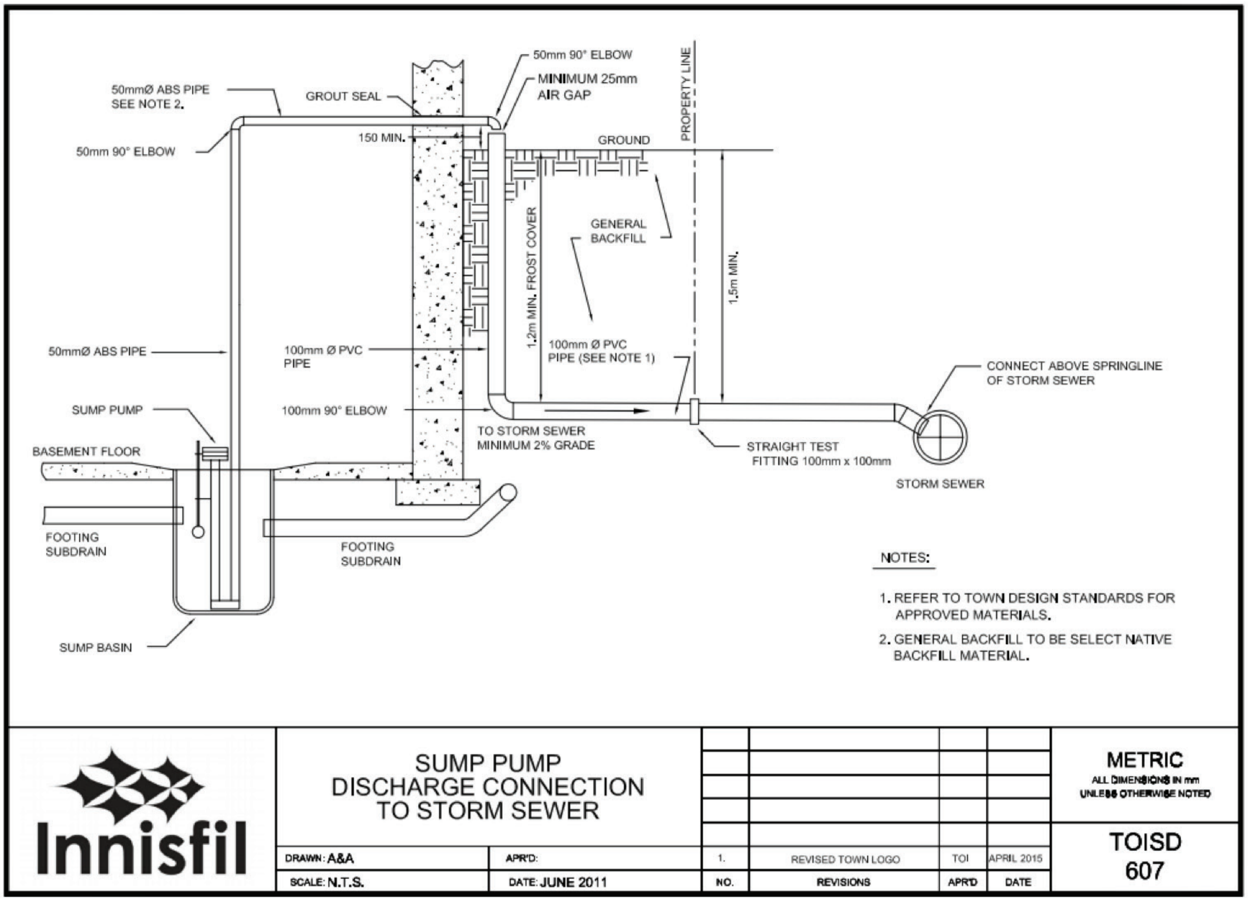


Figure 3l: Sump Pump Discharge Pipe Entering a Downpipe (Collingwood, Ontario)

Dillon Consulting (2017) provides a detailed summary of foundation drainage and discharge provisions for approximately 20 jurisdictions in Canada and the U.S.:[17]

- methods for assessing groundwater levels prior to construction,
- requirements for access to foundation drainage systems for maintenance,
- discharge and drainage provisions (including drainage to surface, to storm systems and to FDC systems), and
- elevation of footings above high HGLs.

The summary indicates jurisdictions that may be involved in the development of generalized national guidance on foundation drainage discharge.

3.2.5. Rationale for Regional Sump Pump System and Backwater Protection Requirements

A number of jurisdictions that had published design drawings for sump pump systems and discharge options (including backwater protection methods) were asked why the design criteria were developed and what resources (e.g., standards or guidelines from exterior agencies) were used in their development. A summary of the responses follows.

Motivation for the development of design criteria:

- severe icing issues associated with sump pump discharge, resulting in connection of discharge pipes to municipal collection systems,
- surface water "nuisance" issues (e.g., soggy lawns and yards) where pumps were running frequently,
- issues associated with the recirculation of sump pump discharge into foundation drainage systems (for systems discharging to the surface), or
- basement flood protection programs, including disconnection of foundation drainage systems from sanitary building sewers and provision of sump pits and sump pumps for discharge.

Resources used in the development of design criteria:

- practices applied in local and neighbouring jurisdictions, or
- unknown (e.g., because developed decades ago and by staff no longer employed by the municipality).

Other highlights:

- Overland flow systems (with splash pads) have been incorporated in some jurisdictions to address potential receiving system surcharge during extreme rainfall events.
- Not all jurisdictions require check valves on discharge lines.
- Several jurisdictions require a backwater valve in gravity-drained foundation drainage systems.
- There is an interest in incorporating requirements for backup power for sump pump systems.
- Guidelines to ensure a minimum height of foundations, basement floors or footings above high water tables have been applied in some jurisdictions, and there is a desire to develop similar guidelines in jurisdictions where they are not currently in place.
- A slow discharge tank was developed by the City of Lethbridge to allow foundation drainage discharge to slowly drain into the sanitary sewer system but to drain to the surface during significant rainfall events. This tank was developed for properties with frequently running sump pumps and no storm service connections.[52]
- Emergency overflows connecting sump pits to sanitary sewers (e.g., via the floor drain above the

P-trap) have been applied in some jurisdictions. These overflows are not considered ideal, however, as sump pump failures may go unnoticed and foundation drainage may continuously drain to sanitary sewers.[52]

3.3. Knowledge Gaps, and Research and Data Needs

- **Optimization and sizing of sump pumps and sump pits:** The optimization of sump pumps and sump pits is considered a critical aspect of ensuring acceptable long-term performance of sump pump systems. However, limited guidance is available on this topic. The existing guidance in a number of jurisdictions in Canada includes prescriptive measures related to sump pit size and depth, and sump pump discharge capacity. Assessing the flow of discharge into sump pits and the total dynamic head may be too complicated for the average homeowner, however. What easily applicable prescriptive measures can be used to assess potential flows to foundation drainage and sump pump systems, particularly for infill development and retrofits?

- **Sump pump lifespan:** Standardized information on the expected lifespan of sump pumps is lacking. An initial review of sump pump data suggested that sump pumps commonly fail before they reach 10 years of age. Information on the expected lifespan of sump pumps may be necessary to provide reliable guidance (e.g., to homeowners) about maintenance and replacement schedules. Questions related to this information gap include the following:
    - What practical measures exist to assess the frequency of pump cycling and to develop pump maintenance and replacement schedules?
    - As proposed in Section 3.2.3.4., one indicator of pump lifespan is the lifespan of its microswitch (as measured in on/off cycle counts). Can manufacturers be encouraged to incorporate on/off cycle counters into the design of sump pumps to facilitate the prediction of pump lifespan?
    - What additional measures may be applied to reduce the risk of sump pump failure associated with switch failure (e.g., of high/low switches)?
    - A concern was expressed by those involved in the development of the Durham Standard (2018) that the sealing of sump pits would reduce the likelihood that they would be inspected and maintained. What approaches can be applied to ensure that sealed sump pump systems remain accessible for maintenance?

- **High water tables:** Is there a need for standardized guidance on assessing seasonally high water table levels for the purpose of reducing groundwater flood risk and reducing loads on foundation drainage systems (sump pump systems, FDCs, storm systems, etc.)? What are the potential impacts of climate change on foundation footing heights with respect to seasonally high water table levels?

- **Backfill compaction:** Guidance documents identify a need for appropriate compaction of backfill to reduce the amount of surface water that enters foundation drainage systems. However, code officials may not have the expertise or resources to inspect backfill compaction, which may result in damage to the foundation, utilities, foundation drainage systems, etc. if not carefully executed. Is it reasonable or necessary to develop guidelines for backfill compaction?

- **Battery backup systems:** Battery backup systems are recommended for sump pump systems. What are the implications for battery backup systems of an increasing risk of power outages? How may an increasing duration of power outages affect the selection of materials and equipment for battery backup systems? Prolonged power outages may be a particular stressor in rural, isolated areas.

- **Quality of construction:** A consistent finding throughout this guide is that the inadequate performance and failure of private-side drainage features may often be related to improper construction or installation rather than inadequate guidance. How can AHJs ensure that critical drainage features, specifically those that are expensive to inspect, maintain and repair, are constructed and installed according to the best available guidance?

- **Backwater protection and sump pump systems for gravity-drained foundation drainage systems:** Gravity-drained foundation drainage systems that are protected by a backwater valve may also require a sump pump system. The purpose of the sump pump system is to collect foundation drainage and pump it to the surface during backwater events when the valve is closed. There is no standard method to assess whether the valve is likely to be closed long enough during backwater events to warrant the installation of a sump pump system. Given their installation cost and maintenance requirements, sump pump systems should be avoided wherever possible.

- **Normally open vs. normally closed backwater valves:** Current code provisions may be interpreted to require normally open backwater valves on storm sewer connections; however, in many jurisdictions in Canada, normally closed backwater valves are used on storm sewer connections. A discussion with City of Ottawa staff[BBB] indicated that the long-term performance of normally closed valves is unknown, particularly when they are installed in close proximity to a sump pump that is continually discharging water through the valve. Additional information on the performance of a variety of types of backwater valves in storm drainage applications may be needed.[CCC]

- **Radon:** Post-publication comments on CSA Z800-18 indicated that installations requiring the excavation of basement floor slabs (e.g., the implementation of backwater valves or sump pits) should also comply with applicable provisions related to radon and air barriers. Products have been introduced to address radon infiltration and the maintenance of an air barrier,[DDD] which are recognized issues in the construction industry. Appropriate means should be developed to ensure that basement flood protection measures do not increase radon-related risks.

[BBB] A City of Ottawa staff member stated that the normally closed backwater valves that are commonly used to protect foundation drainage systems from backwater are not designed to receive water that has been discharged by a sump pump at close range. For example, if a sump pump system is installed without looping the discharge pipe over the foundation wall, water may constantly jet through the backwater valve, which may reduce its lifespan. (Personal communication between Dan Sandink and Charles Warnock, City of Ottawa, February 28, 2018.)

[CCC] Reviewer comment (Nov. 2018): "Fail mode in open position poses a risk only at the time of surcharge or backwater. Fail mode in closed position poses a risk at any time. Further study would be needed to quantify failure rates based on effluent type. I do see that due to silt and fines transmission, normally open (gate action from bottom to top) valves could be more prone to 'stick down.' Normally open (from top) valves might not seal as closing from top could be impeded due to siltation. As with any mechanical device, the active participation of the owner via proper inspection and maintenance is a requirement."

[DDD] See, for example, the bladder seal at: http://backwatervalve.com/Upload/products/bladder-seal/bladder%20seal%20brochure.pdf

4. Private-Side Sewer Connections (Sanitary Building Sewers)

4.1. Recommendations

4.1.1. Pipe Joints

- In accordance with CSA B182.11-18, “Standard practice for the installation of thermoplastic drain, storm, and sewer pipe and fittings,” pipe joints in private-side sanitary sewer connections (sanitary building sewers outside of the house) should be gasketed.[2,3,53]

4.1.2. Bedding and Backfill for Flexible Pipe (Including PVC Pipe)

4.1.2.1. Embedment[EEE]

- Embedment (bedding for flexible pipe) should start at least 150 mm below the pipe, at the bottom of the trench.[54]
- Embedment should continue to at least 300 mm above the crown of the pipe.[54]
- The embedment material for flexible pipe should be Granular A or B.[55]

4.1.2.2. Backfill and Compaction[FFF, GGG]

- Compaction to 95% maximum dry density should be completed.[HHH]
- Haunching materials (beside and beneath the pipe) should be compacted in accordance with CSA B182.11-18.[53]
- Backfill should be carefully placed and compacted, in 200 mm lifts,[55] simultaneously on both sides of the pipe.
- At least 900 mm of cover should be installed and compacted before any heavy equipment is permitted to drive over the trench or complete compaction.

4.1.3. Grading of Sanitary Building Sewers

- Sanitary building sewers should have a downward grade of at least 2% and at most 8% toward the receiving system.[III]
    - If a steeper grade is desired, the designer should ensure that the proposed grade will result in velocities between 0.6 m/s and 2.0 m/s in the sanitary building sewer.[56,57,JJJ]

4.1.4. Protection from Backflow through Utility Trenches

- Utility trenches should be graded to ensure that water is directed away from foundations.[4]
- Bedding materials (e.g., Granular A or B[3]) that do not convey water as readily as clear stone should be used for storm and sanitary sewer trenches on the private side of the property line.

[EEE] As defined in OPSS 401, 401.03 Definitions:

> **Embedment Material** means material as it relates to flexible pipe, from the bottom of the trench to the bottom of the backfill.
>
> […]
>
> **Flexible Pipe** means pipe that can deflect 2% or more without cracking such as polyvinyl chloride, polyethylene, or steel pipe.

[FFF] Reviewer comment (Nov. 2018): “Proper compaction of bedding and embedment is extremely important for the structural integrity of pipe and jointing.”

[GGG] Compaction is essential to ensure that the pipe is installed securely in place and must occur in lifts.

[HHH] It is recommended that a geotechnical engineer perform compaction testing. Since the developer will already be working with a geotechnical engineer on the municipal side, this recommendation should not represent undue hardship.

[III] Note that excessive grade can lead to solids being left behind as liquids flow onwards, potentially creating a blockage in the sanitary building sewer.

[JJJ] See Drawing S7 and Section 33 30 01 in MMCDA 200 and OPSD 1006.010.

- A clay seal or related system (e.g., bentonite trench plug) should be incorporated into pipe trenches on the private side of the property line to reduce the risk of water backing up through the trenches.[KKK]
    - See, for example, OPSD 802.095, "Clay Seal for Pipe Trenches," presented in Figure 4a.[3]
    - The geotechnical engineer of record for the development should make recommendations with respect to clay seals.
- Utility trenches should be designed and located to minimize the risk of water flowing from the utility trenches to the sanitary and storm sewer trenches.

4.1.5. Reducing the Risk of Cross-Connections

- Pipe used for sanitary and storm building sewers should be differentiated to reduce the risk of construction errors causing cross-connections. Specifically:
    - Sanitary building sewers should be 100 mm in diameter.
    - Storm building sewers should be 125 mm in diameter.

4.1.6. Foundation Drainage Systems

- Foundation drainage systems should not directly or indirectly connect to sanitary building sewers, unless no other alternative is available and approval is obtained from the AHJ.[2]

4.2. Observations

Standards for municipal-side sanitary service connections may exceed the minimum requirements of provincial plumbing codes and apply only to the public side of the property line.[LLL] These standards serve as the basis for the recommendations for private-side sanitary sewer connections presented in Section 4.1. Key provisions from municipal and provincial sanitary and wastewater service standards are reviewed here, with a focus on provisions that may reduce flood risk and inflow/infiltration (I/I) (specifically, provisions related to pipe joints, bedding and backfill, grading, and protection from backwater through utility trenches). Because there is no expectation that soil conditions will differ between the municipal side and the private side within a subdivision, it is considered reasonable that improved, standards for municipal-side sanitary service connections be adopted for private-side building sanitary sewers.

4.2.1. Pipe Joints

Recent work focused on southern Ontario municipalities has revealed unacceptable rates of I/I in new subdivisions, as identified by the municipalities themselves. This work has further revealed limited enforcement of OBC provisions related to support for underground horizontal piping (OBC Article 7.3.4.6.), backfilling (embedment) of pipe trenches (OBC Article 7.3.5.1.), and testing of drainage systems (OBC Subsection 7.3.6.). The failure to enforce these provisions has contributed to I/I in new subdivisions.[58,59]

The design life of a sanitary sewer pipe should be defined as the time period over which it performs its function, in this case, the delivery of sanitary sewage from the house to the sanitary sewer main without leakage.

Displaced or offset joints, which frequently result from poor jointing, reduce the lifespan of the pipe.

[KKK] Reviewer comment (Nov. 2018): "Use of a trench plug in the private-side utility trench, while protecting a building from backflow via the trench, may limit opportunity for water to drain away from buildings."

[LLL] See, for example, OPSD 1006.010, which states that a minimum slope of 2% is desirable for municipal-side sanitary service connections.

As water starts to infiltrate into the pipe, the water carries with it fine material from the surrounding soil (soil fines). The transfer of soil fines into the pipe results in the shifting of pipe bedding, which potentially widens the joint gaps, resulting in a positive feedback loop. Depending on the circumstances, this process can significantly decrease the lifespan of the entire pipe run.

A comparison of an NPC provision related to transition joints in sanitary building sewers and provincial/municipal provisions related to public-side sanitary service connections is provided in Table 4a. Several provincial and municipal standards require gasketed pipe for municipal-side sanitary service connections, whereas the NPC allows glued transition joints.[60]

Table 4a: Provisions Related to Joints in Building Sanitary Sewers and Municipal-Side Sanitary Service Connections

Guidance Document	Provision	Interpretation
Ontario Ministry of the Environment Design Guidelines for Sewage Works (2008)[60] (referred to as "MOE (2008)")	**5.7.11.1 Joints** The types of joints and the materials used should be included in the specifications. Sewer joints should be designed to minimize infiltration and to prevent the entrance of roots throughout the life of the system. **5.7.11.2 Service Connections** […] • Materials: Reference should be made to the Ontario Provincial Standards - OPSS 410 for acceptable alternate materials for services [...]	MOE (2008) provisions for joints have a clear intent: reducing likelihood of infiltration and root penetration throughout the life of the system.
OPSS 1841 (2015),[61] Material Specification for Non-pressure Polyvinyl Chloride Pipe Products	**1841.05.01 Requirements** […] The extruded, moulded, and fabricated material shall be polyvinyl chloride plastic according to CSA B182.1, CSA B182.2 (which refer to bell and spigot joints with elastomeric gaskets).	OPSS 1841 requires that PVC pipe (including municipal-side sanitary service connections) have gasketed bell and spigot joints, per CSA B182.1 or CSA B182.2.
OPSS 410 (2012),[55] Construction Specification for Pipe Sewer Installation in Open Cut	**410.07.12.06 Polyvinyl Chloride Pipe** Polyvinyl chloride pipe shall be jointed, as recommended by the manufacturer, using a bell and spigot joint with an elastomeric gasket.	OPSS 410 requires that PVC pipe for municipal-side sanitary service connections have gasketed bell and spigot joints.
BC Master Municipal Specifications, Sanitary Sewers, Service Connections[56]	PVC service connection pipe and fitting joints: push-on type comprised of integral bell with single elastomeric gasket to ASTM D3212 and ASTM F477.	Specification requires gasketed push-on joints for municipal-side sanitary service connections.

Guidance Document	Provision	Interpretation
NPC 2015[14]	**2.2.5.9. Transition Solvent Cement** [...] 1) Solvent cement for transition joints shall conform to, a) CAN/CSA-B181.1, "Acrylonitrile-Butadiene-Styrene (ABS) Drain, Waste, and Vent Pipe and Pipe Fittings," or b) CAN/CSA-B181.2 "Polyvinylchloride (PVC) and Chlorinated Polyvinylchloride (CPVC) Drain, Waste, and Vent Pipe and Pipe Fittings." [...]	NPC permits drainage pipes with glued transition joints, and specifically identifies the types of transition solvent cement that can be used to joint them.

As a result of the work investigating I/I in new subdivisions, recommendations for the use of gasketed pipe in building sanitary sewers were included in both CSA Z800-18 and the Durham Standard (2018) (see Table 4b). Gasketed pipe provides a safety factor for cases where pipes are not properly tested, bedded or backfilled. These provisions are a first step toward better practices in the design and construction of building sanitary sewers. Provisions relating to the protection of municipal-side sanitary service connections from infiltration and root penetration are found in existing provincial and municipal standards.

Table 4b: Durham Standard (2018) Recommendation for Gasketed Pipe in Building Sanitary Sewers[3]

#	Recommendation	Purpose	Notes
21.	Pipe used for private-side sewer laterals (building sewers outside of [the house]) should be gasketed.	• Cracking and loose joints increase risk of private-side infiltration into public sanitary sewer systems and [increase] risk of root blockages over the lifecycle of the sewer connection. • When improperly bedded and backfilled, glued joints have been identified as being vulnerable to cracking and failure in new subdivisions, increasing potential for infiltration into sanitary systems, and increasing risk of lateral failure over the expected lifespan of the lateral.	• Gasketed pipe is [required] for municipal sanitary sewer stubs. This recommendation would result in application of gasketed pipe for building sewers on the private-side of the property line. • Gasketed pipe should conform to existing OBC requirements and referenced standards related to building sewers/plastic pipe and fitting used underground (see OBC 7.2.5.10). • Testing of lateral connections is critical to ensure proper performance, including limiting risk of infiltration/exfiltration (see OBC 7.3.6). • While properly installed solvent cement joints perform well for private-side sanitary lateral applications, recent work in Southern Ontario has indicated that required installation procedures are often not adhered to. A survey of municipal officials related to high

#	Recommendation	Purpose	Notes
			rates of I/I in new subdivisions has [identified inadequate jointing,] improper bedding and backfilling practices, [and failure to inspect the connection at property increases] risk of I/I associated with private-side sanitary laterals.*

*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.

Further:

> "The main culprit of infiltration is mortared or mastic joints and non-gasketed coupler or banded connections. All of these types of joints do not provide a watertight seal or control infiltration. The mortared or mastic joints may initially be watertight, but they cannot accommodate pipe-to-pipe or pipe-to-structure settlement resulting in cracking of this filler material and subsequent leaking. The bands or couplers are or eventually become plastic-to-plastic or metal-to-metal, which prevents creating a watertight seal.
> The structural integrity of a system can, therefore, only be assured by preventing infiltration, which requires a silt-tight or watertight system."

Source: Kurdiel, J.M. 2002. The evolution of watertight storm drainage systems. American Society of Civil Engineers, Pipelines 2002, Beneath our Feet, Challenges and Solutions.

4.2.2. Bedding and Backfill for Pipe

Boxes 4a and 4b reproduce the NPC provisions for pipe bedding and backfill, respectively. The requirements include relatively subjective terms such as "firm and continuous," and there is no specific requirement for tamping of bedding material. Meeting these requirements may necessitate shimming of pipes and ensuring that there are no voids or projections that could result in cracking of pipes when a load (e.g., backfill) is placed on the pipes. Because the design structural integrity of plastic pipe is derived from the soil around it, proper backfilling procedures are essential to the adequate performance of the pipe over its lifespan.

Box 4a: NPC 2015 Provisions Related to Support for Underground and Horizontal Piping[14]

2.3.4.6. Support for Underground Horizontal Piping

1) Except as provided in Sentence (2), *nominally horizontal* piping that is underground shall be supported on a base that is firm and continuous under the whole of the pipe. (See Note A-2.3.4.6.(1).)

2) *Nominally horizontal* piping installed underground that is not supported as described in Sentence (1) may be installed using hangers fixed to a foundation or structural slab provided that the hangers are capable of

- a) keeping the pipe in alignment, and
- b) supporting the weight of
  - i) the pipe,
  - ii) its contents, and
  - iii) the fill over the pipe.

A-2.3.4.6.(1) Support for Underground Piping. See explanation for Subsection 2.3.5. for additional protection required for underground pipes. Permitted installations are shown in Figure A-2.3.4.6.(1)(a). The methods of support shown in Figure A-2.3.4.6.(1)(b) are not permitted because the base does not provide firm and continuous support for the pipe.

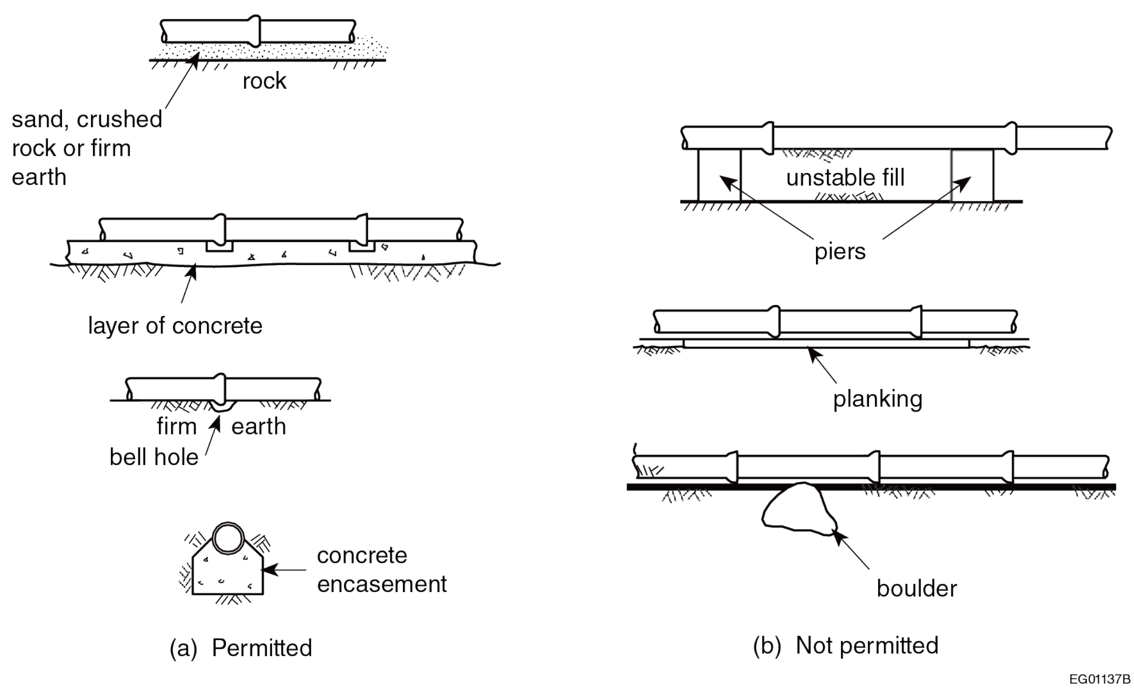


Figure A-2.3.4.6.(1)
Support for Underground Piping

Box 4b: NPC 2015 Provisions Related to Backfilling of Pipe Trenches[14]

2.3.5.1. Protection of Piping

1) Underground piping shall be protected

a) in the absence of the pipe manufacturer's instructions for backfill, by backfill that is (see Note A-2.3.5.1.(1)(a))

i) placed and compacted to a height of 300 mm over the top of the pipe, and

ii) free of stones, boulders, cinders and frozen earth or other material capable of damaging the piping, or

b) by concrete that is at least 75 mm thick and at least 200 mm wider than the pipe.

A-2.3.5.1.(1)(a) Backfilling of Pipe Trench. Stronger pipes may be required in deep fill or under driveways, parking lots, etc., and compaction for the full depth of the trench may be necessary.

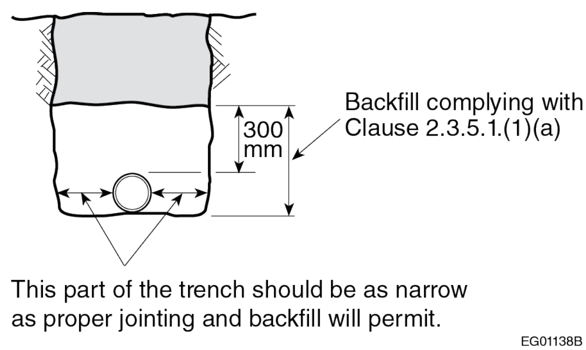


Figure A-2.3.5.1.(1)(a)
Backfilling of Pipe Trench

The installation of pipe is covered extensively in Ontario Provincial Standard Specifications (OPSSs) and Drawings (OPSDs). It is also covered in MOE (2008). As illustrated in OPSD 802.010, "Flexible Pipe Embedment and Backfill, Earth Excavation," for flexible pipe (such as PVC pipe), the embedment starts at least 150 mm below the pipe at the bottom of the trench. The embedment is typically required to continue to at least 300 mm above the crown of the pipe (outside of the top of the pipe). As described in OPSS 401, "Construction Specification for Trenching, Backfilling, and Compacting," the embedment material for flexible pipe must be Granular A or B.[62]

Compaction is essential to ensure that the pipe is installed securely in place. According to OPSS 401, compaction must occur in lifts of no more than 200 mm that are laid simultaneously on each side of the pipe (see Box 4c).[62] In addition, OPSS 501, "Construction Specification for Compacting," requires compaction testing, which is performed by a geotechnical engineer. Compacted haunching is required to compact the soil beside and beneath the round pipe. OPSS 401 requires that 900 mm of cover be installed and compacted before any heavy equipment is permitted to complete compaction (i.e., a jumping jack is to be used beforehand).

In addition, OPSS 410 specifies that a new pipe length shall not be laid until the preceding pipe joint is complete and the preceding pipe length is secure. This specification ensures that well-placed pipe lengths are not disturbed by moving an adjacent length, which could affect their bedding or jointing.

Box 4c: OPSS 401 (Nov. 2015), Construction Specification for Trenching, Backfilling, and Compacting[62]

401.05.01 Bedding Material and Embedment Material [for flexible pipe, from bottom of trench to bottom of the backfill]
Bedding and embedment materials shall be one of the following, or as specified in the Contract Documents:

a) Granular A.
b) Granular B, Type l, II, or III, with 100% passing the 26.5 mm sieve.
c) Unshrinkable fill.

401.07.10 Backfilling and Compacting
[…]
401.07.10.03 Bedding
[…]
The surface upon which the pipe is to be laid shall be true to grade and alignment.
[…]
Bedding material placed in the haunches shall be compacted prior to continued placement of cover material.

Bedding material shall be placed in uniform layers not exceeding 200 mm in thickness, loose measurement, and each layer shall be compacted according to OPSS 501 before a subsequent layer is placed.

Bedding material shall be placed on each side of the pipe and shall be completed simultaneously. At no time shall the levels on each side differ by more than the 200 mm uncompacted layer.

401.07.10.04 Cover
Cover material shall be placed so that damage to or movement of the pipe is avoided.

Cover material shall be placed in uniform layers not exceeding 200 mm in thickness, loose measurement, and each layer shall be compacted according to OPSS 501 before a subsequent layer is placed.

Cover material shall be placed on each side of the pipe and shall be completed simultaneously. At no time shall the levels on each side differ by more than the 200 mm uncompacted layer.

401.07.10.05 Backfill
Backfill material shall be placed in uniform layers not exceeding 300 mm in thickness, loose measurement, for the full width of the trench and each layer shall be compacted according to OPSS 501 before a subsequent layer is placed.

Power operated tractors or rolling equipment shall not be used for compacting until backfill material has been placed to a minimum depth of 900 mm above the crown of the pipe. Uniform layers of backfill material exceeding 300 mm in thickness may be placed with the approval of the Contract Administrator.

With respect to pipe bedding materials and compaction, Halifax Water (2016) includes the following provisions for water, wastewater and stormwater systems:[63]

> **4.3 PIPE BEDDING**
> The bedding shall be engineered based on soil condition, depth of bury and type of pipe. Special bedding requirements must be met in certain wastewater situations (see Section 5.0 (WASTEWATER SYSTEM)).
>
> At minimum, bedding material shall be Type 1 gravel compacted to 95% Standard Proctor density. Under some conditions, the Engineer may approve clear stone substituted for Type 1 gravel.
>
> The bedding shall be engineered so as not to affect the ground water adversely.

4.2.3. Grading of Sanitary Building Sewers

Appropriate grading of sanitary sewer services is necessary to reduce the likelihood of blockage due to the accumulation of solids and debris. MOE (2008) recommends a grade of 2% for municipal-side sanitary service connections,[60] as does OPSD 1006.010, "Sewer Service Connections for Main Pipe Sewer." Similarly, Halifax Water (2016) states that "residential service connections shall be laid at a minimum grade of 2%."[63] The implementation of a maximum grade is necessary to reduce the potential for hydraulic interference and the deposition of solids (as the liquid may just run over the solids in a pipe that is too steep).

4.2.4. Protection from Backflow through Utility Trenches

ANSI/ASCE/EWRI 12-13 describes a common problem related to subsurface drainage infrastructure as follows:[12]

> [it] involves preferential groundwater flow paths created when the pervious bedding and backfill of utility trenches create flow pathways from ponds to areas where this water can cause problems. The designer of subsurface drainage facilities should investigate any probable surface water sources and, if appropriate, incorporate surface drainage improvements into the design.

Addressing a similar concern, Horizon Engineering (2020) recommends the installation of a concrete "dam" or seepage collar in groundwater interception trenches containing a perforated pipe. The dam forces water to flow into the pipe and ensures that the water does not travel down a preferential path through clear stone bedding in the trench.[4] The grading of service connection trenches and the installation of clay plugs in the trenches to minimize the risk of groundwater collecting near buildings are considered by Halifax Water (2016).[63]

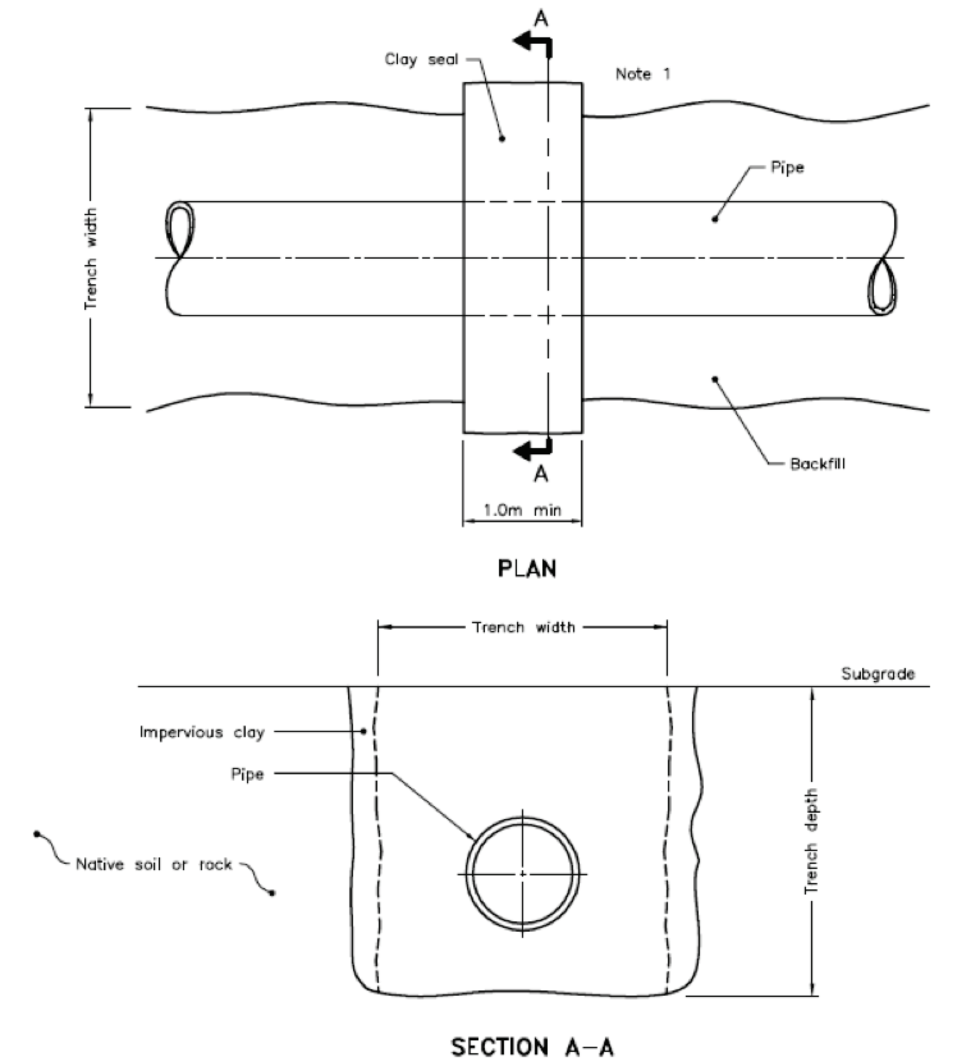
The Durham Standard (2018) incorporates a performance-based provision related to the protection of buildings from backflow through bedding in pipe trenches (see Table 4c). The recommended methods of satisfying this provision are the use of Granular A or B bedding material, which is a common practice, and the incorporation of a clay dam in pipe trenches on the private side of the property line, as illustrated in OPSD 802.095 (see Figure 4a).[MMM] Clay seals should be installed under the authority of the geotechnical engineer of record for the development.

[MMM] Reviewer comment (Nov. 2018): "It may be better to incorporate trench plugs in utility service trenches at the point where they leave the main utility trench and ensure that the height of the dam/trench does not exceed the invert of trench at the property line."

Table 4c: Durham Standard (2018) Recommendation on Protection from Flooding Associated with Infrastructure Trenches[3]

#	Recommendation	Purpose	Notes
14.	Incorporate means to protect against reversal of water flow through infrastructure (pipe) trenches.	• Reduce risk of water backing up through clear-stone gravel bedding material in pipe trenches and entering basements via infiltration/seepage flooding, and overwhelming foundation drainage systems.	• Flood hazards associated with water flow through infrastructure (pipe) trenches during flood events considered particularly high if pipes are bedded with clear stone gravel, as this type of bedding contains many voids and readily conveys water. • Compliance with this recommendation may include: ○ Application of alternative bedding material that does not convey water as readily as clear stone bedding for sewer connection trenches on the private-side of the property line. This material may include Granular A or B. *And* ○ Incorporation of a clay seal in the pipe trench on the private-side of the property line to reduce the risk of water backing up through utility trenches. See: Clay Seal for Pipe Trenches, OPSD 802.095.

Figure 4a: OPSD 802.095, Clay Seal for Pipe Trenches[64]



NOTES:
1. Key into undisturbed trench soil.
A Clay seal shall extend from bottom of trench excavation to the subgrade.
B Clay seal shall be located so that no pipe joints are within the clay seal material.
C All dimensions are in metres unless otherwise shown.

ONTARIO PROVINCIAL STANDARD DRAWING	Nov 2016	Rev 2
CLAY SEAL FOR PIPE TRENCHES		OPSD 802.095

4.2.5. Additional Considerations

4.2.5.1. LID Features and Infiltration into Sanitary Building Sewers

A recurring topic of conversation amongst TC members for both CSA Z800-18 and the Durham Standard (2018) was a need to better understand how LID features may affect infiltration risk.

Specifically, because LID features typically focus on increasing the infiltration of surface water (e.g., stormwater) into the ground, they may exacerbate the flood risk in areas served by sanitary sewers prone to infiltration. These concerns led the Basement Flood TC for the Durham Standard (2018) to include the following paragraph in the commentary section of the Durham Standard (2018):[3]

> Technical Committee discussion further outlined the need to balance the use of Low Impact Development (LID) measures and the need for basement flood protection. For example, it was noted that even in new developments, high rates of I/I have been associated with leaking private and municipal-side sanitary infrastructure. In these instances, it is possible that LID features could exacerbate I/I, and therefore increase basement flood risk. The need to ensure that LID features are hydraulically disconnected from basements, structures, and the suite of drainage infrastructure servicing individual homes (e.g., foundation drainage systems) was further highlighted by Technical Committee members, as was the need to ensure that private-side LID measures are properly maintained.

It was acknowledged that guidance on LID design and construction does not typically account for the risk of infiltration into sanitary and storm sewers. The need to understand how LID features interact with critical private-side drainage systems (e.g., foundation drainage systems, drainage layers) was also raised during TC discussions. As noted in Section 2.2.7., minimum separations between LID features and buildings (e.g., 3 m or 5 m) are stipulated in guidelines focused on the private-side installation of LID features; however, these guidelines may not provide specifications for the location of infiltration features above private-side service connections that may leak. Further study is required to identify existing best practices to minimize the negative impacts of LID features on underground sewer systems, notably those vulnerable to infiltration.

The May 2020 draft of the "Low Impact Development (LID) Stormwater Management Guidance Manual," by the Ministry of Environment, Conservation and Parks (MECP) of Ontario, recognizes the following as constraints on meeting the local 90th percentile runoff volume control target through the application of LID:[20]

> Flood risk prone areas or structures and/or areas of high inflow and infiltration (I/I) where wastewater systems (storm and sanitary) have been shown through technical studies to be sensitive to groundwater conditions that contribute to extraneous flow rates that cause property flooding / sewer back-ups and where LID BMPs [best management practices] have been found to be ineffective […]

Given that I/I has been shown to occur in many new subdivisions, the condition that I/I only needs to be considered if technical studies indicate that wastewater systems are sensitive to groundwater conditions may be considered too restricted.[NNN]

4.2.5.2. Pipe Material and Sizing Specifications in Provincial and Municipal Standards

A number of provisions for pipe materials, including provisions related to pipe dimension ratio (DR) and diameter, are included in design standards for municipal-side sanitary service connections. For example, Halifax Water (2016) contains the following provisions for wastewater service connections, which exceed typical practice (i.e., the use of DR35 PVC pipe of 100 mm in diameter):[63]

> **4.6 SERVICE CONNECTIONS (WASTEWATER AND STORMWATER)**
>
> **4.6.1 Residential**
>
> In those areas where service connections have already been installed, the connections shall be extended into the lot at the same diameter as those found in the ground.
>
> **4.6.1.1 Wastewater Service Connections**
>
> - New residential Single Unit Dwelling service connections shall be a minimum of 125 mm in diameter.
> - Gravity wastewater service connections of 150 mm diameter or less shall be PVC DR28 (white) from the main to the building foundation.
>
> [...]

The Design Guideline Manual (2009) of the BC Master Municipal Construction Documents Association contains the provisions related to sanitary service connections provided in Box 4d.[56] Note the requirement for the use of DR28 PVC pipe for 100 mm diameter sanitary service connections. Unless DR28 PVC pipe is specified, DR35 PVC pipe, which is less expensive, is more likely to be used for sanitary building sewers.

[NNN] Reviewer comment (Nov. 2018): "The point of LID is to reduce the amount of runoff making it to creeks and receiving waters, and/or lengthen the time it takes to get to the creek. The main conveyance is via municipal pipes which may or may not have adequate capacity to convey based on storm return period. Therefore, surcharge of both sanitary and STM [minor] systems occur. Surcharge due to inflow is the major contributor to basement flooding, yes, with some capacity/conveyance issues being compounded by infiltration. Maybe it's as simple as, prior to any LID permit being issued, a CCTV inspection must be performed and provided to AHJ for review: I/I present or older pipe materials existing liner required, too many components at play here to discuss in text."

Box 4d: BC Master Municipal Specifications, Sanitary Sewers, Service Connections[56]

- Sanitary service connections to be 100 mm minimum diameter; maximum diameter as specified In Contract Drawings.
- Sanitary sewer service connections 100 mm and 150 mm to be PVC type DR28 sewer pipe.
- 100 mm and 150 mm DR 28 PVC storm sanitary service connection pipe to have a minimum pipe stiffness of 625 kPa. Pipe to be manufactured to ASTM D3034 and certified by Canadian Standards Association to CSA B182.2.
- Sanitary sewer service connections greater than 150 mm diameter to be of size and material specified on Contract Drawings and to conform to applicable specifications for mainline pipe.
- Manufactured connections to non-reinforced or reinforced concrete mainline pipe to be made using standard PVC pipe male end stub with integral bell by either:
  - Stub grouted into neatly chipped hole in pipe wall by concrete pipe manufacturer. Grout to be Portland cement-based grout.
  - Stub epoxy resin cemented into neatly cored hole in pipe wall by concrete pipe manufacturer.
- Stub and bell orientation to be 45° to centreline of mainline 2 pipe (wyes) for concrete pipe less than 1050 mm diameter. Orientation may be 90° to centreline of mainline pipe (tees) for concrete pipe 1050 mm diameter or larger. No section of service stubs to protrude past inside of concrete pipe wall.
- Manufactured wye connections to PVC mainline pipe to be made with extrusion moulded PVC or fabricated PVC fittings manufactured to ASTM D3034 and CSA B182.2.
- Field installed tees and wyes:
  - In-situ installation of tees and wyes into concrete or PVC mainline pipe shall be made with approved PVC saddle installed to the manufacturer's specifications into a neatly cored hole in the pipe wall.
  - In-situ installation of tees into concrete or PVC mainline pipe shall be made with an insertable tee when connection is more than two sizes smaller than the mainline.
- PVC service connection pipe and fitting joints: push-on type comprised of integral bell with single elastomeric gasket to ASTM D3212 and ASTM F477. Normal pipe laying length joint to join to be 4.0 m.
- Pipe and fitting joints for service connection pipe materials other than PVC type PSM sewer pipe to be as specified for applicable mainline pipe.

Differentiating the size and consistently locating the pipe for storm and sanitary building sewers would reduce the risk of cross-connections. The recommendations in Section 4.1.5. specify pipe diameters of 100 mm for sanitary building sewers and 125 mm for storm building sewers. These pipe sizes are recommended to ensure adequate flow speed of sanitary sewage. It is noted that the Region of Peel's Standard Drawing Number 2-4-4, "New Development Connections Extending Services Beyond Property Line," specifies diameters 100 mm for sanitary service pipes and 125 mm for storm service pipes.

4.2.5.3. General Design Considerations

Unlike the design of private-side sanitary building sewers, the design of sanitary sewers on the municipal side requires an engineering analysis. MOE (2008) includes specific instructions regarding the design of sanitary sewers. Although many of these provisions do not apply on the private side, some of them do.

Specifically, MOE (2008) advises that loads—including live, dead and frost loads—should be considered in sewer design (see Box 4e).[60] These loads should be considered in the context of soil type, groundwater and trenching. The loads are likely similar for most sewer laterals, as they are installed at the minimum allowable slope and depth to the property line, at which point they descend to the depth of the public sanitary sewer, if necessary. This configuration avoids unnecessary excavation on the private side of the property line. The designer of a public sanitary sewer and lateral is instructed to consider a pipe material's life expectancy, ease of handling, strength, joints, installation issues, fittings, sizing and cost, among other factors.

Design parameters to be taken into account include installation requirements. MOE (2008) recommends that installation requirements be based on industry criteria and standards (see Box 4f).[60] MOE (2008) specifically recommends the use of bedding and backfill measures that will not damage the pipe or cause ovalation. (Ovalation of PVC pipe may occur when the backfill is not installed according to the requirements for PVC pipe.) OPSS 514 for trenching, backfilling and compacting, and OPSS 410 for open-cut installation of sewer pipes are specifically referenced in MOE (2008).

Box 4e: MOE (2008), Design of Sewers, Pipe Materials[60]

Chapter 5. Design of Sewers
5.7.9 Pipe Materials

[…]

Sewers should be designed to prevent damage from superimposed live, dead and frost induced loads. Proper allowance for loads on the sewer should be made for soil type, groundwater conditions, as well as the width and depth of the trench. Where necessary, special bedding, haunching and initial backfill, concrete cradle, or other special construction should be used to withstand potential superimposed loading or loss of trench wall stability.

[…]

In choosing pipe material, the designer should consider the following factors:

- Life expectancy and use experience;

[…]

- Ease of handling and installation;
- Physical strength;
- Type of joint - water tightness and ease of assembly;
- Availability and ease of installation of fittings and connections;
- Availability in sizes required; and
- Cost of materials, handling and installation.

Box 4f: MOE (2008), Design of Sewers, Installation[60]

Chapter 5. Design of Sewers
5.7.10 Installation
Installation specifications should contain appropriate requirements based on the criteria and standards established by industry in its technical publications. Requirements should be set forth in the specifications for the pipe and methods of bedding and backfilling thereof so as not to damage the pipe or its joints, impede cleaning operations and future tapping, nor create excessive side fill pressures and ovulation of the pipe, nor seriously impair flow capacity.

Excavation for placing sewer pipes, backfilling and compacting should be specified in accordance with *Ontario Provincial Standards Specifications* (OPSS) 514, *Construction Specifications for Trenching, Backfilling and Compacting*. Final backfill should be placed in such a manner as not to disturb the alignment of the pipe.

Ring deflection testing should be performed on all sewers constructed using plastic pipe. The designer should reference OPSS 410, *Construction Specifications for Pipe Sewer Installation in Open Cut* for details on the testing procedure.

4.3. Knowledge Gaps, and Research and Data Needs

- Is there a relationship between the increased use of LID features and infiltration risk for improperly installed sanitary service connections? How will this risk be affected by the effects of climate change, specifically short-duration high-intensity rainfall and higher groundwater levels?

- What separation distances are appropriate between infiltration features and buildings or underground utilities (e.g., building sanitary sewers)?

- What information is required by stormwater, wastewater and building departments to ensure the proper governance of the construction and testing of building sanitary sewers?

- Determine how to increase compliance with the inspection and testing required by construction codes.

- Currently there is no guidance on how to construct the lateral connection at the property line (i.e., the connection between the private-side sanitary building sewer and the municipal-side sanitary service connection). This connection cannot practically be water-tested and has historically represented a significant I/I risk. Therefore, a standard connection protocol that is more robust than current connection methods may be required (e.g., using fittings similar to water pipe fittings).

- The requirements for pipe and jointing on the private side should be reviewed. Testing of the thin-walled PVC pipe that is currently being used should be conducted by the industry. Particularly, testing of the performance of this pipe in service over time would be relevant to whether its use should be permitted. The pipe lifespan should be estimated (lifespan being defined as the amount of time the pipe functions as intended, without leakage). There is currently insufficient information about the robustness of this pipe to justify installing it widely.

- Regarding pipe thickness, DR35 PVC pipe is typically used on the private side, but provincial and municipal standards sometimes require DR28 PVC pipe for sanitary service connections. Should the thicker-walled DR28 PVC pipe be required for building sanitary sewers, or should careful pipe installation be the focus (since stronger pipe can still be poorly laid and jointed)?

- What is the expected lifespan of sanitary building sewers? How do material specifications (e.g., for bedding, backfill) affect lifespan? What advice should be given to homeowners about how often to replace their sanitary building sewer?

- The expected lifespan of the private-side lateral should be determined and accounted for in the expected lifespan of the house. Sanitary sewers on the municipal side, which are laid according to much more rigorous guidelines, are expected to last on average 40 years until the first rehabilitation or replacement is required. Homebuyers are likely unaware that their private-side lateral may need replacement after 40 years or less.[ooo]

- All of the above bullets may also apply to storm and FDC connections. Exfiltration from storm connections has the potential to increase the load on sanitary sewer systems, and I/I must also be managed for FDC connections.

[ooo] Reviewer comment (Nov. 2018): "The application of increased inspection of private-side laterals based on I/I reduction strategies using isolated flow monitoring may make it possible to develop politically acceptable and mutually beneficial execution of inspections and refurbishment."

Endnotes

[1] Canadian Commission on Building and Fires Codes (2015). National Building Code of Canada 2015. Ottawa: National Research Council of Canada.
[2] CSA Group (2018). "Guideline on Basement Flood Protection and Risk Reduction." CSA Z800-18.
[3] Durham Region-Institute for Catastrophic Loss Reduction (2018). "Durham Region Climate Resilience Standard for New Houses." Part A: Basement Flood Protection. Whitby: Durham Region.
[4] Horizon Engineering Inc. (2020). "Builder Guide to Site and Foundation Drainage. Best Practices for Part 9 Buildings in British Columbia." Draft. Currently unpublished. Prepared for BC Housing.
[5] Bureau de normalisation du Québec (BNQ) (2012). "Dépôts d'ocre dans les systèmes de drainage des bâtiments." BNQ 3661-500/2012. PARTIE II : Méthodes d'installation proposées pour nouveaux bâtiments et bâtiments existants. Montreal: BNQ.
[6] Personal communication between Barbara Robinson and Roberto Vani, Manager of Inspections / Deputy Chief Building Official, City of Windsor, December 2017.
[7] Personal communication with C. Ziccarelli, Flood Prevention Advisor, Edmonton, August 2017.
[8] Building Safety Standards Branch (2018). British Columbia Building Code 2018. Victoria: Crown Publications.
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Methods for determining seasonal groundwater elevations, as outlined in Dillon Consulting (2017):

- Wisconsin Administrative Code, Chapter SPS 385 – pre-construction requirements:
  - At least 3 groundwater elevation pipes shall be installed to delineate area under investigation, or more as required,
  - The observation period for soil saturation determinations shall begin on or before the appropriate date specified (varies from February 15 to March 15), ends June 1;
  - Observations shall be made on the first day of the observation period and at least every seven days thereafter until the observation period is complete;
  - The results of soil saturation determinations shall be considered inconclusive if precipitation levels do not equal or exceed specified minimum levels
- City of Calgary:
  - Test holes to be installed on an approximate 150 m grid
  - Seasonal high water table is then determined through successive groundwater level readings collected over 6 months at a 1-month interval
  - Water levels are adjusted for seasonal variations according to a curve showing known average variations.
- State of Connecticut:
  - Recommends determining depth to water by monitoring test wells during the seasonal high water table period
  - They acknowledge that this depth can be estimated using redoximorphic features (soil colour criteria) … *but need to acknowledge uncertainty related to using this method*
- State of Rhode Island:
  - Guide to Monitoring the Depth and Duration of the Seasonal High Water Table in Rhode Island
  - Installation of monitoring wells on the site and then using electronic level loggers to measure water levels over an

entire wet season (3–4 months) with a measurement interval of less than 1 h over that period.
  - Recommend that these measurements are supplemented by manual measurements conducted during weekly site visits
  - Once measurements are acquired, a precipitation model (using archived precipitation data) can be applied to predict long term water table fluctuation. The investigation should also include a test pitting program to assess soil conditions and how they may pertain to fluctuations in the seasonal water table… guide is in Appendix A
- Commonalities in above groundwater ID approaches:
  - Recognition that the water table fluctuates in elevation seasonally and that extended periods of observation are required to provide a reasonable estimation of the seasonal high.
  - Specific reference to post-development lowering of the level due to dewatering effects of service trenches was generally not included.
  - Dillon Consulting (2017) notes however that this effect is commonly observed, though the magnitude of any such lowering may be difficult to predict.

It is also noted that the effects of this lowering may not entirely compensate for potentially wetter conditions or more extreme weather events in the future.

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