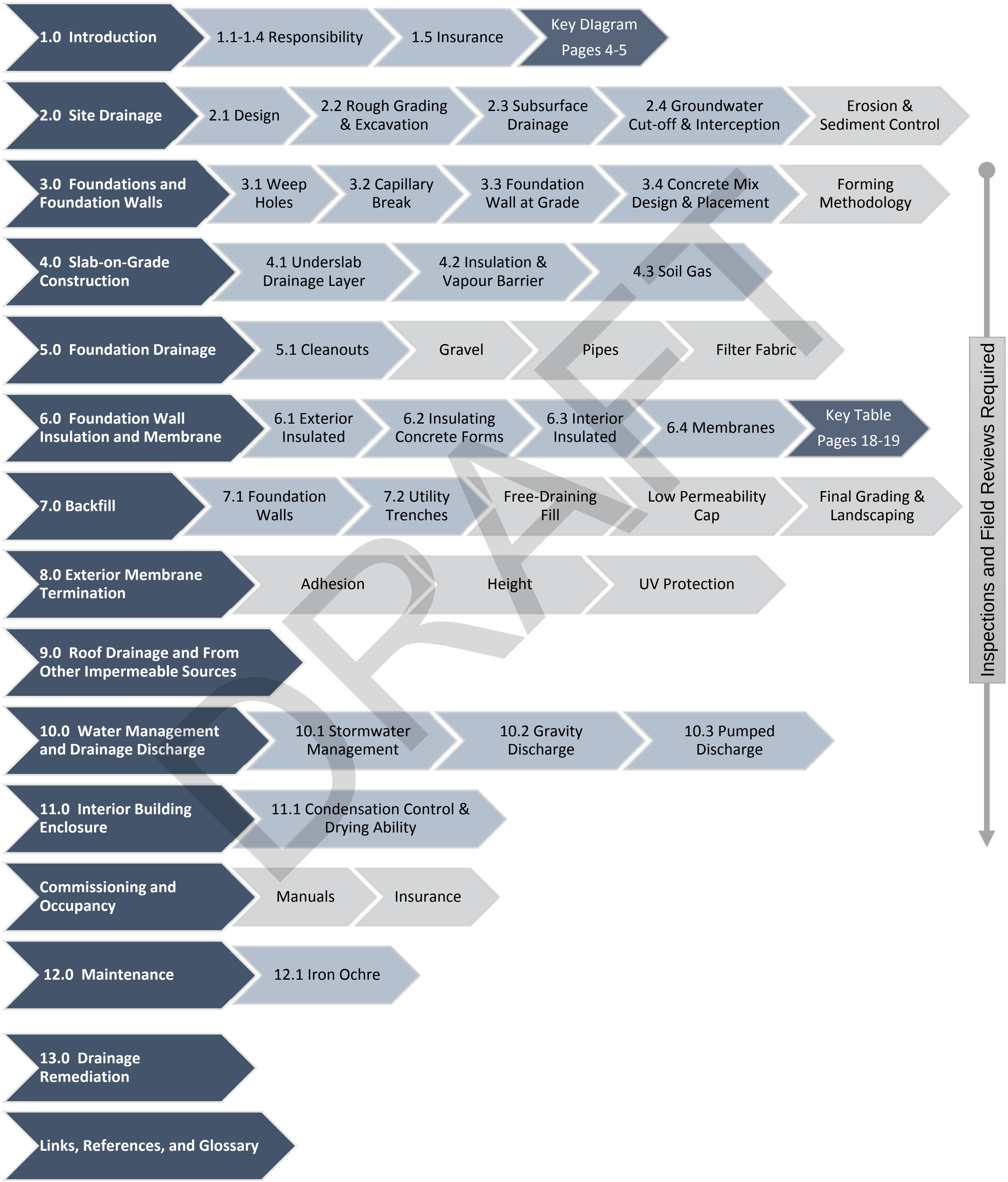
A BUILDER'S GUIDE TO SITE AND FOUNDATION DRAINAGE

BEST PRACTICES FOR PART 9 BUILDINGS

DRAFT – DECEMBER 5, 2017

THE GUIDE AT A GLANCE

This guide has been organized in a manner to be consistent with typical construction sequencing. Use Figure 1 as a key to identify design and construction elements.



1.0 INTRODUCTION

This guide has been prepared to:

- Serve as a reference tool for Part 9 buildings in conjunction with the 2012 BC Building Code (Building Code).
- Facilitate communication between owners and builders with respect to drainage and building enclosure systems for single- and multi-family buildings.
- Provide clarity and/or guidance where the Building Code is vague or silent.
- Present current best practice guidelines according to registered industry design professionals.
- Emphasize some basic Building Code requirements.

Initiation of this document was driven by a common experience of warranty providers encountering foundation drainage problems and moisture problems at relatively new buildings, many of which could have been avoided had best practices been incorporated into the original design of the building and into the original site grading and construction. The topics herein are also of demonstrated interest to Building Officials.

Water ingress into or accumulation within living spaces or basements can have various consequences, ranging from being a minor nuisance to resulting in more serious structural damage and/or health issues. The causes of such moisture can be difficult to diagnose, and challenging and expensive to remediate due to access limitations and the invasive nature of some repairs.

Some of the primary causes of water ingress into buildings include inadequate attention paid to site and foundation drainage design considerations, inappropriate details and/or workmanship for drainage elements, inadequate building enclosure systems installed during building construction, and/or inadequate maintenance.

This guide focuses on three key considerations: Site Drainage, Foundation Drainage, and Building Enclosure. A discussion of some post-construction remedial measures (e.g., for older buildings) is also appended. Site Drainage is relied upon to direct surface water away from a building. Foundation Drainage is relied upon to manage moisture below slabs-on-grade and remove water from against foundation walls. The below-grade Building Enclosure (i.e., wall and slab on grade floor assemblies) are the last line of defence for groundwater control. The below-grade building enclosure, through various materials and interfaces, is relied upon specifically to control moisture in all forms (groundwater, rain water, snow melt, vapour condensation, etc.), control air leakage and soil gas entry, and minimize heat loss / gain through the proper installation and detailing of thermal insulation.

Where foundation drainage and building enclosure is not adequately addressed, water may enter (e.g., through shrinkage cracks, cold joints, other small penetrations in the building foundation wall, or through capillary action through the concrete itself) or accumulate within (e.g., condensation) a building. Where unintended moisture is present in a building, damage and mould often result, and remediation is usually iterative, expensive, and almost always frustrating for the owner or occupant, and often the builder.

As the availability and quality of developable land decreases, and land values increase, there is a trend towards maximizing the habitable square footage of new developments, including more (and deeper) finished basements. This, in combination with ongoing climate change and a resulting increase of intense storm events, means that proper drainage for below-grade spaces is becoming more important to protect the investments of owners.

There is valuable information contained and discussed within this guide. However, if a single best practice were to be promoted, it would be to have clear gravel used beneath every slab-on-grade serving a finished space. Additionally, it is important to note that where it is possible to negate the need for a pumped foundation drainage system, whether through site selection or design of a building, this should be pursued. This will result in decreased construction and operating costs in addition to reducing long-term flooding risks (and likely insurance premiums). In some residential buildings, the requirement for a pumped system could be completely eliminated if the basement floor slab was to be raised by only a few inches, and the potential for future water damage therefore substantially reduced. Where a gravity drained system is feasible, it is recommended that building elevations be carefully selected so as not to eliminate this possibility.

Specific topics in this guide are discussed in the general order in which they are addressed for a project, starting with design. Sections start with a summary of the issues considered to be most important by the guide authors and reviewers and ends with a comparison between Building Code minimum requirements and current best practices. A glossary of *italicized* terms in this guide is included in the Glossary appended to this guide.

The key diagram shown in Figure 1 on pages 4 and 5 illustrates site and foundation drainage elements and overall building enclosure assemblies, with reference numbers corresponding to the relevant sections in the guide, where further discussion and design and construction details are provided. The table on pages 18 and 19 provides a summary of current damp- and water- proofing products and application methodologies for various environments and foundation construction factors in order to attain a suitable level of water ingress resistance.

1.1 Builder Responsibility

The builder, as the party carrying out the construction, is seen to have the following responsibilities:

- Adhere to the contract with the owner,
- Adhere to current Building Code,
- Implement design details as provided by design professionals, and request clarification if required to facilitate understanding of the design intent,
- Advise the owner,
- Quality Assurance and Quality Control,
- Schedule inspections by Authority Having Jurisdiction
- Schedule field reviews by registered design professionals, and
- Manage budget.

Actual responsibilities will be as outlined on the contract with the owner.

1.2 Professional Responsibility

Letters of Assurance (Schedules) are standard forms contained within the Building Code which are required to be signed by registered Professionals and submitted at the time of Building Permit application. They specify which aspects of a project are the responsibility of a particular registered professional. Schedules are sometimes required for single-family, and usually required for multi-family, buildings. Some Authorities Having Jurisdiction (AHJ hereafter) do not require Schedules or involvement of registered professionals, and instead rely on Building Inspectors.

Typically, the civil or mechanical engineering consultant signs off on Item 4.2: Site and Foundation Drainage for multi-family residential projects, with the civil engineering consultant signing off on townhouse complexes and the mechanical engineering consultant signing off on apartments. The civil engineering consultant would prepare drawings showing drainage pipe and sump layouts and *invert elevations* between townhouse buildings and the mechanical engineering consultant would show this information within a building footprint and specify pump types and configurations. It is important that these consultants reconcile their design recommendations with those of the geotechnical engineer for the project so that the design can be vetted against local geology, soil *permeability*, the local groundwater table, and other site-specific geotechnical considerations.

If a Professional Engineer has undertaken responsibility for Item 4.2 on the Schedule B, they should be provided with the opportunity to review installation of as well as test elements of the system for which hey have provided design recommendations. For single-family buildings, typically, the professional's responsibility includes stormwater management elements 'downstream' of a building sump, while the Building Inspector from the AHJ often checks those elements 'upstream' of the sump.

1.3 Warranty Providers' Responsibility

- *Require professionals for new home warranty?*
- *Would they enforce certified installers?*
- *Documentation required?*

1.4 Owner Responsibility

Although builders will likely be the primary audience implementing the strategies discussed in this guide, the Building Code (*Division A clause 1.2.1.2*) places the responsibility to build in conformance with Building Code on the owner.

The Owner also has a responsibility to hire suitably qualified builders and design professionals, to carefully consider post-construction insurance coverage (including exclusion clauses), and to carry out routine maintenance as required to protect their investment.

The owner is protected by checking the references for, and having written contracts with, all parties. Contracts could transfer the responsibility for ensuring adherence to the Building Code to these builders. Contracts could also outline a requirement to adhere to a higher standard than the Building Code, such as this guide and/or the Geotechnical Guidelines referenced in the Links section at the end of this document. For additional information, please refer to the Geotechnical Guidelines.

1.5 Insurance

Suitable Comprehensive General Liability (CGL) insurance coverage is critical at sites where there is a risk of water ingress, whether due to pump failure or other sources. This insurance must be put into place by the owner and is different from the insurance put into place by the builder to cover the period of construction as well as CGL policies put into place by building tenants. For sites with pumped drainage systems, having an appropriate understanding of the risks associated with these systems is important for owners and tenants in order to take measures to safeguard against potential damage. Builders should discuss these risks with owners so that appropriate steps may be taken following construction. Placing covenants on the property is one way to ensure that such information does not get lost to future owners.

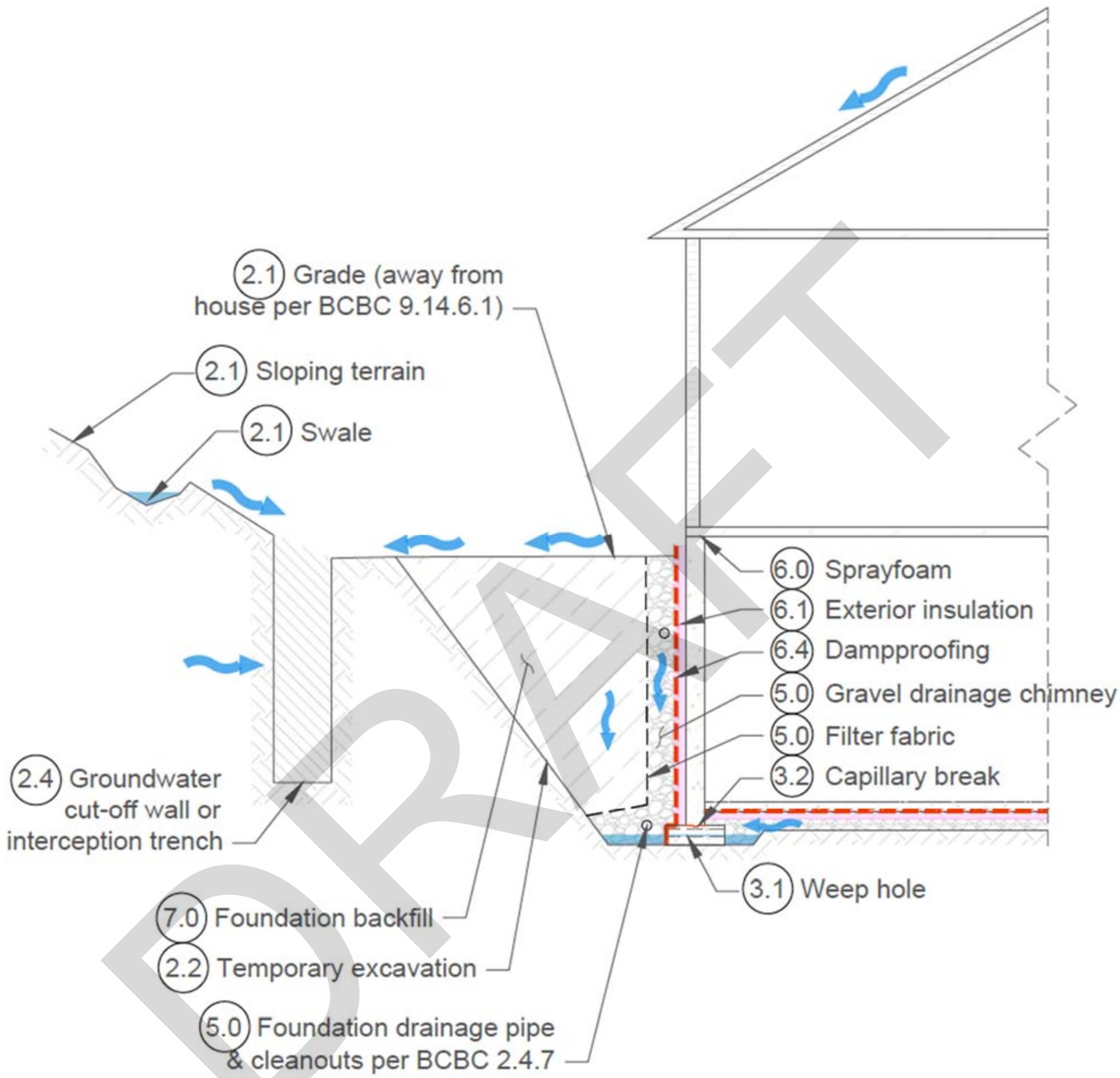
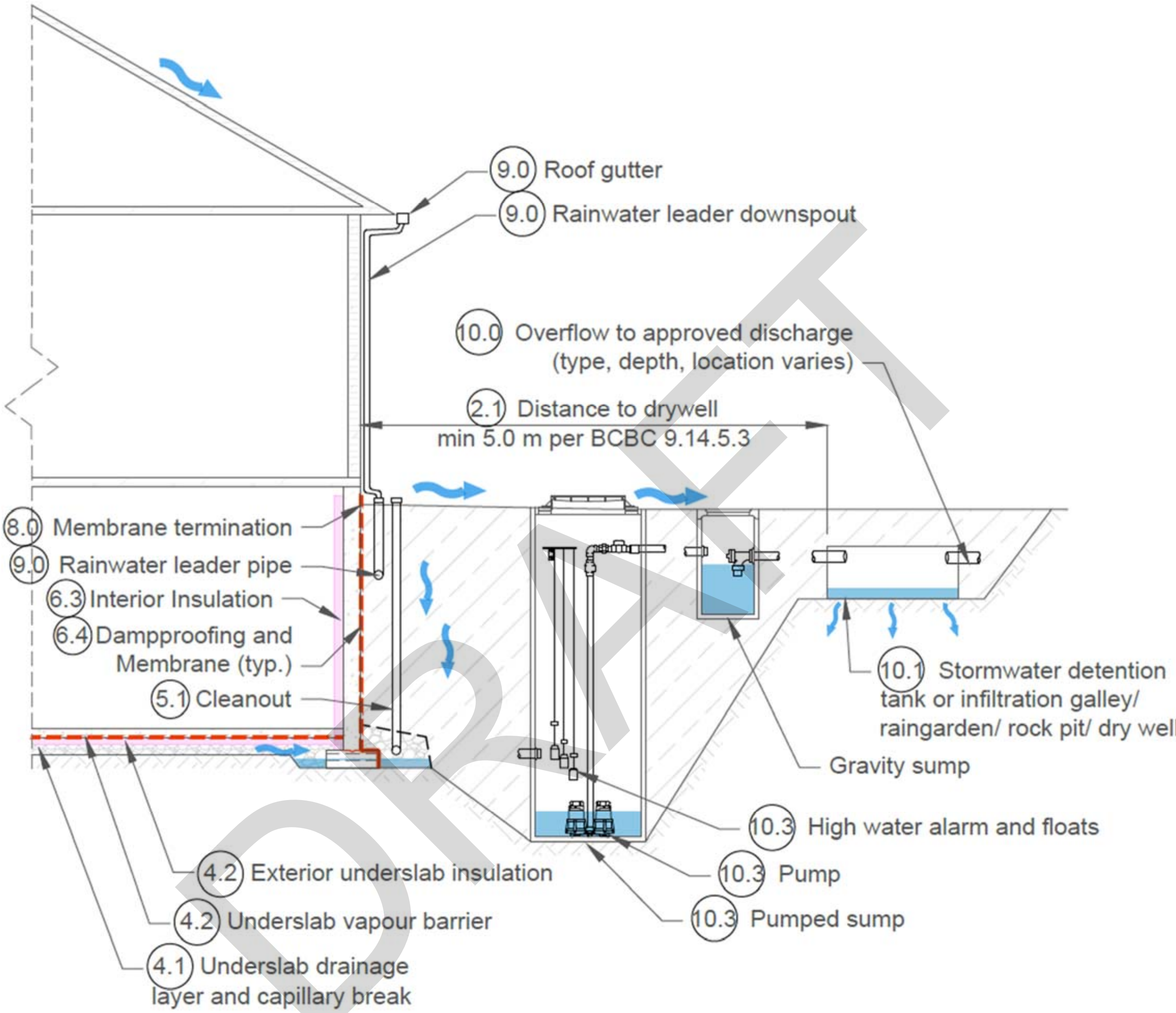


Figure 1: KEY DIAGRAM


9.0 Roof gutter
9.0 Rainwater leader downspout
10.0 Overflow to approved discharge
(type, depth, location varies)
2.1 Distance to drywell
min 5.0 m per BCBC 9.14.5.3
8.0 Membrane termination
9.0 Rainwater leader pipe
6.3 Interior Insulation
6.4 Dampproofing and
Membrane (typ.)
5.1 Cleanout
10.1 Stormwater detention
tank or infiltration galley/
raingarden/ rock pit/ dry well
Gravity sump
10.3 High water alarm and floats
10.3 Pump
10.3 Pumped sump
4.2 Exterior underslab insulation
4.2 Underslab vapour barrier
4.1 Underslab drainage
layer and capillary break
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2.0 Site Drainage

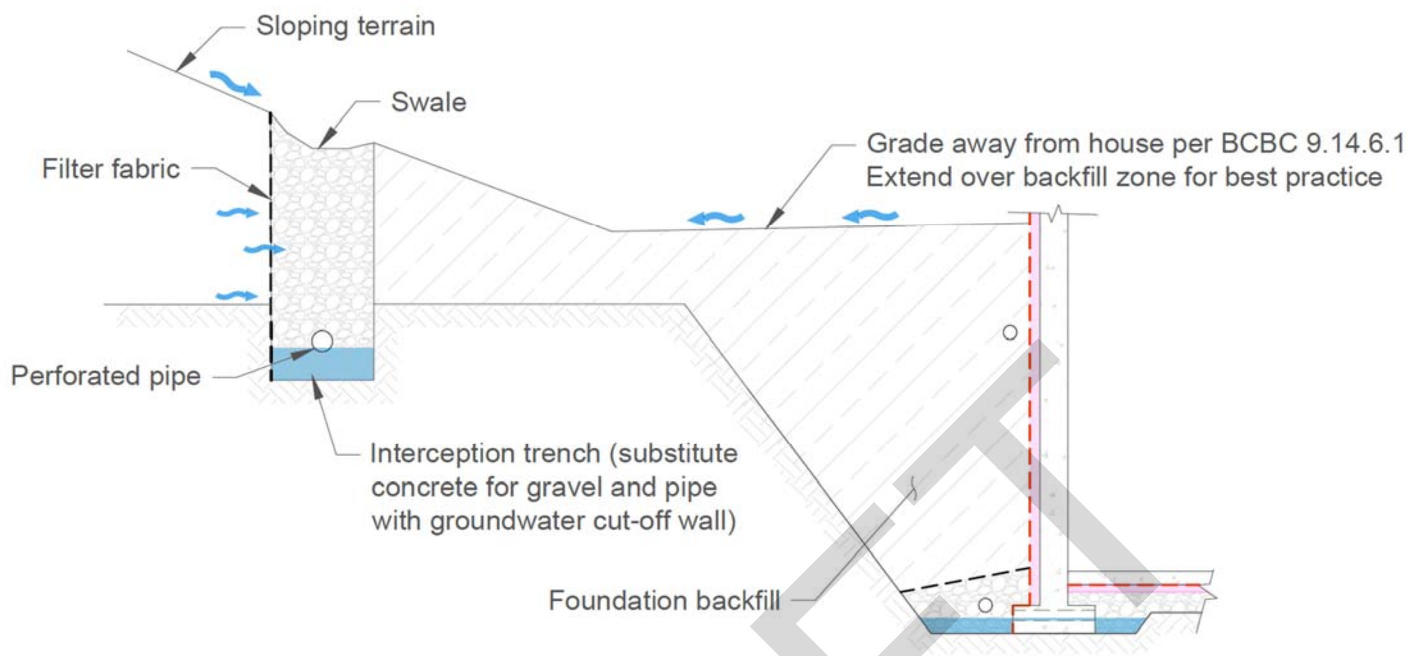


Figure 2: Example site drainage collection in a swale for a sloping property

MOST IMPORTANT:

- The ground surface should be **graded to slope down and away from buildings** (*9.14.6.1.(1)*) and surface water should be directed to suitable disposal.
- 'Rough' grading (i.e., site stripping during construction should slope down and away from the building location.
- Grade the building excavation and utility trenches to promote drainage away from the building and otherwise toward the sump during excavation works.
- Excavation for footings and depth between slab-on-grade and underside of footing to allow for sufficient 'fall' of future, perimeter, foundation drain pipe.
- **Infiltration fields** (aka, rock pits and dry wells) **should not be located within 5 metres of a basement, or below the water table** (*9.14.5.3*), **or in impermeable / sensitive soils.**
- Provide interception features to minimize water entering the excavation, where required.

2.1 Design

The best time to minimize future risk of water ingress into a structure is during the original site selection and design phase of a project including setting slab elevations and designing lot grading. Sites that are known to have high groundwater tables, or were the historic locations of ravines, channels, creeks, or other features associated with conducting water, may have a higher risk of post-construction problems than sites without these features.

If consulted early in the project, a Geotechnical Engineer can provide guidance on site selection, lot grading, and building design to reduce the risk of water ingress.

The Building Code requires that buildings be located, or the building site be graded so that "water will not accumulate at or near the building" (*9.14.6.1.(1)*). Appropriate grading of sites is the simplest means of controlling surface water, although other strategies may also be implemented to help minimize surface water problems. Surface elements that may be incorporated into a grading plan include swales, ditches, and/or raingardens. Subsurface elements include groundwater interception trenches (i.e., French drains) and groundwater cut-off walls. Most of these features require ongoing maintenance during the life of the development.

On flat properties, adequate site drainage can be achieved by ensuring that both "rough" grading (i.e., below topsoil) and final grading of landscaping (e.g., lawns, patios and/or sidewalks) are sloped down and away from the building.

On a sloping property, good site grading can be more difficult to achieve, particularly "upslope" of building walls (as shown at the left of Figure 1 and on Figure 2), since the natural grade promotes water to be directed towards the building.

It is considered best practice to grade landscaping away from the building for a distance of 3 metres, or past the backfill zone of the foundation walls as shown on Figure 2. This surface water can then be collected in a swale, French drain, lawn basin, raingarden, or other surface water management feature (as discussed in greater detail in Section 10.0. Any pipes should discharge to an approved location.

Stormwater infiltration features should be downslope of buildings and sufficiently distant from below-grade basements (Building Code says minimum 5 metres, but greater distances may be recommended by a geotechnical consultant depending on subsurface soil conditions.

Where a site is sloped, and groundwater flows are significant, it may be possible to control the amount of water reaching a foundation drain by use of a groundwater cut-off wall. This is a low permeability feature requiring geotechnical design. It may increase nearby groundwater elevations; thus, the potential for off-site impacts should be assessed.

Where it is possible to negate the need for a pumped system, whether through site selection or the design of a building (i.e., during setting of finished floor elevations), this would be preferred. Eliminating the requirement for a pumped system can substantially reduce the potential for future water ingress. Where it is feasible to drain collected water via gravity to the discharge location (commonly a municipal sewer), it is recommended that building elevations be carefully selected so as not to eliminate this possibility.

2.2 ROUGH GRADING AND EXCAVATION

Areas adjacent to the crests of the excavation slopes should generally be graded to direct surface water away from excavation slopes; this will have the benefit of minimizing the amount of water which must be managed by foundation drainage in the future. The base of the building excavation should be graded during excavation works to promote drainage toward the storm sump. The slopes of trenches required for any utility installation should be graded to thoughtfully direct water which collects at the inverts of these trenches; it is noted that this may be counter to the grading of the surface of pipe bedding.

All temporary excavations should be carried out in accordance with the requirements of WorkSafeBC, and under the supervision of a suitably qualified Professional Engineer, where required. It may be suitable and/or required to implement erosion and sediment control measures.

2.3 SUBSURFACE DRAINAGE

Water that travels through preferential subsurface drainage paths into foundation backfill materials can be of natural origin (e.g., groundwater, infiltrated rain water, adjacent lakes or ocean, buried streams) or from other sources such as irrigation systems, rainwater leader downspouts, leaking utilities, or unfavourably sloped trenches (surficial or buried).

In managing subsurface water at a site, an important design consideration is the *hydraulic conductivity/permeability* of the soil. The hydraulic conductivity describes the ability of water to flow through or infiltrate into a soil and is related to the particle size, compaction, and soil composition.

Low hydraulic conductivities (e.g., 10^{-6} metres per second and below) indicate that a soil is relatively *impermeable* and that water on top of such soil will likely "pond" for a relatively long time without infiltrating into this material, and, similarly, water will not easily travel through this material to other areas of a site or to a drain pipe. Materials that generally have a low permeability include clays, silts, glacial till or 'hard pan.' Infiltration systems are typically not recommended at sites where the hydraulic conductivity of the soil is relatively low.

Higher hydraulic conductivities (e.g., 10^{-5} metres per second and above) indicate that a soil is more *permeable*, and that water will be able to infiltrate with relative success. These materials are generally considered free-draining and are may comprise relatively "clean" sands (e.g., free of fines such as silt or clay) to gravel. More flow can occur through high permeability soils than lower permeability soils.

Sensitive or collapsible soils can behave unpredictably when water is introduced, and this can negatively affect bearing conditions for nearby buildings; thus, water infiltration (e.g., via dry wells or stormwater infiltration tanks / trenches / fields / galleries) into these types of soils should be avoided.

It may be helpful to imagine water travelling through the "easiest" path available, whether this is 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 openings in a building wall. For this reason, it is important to consider the overall site and construction layout when designing a drainage system.

2.4 GROUNDWATER CUT-OFF WALLS AND INTERCEPTION TRENCHES

Upslope (ground)water interception trenches can be constructed to collect surface or *perched groundwater* beyond the building basement backfill zone. Where it is desirable to intercept groundwater, it is best to consult a geotechnical engineer, including about surficial geology governing local groundwater flows. These high-permeability interception trenches extend into a low permeability soil stratum, are generally filled with clear gravel and contain a perforated pipe which collects water and allows for some future maintenance. A concrete "dam" should be installed in the interception trench at the transition between this perforated pipe and the solid discharge pipe, as shown in Figure 3. Alternatively, a sump could be installed at this transition if the exterior is backfilled with concrete. Filter fabric may be recommended on the upslope side of the trench and near the top of the trench. The ground surface is generally 'swaled' to promote surface water infiltration to the trench and maintenance of the trench surface will be required to ensure that silt, leaves and other garden debris, etc. do not collect which could inhibit water infiltration.

Generally, upslope groundwater cut-off walls can also be constructed to inhibit the amount of groundwater flowing toward a basement structure. These low-permeability features might comprise a trench (possibly extending below the elevation of the basement) which is backfilled with concrete or a continuous caisson or secant pile wall. These features would be expected to result in an increased groundwater elevation above and beside the cut-off. Seepage modelling by a suitably qualified geotechnical consultant would be required to assess the required depth, plan extent of a groundwater cut-off wall as well as to quantify the potential, proximate and distant (i.e., off-site) impacts. Depending on the topography and geology, the groundwater cut-off structure may be required to surround the basement.

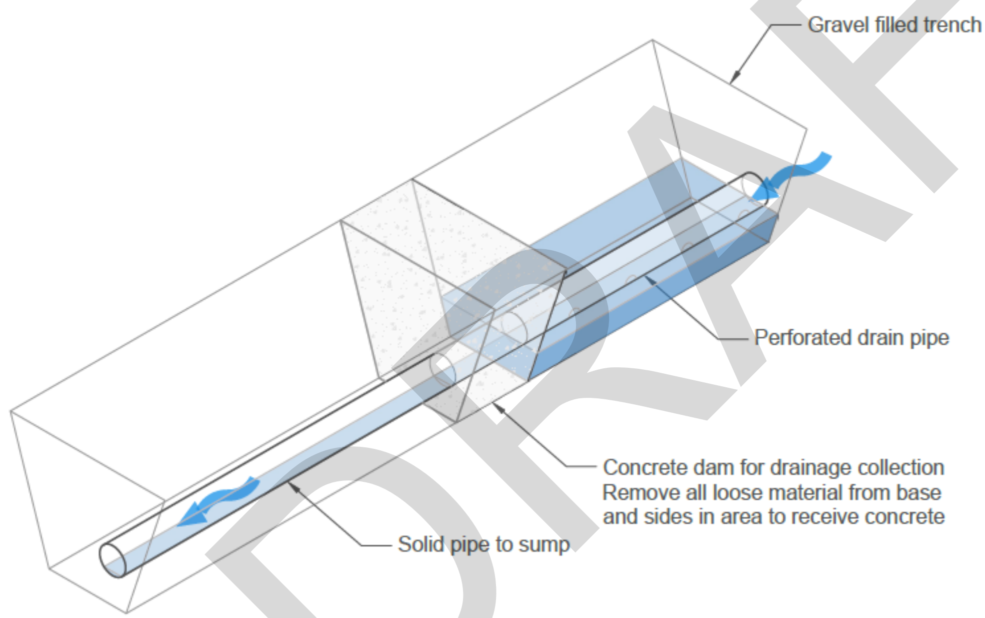


Figure 3: Detail for transition from perforated pipe of interception trench to solid discharge pipe.

Building Code Requirement: Site Drainage	Best Practice / Comment
The building shall be located or the building site graded so that water will not accumulate at or near the building (*9.14.6.1.(1)*).	Ensure both 'rough' grading and final grading is sloped down and away minimum 2% from a building past the backfill zone of the building.
The building shall be located, the building site shall be graded, or catch basins shall be installed so that surface water will not accumulate against the building (*5.7.1.1.(1)*), except where specifically designed to accommodate such.	Where possible, negate the need for a pumped foundation drainage system, whether through site selection or design of a building Where a gravity drained system is feasible, it is recommended that building elevations be carefully selected so as not to eliminate this possibility.

3.0 Foundations and Foundation Walls

This section pertains to site and developments where conventional construction techniques are suitable (i.e., not "tanked").

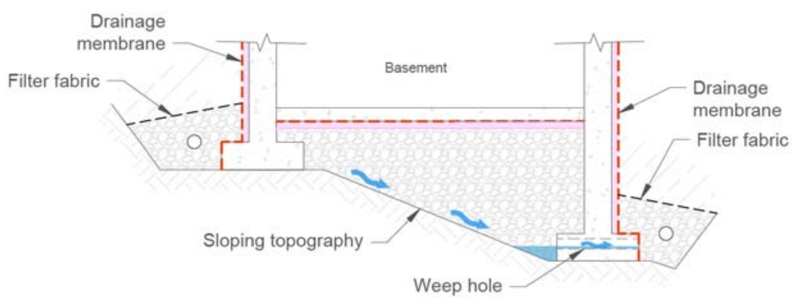


Figure 4: Typical weep hole configuration.

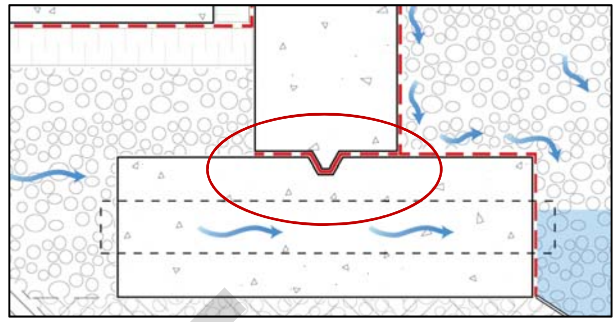


Figure 5: Capillary break between footing and foundation wall.

MOST IMPORTANT:

- **Good quality concrete, reinforced to control shrinkage cracks and resist backfill pressures.**
- **Weep holes through footing, rather than at bottom of foundation wall (as is conventionally done).**
- **Top-of-wall to extend above grade (minimum 8 inches clearance).**

3.1 Weep Holes

Careful thought should go into deciding whether to provide a direct hydraulic connection (i.e., through foundation weep holes) from the underslab fill to exterior foundation drain pipes. Specifically, considering that water will be collecting in the gravel bedding below perimeter drainage and in the underslab gravel, it may be desirable to have weep holes on only the 'downstream' side of the building footprint as shown in Figure 4 so that water can drain out of, and not in to, the underslab gravel area.

In order to allow a water-stop to be installed between the footing and foundation wall (as discussed later in this guide), it is recommended to install weep holes through the foundation (and not through the foundation wall) as shown in the figure above. Typically, 3-inch diameter weep holes at 6 to 8 feet spacing or as required by the geotechnical engineer and as acceptable to the structural engineer are suitable.

3.2 Capillary Break Between Footing and Foundation Wall

An impermeable capillary break consisting of a continuous application of a liquid or a sheet applied damp-proofing or waterproofing membrane should be installed between the top of the footing and foundation wall. When reinforcing is present, liquid-applied membranes are easier to install. This impermeable material helps to reduce the direct uptake of moisture from the wet footing into the foundation wall (i.e. 'rising damp'). This will result in a drier foundation wall and help protect interior finishes and wood framing from moisture damage. A keyway is also suggested to improve the structural resistance at this interface, especially when a membrane is installed. This detail is shown in Figure 5.

Alternately, a capillary break could be installed around the entire footing (such as where exterior insulation is used below the footing); however, this would require a professional to evaluate the structural implications as the friction coefficient against sliding will be significantly reduced from soil properties usually relied upon.

3.3 Foundation Wall at Grade

A minimum distance of 8 inches (200 mm) is required from the finished/graded soil to the top of the concrete foundation wall and start of the wood-framing. This is to provide additional protection against water entry into the building and keep the wood framing dry.

3.4 Concrete Mix Design & Placement

Assuring performance of below-grade concrete walls must include typical good concrete construction practices, such as proper mix design, construction and control joint waterproofing, and crack control. Hydrophobic crystalline admixtures can be added to the concrete mix to minimize the transmission of water through micro cracking that forms in the concrete. For additional protection, PVC, bentonite, or synthetic swelling rubber 'waterstops' are recommended at all construction joints in concrete. Hydrophobic crystalline joint treatment and 'waterstop' grout can also be installed as the last line of defence against water ingress through construction joints.

4.0 SLAB-ON-GRADE CONSTRUCTION: UNDERSLAB INSULATION, DRAINAGE, AND VAPOUR BARRIER

4.1 UNDERSLAB DRAINAGE LAYER

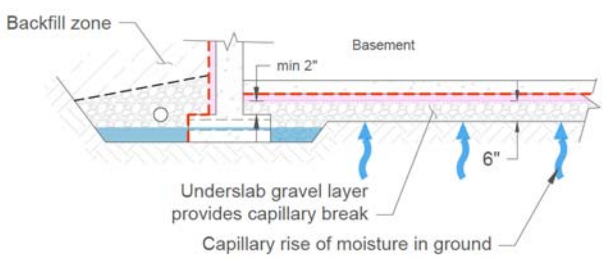


Figure 6: Best practice underslab and perimeter drainage configuration.

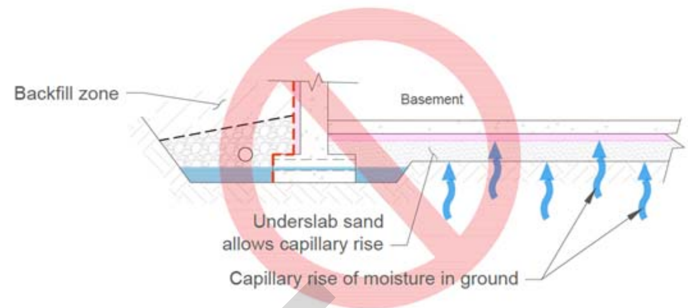


Figure 7: Common practice for underslab gravel includes using sand under the slab; does NOT meet Building Code.

MOST IMPORTANT:

- **PROVIDE CLEAR GRAVEL UNDERSLAB DRAINAGE LAYER** to reduce the uptake of moisture into concrete slabs. It is very expensive to remediate poor underslab material post-construction.
- Sand is **not** suitable for use below floor slabs without a layer of underslab gravel.
- Provide minimum 4 inches of clear gravel underneath slabs-on-grade (**6 inches is better**) including minimum 2 inches on top of footings.

Generally, the success of a perimeter foundation drainage system relies on a suitable underslab drainage layer. The Building Code requires that slabs-on-grade for buildings with residential occupancies in areas where radon is a concern (i.e., Radon Area 1) be underlain by a gas-permeable, coarse, clean granular layer (*9.13.4.3.(3)a*). Best practice would be to provide at least a 6-inch thick layer of clear gravel immediately below any interior slab-on-grade to provide a *capillary break* and act as a drainage layer. Although not required by the Building Code, best practice is to compact the underslab gravel to minimize potential settlement that could result in cracks in the slab-on-grade (Photo 1).

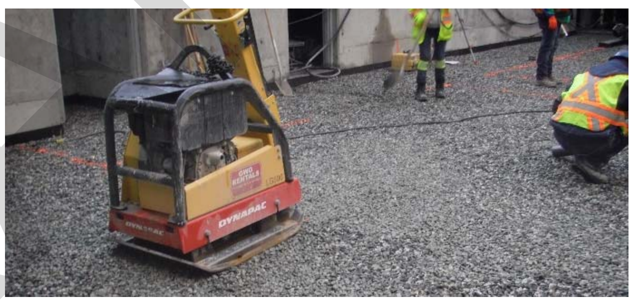


Photo 1: Example of clear crushed gravel being placed and compacted for underslab drainage.

The gradation specified in the Building Code for gravel is not ideal. An ideal gravel is considered to range in size from ¾ to 1 inch and be angular (thus more compactible).

Sand will generally not provide a suitable capillary break, as water can wick upwards as much as several feet in sand.

Polyethylene sheeting is also not an equivalent substitute for clear underslab gravel; however, it is now required to cover the gravel as a second barrier against moisture ingress and as a barrier to possible soil gas (discussed following).

4.2 UNDERSLAB INSULATION, AIR AND VAPOUR CONTROL AND SEALING OF AIR BARRIER

A polyethylene sheet is installed below the slab-on-grade, typically on top of the insulation and drainage gravel. This provides a capillary break and vapour barrier between potentially wet gravel and the concrete slab and reduces the uptake of moisture into the concrete.

Critical to the airtightness of the building and control of soil gases, the air barrier beneath the slab-on-grade (typically a polyethylene sheet, taped at seams) needs to be tightly connected to the wall air barrier system. This is typically achieved using a sealant or a compatible tape between the polyethylene sheet and concrete foundation wall. Where sandwiched by insulation or restrained by a termination bar, then the robustness is improved. Where placed directly on crushed rock used as an underslab drainage layer or beneath reinforcing, the barrier may be vulnerable to perforations which should be subsequently sealed. The wall air barrier typically consists of the concrete itself in conjunction with a damp-proofing or waterproofing membrane applied on the exterior.

4.3 Soil Gas Control

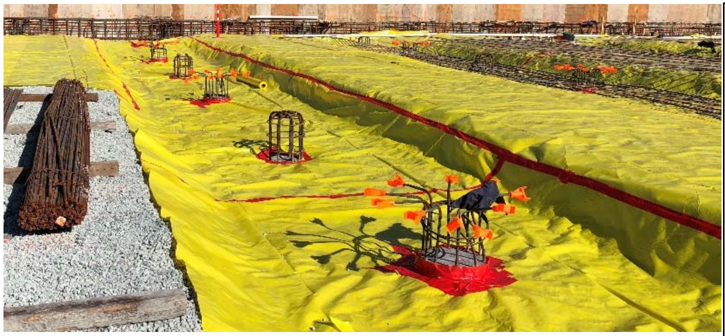


Photo 2: Example of an impermeable liner placed and sealed at a building for soil gas control.

Figure 8: Typical soil gas vent pipe details and offsets.

MOST IMPORTANT:

- Accidental rips and tears as well as penetrations for piles, pipes, and pipe hangers should be sealed, and consideration given to the dead weight of the underslab membrane and how it will be suspended from or affixed to the underside of a pile-supported slab.
- Perforations in the soil gas collection pipe should be facing upwards (i.e., opposite perimeter drainage).

The Building Code requires that an air barrier system be installed to protect conditioned space from the ground as a means for protection against soil gas (*9.13.4.2.(1)*). Common types of soil gas encountered in BC include radon (produced by decay of uranium in rocks) and methane (produced by decomposing organics such as peat). The Building Code includes a table in Appendix C which indicates locations in BC which require a rough-in for radon mitigation purposes per *9.13.4.3*.

In addition to serving as a capillary break, a polyethylene sheet can be installed below the slab-on-grade, typically on top of the insulation and drainage gravel, for soil gas control, provided this membrane is detailed and sealed airtight. This involves taping/sealing around all penetrations in the membrane, such as for pipe hangers, pipe penetrations, or foundations (e.g., piles and grade beams) prior to pouring the concrete slab. All seams should be appropriately lapped and taped, and edges caulked to perimeter foundation concrete.

The minimum Building Code requirement allows for a 6 mil polyethylene sheet that is resistant to soil gas/radon as being suitable. Better practice is to install a thicker (e.g., 12-15 mil) sheet, which is more durable and less easily damaged during construction. This should be lapped minimum 100 mm and taped at seams. Some manufacturers have products to affix the membrane to the slab underside to address settlement of the underlying ground where the slab is pile-supported.

As part of the soil gas barrier system, a vent pipe may be installed below in the granular layer the slab and stubbed in above. Where a vent pipe is required, it must be terminated at a suitable location. A perforated PVC pipe (with perforations up) could be installed within the underslab gravel layer to provide a means for collection and venting of soil gas to the building exterior. If radon or other soil gases are present, then this pipe could be connected to a sub-slab depressurization system in order to mitigate the potential for infiltration of soil gases into the building. Generally, the underslab gravel layer can also be used as a depressurization rough-in for soil gas.

Building Code: Underslab Drainage & Soil Gas	Best Practice / Comment
Slabs-on-grade for buildings with residential occupancies in Radon Area 1 should be underlain by a gas-permeable, coarse, clean granular layer (*9.13.4.3.(3)a)*. Ingress of water underneath a floor-on-ground shall be prevented by grading or drainage (*9.16.3.1.(1)*).	Use clear crushed gravel with a gradation between 3/4 and 1 inch (i.e., 0% passing a #4 sieve). Use minimum 6 inches of clear crushed gravel under floor slabs and minimum 2 inches to separate underside of slab-on-grade from top of footing beneath.
All wall, roof and floor assemblies separating conditioned space from the ground shall be protected by an air barrier system conforming to Subsection 9.25.3 (*9.13.4.2.(1)*) Except in areas classified as Radon Area 2 in the Building Code, unless the space between the air barrier system and the ground is designed to be accessible for the future installation of a subfloor depressurization system, dwelling units and buildings containing residential occupancies shall be provided with the rough-in for a subfloor depressurization system (*9.13.4.2*).	The noted depressurization system is intended for areas where radon is envisaged to be present. It is considered that a coarse granular layer underside of the slab, in combination with a length of perforated pipe, may serve as a rough-in for a depressurization system.

5.0 Foundation Drainage

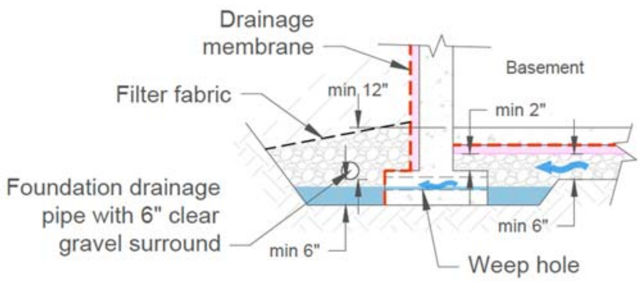


Figure 9: Typical best practice detail for a foundation drainage system.

Photo 3: Perimeter drainage on building with gravel bedding.

MOST IMPORTANT:

- The Building Code requires the bottom of every exterior foundation wall to be drained by drainage tile or pipe or by a layer of gravel or crushed rock, unless shown to be unnecessary (*9.14.2.1.(1)*).
- **Best practice is to grade and install sufficient clear gravel bedding to provide suitable perimeter foundation drainage on its own, then install perforated drain pipe and clear gravel cover.**
- **Rigid, PVC pipe with double 45° fittings at corners is recommended.**
- **Use free-draining backfill materials against building walls.**

The Building Code requires that, unless it can be shown to be unnecessary, the bottom of every exterior foundation wall shall be drained by drainage tile or pipe or by a layer of gravel or crushed rock (*9.14.2.1.(1)*).

Foundation drainage is installed at the bases of most below-grade structures (e.g., basements, crawlspaces and underground parkades) to minimize the likelihood of water accumulating next to below-grade walls. When soil adjacent to building foundation walls is saturated/submerged, it exerts both a *soil pressure* and a *hydrostatic pressure* on a building wall. If the design of a building foundation wall considered only the soil pressure, the addition of water-related pressures could result in structural damage to the wall. Additionally, when water accumulates adjacent to a foundation wall, it can result in dampness or water ingress into the basement.

Elevated pressures on a foundation wall (i.e. due to partially saturated conditions) can result if the foundation drainage at a building is not adequate or if backfill materials are not free-draining.

A 'best practice' perimeter drainage system typically consists of 4- or 6-inch diameter, rigid, perforated, PVC drain pipe which is bedded on and covered by clear gravel in turn covered by a filter fabric to minimize the risk of fine-grained material from entering and potentially clogging the drainage system. The maximum elevation of the top (or crown) of the perimeter drain pipe should not be higher than 2 inches below the top of the slab-on-grade. Additionally, the pipe should be below the frost penetration depth. The invert (i.e., bottom) of the drain pipe should be at least 12 inches below the top of the adjacent, interior slab-on-grade elevation. The perimeter foundation drain pipe should slope down at 1% around the building, with the subgrade surface similarly graded below the pipe bedding. The pipe perforations should be installed facing downwards. Consideration could be given to placing filter fabric between the natural soil subgrade and the gravel pipe bedding.

Perimeter drainage systems should be maintained on a regular basis (by flushing; with snaking as required). For this reason, proper cleanout installation and access is important to the long-term performance of the system.

Sensitive soils

5.1 Cleanouts

The Building Code requires that cleanouts be installed every 15 metres for uni-directional systems, or at every corner of the building.

Cleanouts are essential in order to provide access for future maintenance of the drainage system.

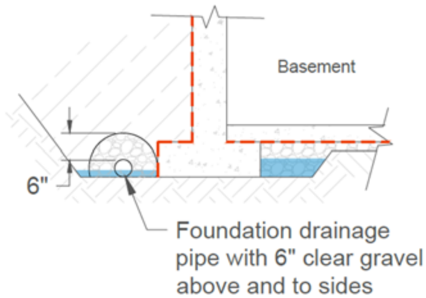


Figure 10: Example of Building Code "Option A" for foundation drainage system (NOT recommended by best practice).

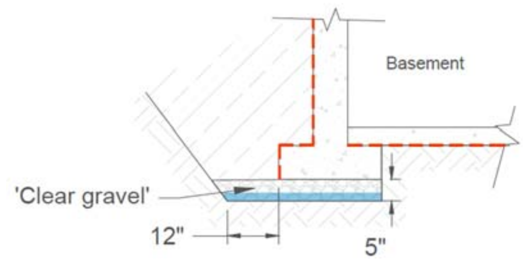


Figure 11: Example of Building Code "Option B" for foundation drainage system (NOT recommended by best practice).

Building Code Requirement: Foundation Drainage	**Best Practice / Comment**
Unless it can be shown to be unnecessary, the bottom of every exterior foundation wall shall be drained by drainage tile or pipe … or by a layer of crushed gravel or crushed rock (*9.14.2.1.(1)*). Building Code allows for foundation drainage to comprise either: a) drainage pipe or tile laid on undisturbed or well-compacted soil with the top and sides covered by at least 15 cm (6 inches) of clear gravel (*9.14.3*) [see Figure 10], or b) a minimum 12.5 cm (5 inch) thick layer of clear gravel beneath the footing, extending 30 cm (12 inches) beyond the outside edge of the footing (*9.14.4*) [see Figure 11]. Drain tile or pipe shall be laid on undisturbed or well-compacted soil so that the top of the tile or pipe is below the bottom of the floor slab or the ground cover of the crawl space (*9.14.3.3.(1)*).	To allow for maintenance of the drainage system, include a rigid, perforated, PVC pipe with perforations installed facing down in the installation, as opposed to using only gravel for drainage. Place at least 15 cm (6 inches) of clear crushed gravel beneath and surrounding the perforated perimeter drainage pipe such that the underlying soil is separated from the pipe. Without this gravel layer, in Option (a), the underlying soil would be expected to 'block' the perforations on the bottom of the pipe. Wrap the clear gravel with a layer of suitable filter cloth to minimize soil migration into the system; do NOT wrap the pipe. Depending on the foundation design, gravel under the footings may not be appropriate. Where present, the gravel layer should be suitably compacted. Where there is a step in the slab-on-grade, interior foundation drains are also recommended, and these should be installed below the elevation of the lower adjacent slab with appropriate location of weep holes. Install pipes with invert elevations at least 30 cm (12 inches) below the top of the adjacent, interior, slab-on-grade elevation. The requirement to have the pipes below the slab elevation and to slope them often results in the bedding material for the pipes being deeper than the adjacent foundation. If the excavation for this installation is too close to the footing, the bearing conditions for the footing can be compromised. In general, the excavation to allow for installation of foundation drains and bedding should not encroach beyond a line extending down from the foundation at 1 vertical : 2 horizontal. Where this is problematic: • This scenario could be planned for and a deeper footing and higher foundation wall could be constructed. • In some soil conditions, as determined by a geotechnical engineer, this line can be steepened to as much at 1 vertical : 1 horizontal. • Filter fabric can be installed between the foundation and drainage subgrade soil and the gravel bedding for the drain pipe if the bedding is less than 6 inches thick, and/or With permission from the plumbing inspector for the authority having jurisdiction or upon approval by the professional undertaking responsibility for Item 4.2 on the Schedule B, the recommended minimum slope of 1% could be reduced.
Every … storm drainage system shall be provided with cleanouts that will permit cleaning of the entire system (*2.4.7.1.(1)*). Maximum permitted cleanout spacing in a drainage system for 4-inch diameter pipes is 15 m for one-way rodding, and 30 m for two-way rodding (*Table 2.4.7.2*). Cleanouts and access covers shall be located so that their openings are readily accessible for drain cleaning purposes (*2.4.7.4.(1)*).	Follow Building Code. Provide cleanouts regularly to allow for access and maintenance to the system, and ensure that cleanouts are not buried or covered which inhibits access. Capped perimeter drainage 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 the maintenance contractor. Ensure that sumps are large enough and equipped with ladder rungs to allow access for the purpose of future maintenance.

6.0 Foundation Wall Insulation and Membrane Strategies

MOST IMPORTANT:

- Exterior insulation on foundation walls is preferred over interior insulation.

The design of the below-grade building enclosure requires careful consideration of three aspects. Firstly, the transfer of heat should be controlled through the use of insulation and detailing to minimize thermal bridging. Secondly, air leakage and soil gas entry should be controlled through a detailed and sealed air barrier system. Finally, moisture should be controlled by the use of various membranes, insulation placement and careful material selection and detailing. This moisture could be in many forms, including but not limited to condensation, groundwater, snow melt, and rain water.

There are several possible wall assemblies that could be utilized for below-grade concrete wall construction. Three such better practice arrangements are shown below in Figure 12 through Figure 14. These figures provide details for exterior insulated foundation walls, foundation walls constructed using insulating concrete forms [ICFs], and foundation walls insulated at the interior insulated. In addition to details and configuration of elements, commentary is provided regarding air, vapour, and moisture management.

6.1 Exterior Insulated Foundation Wall

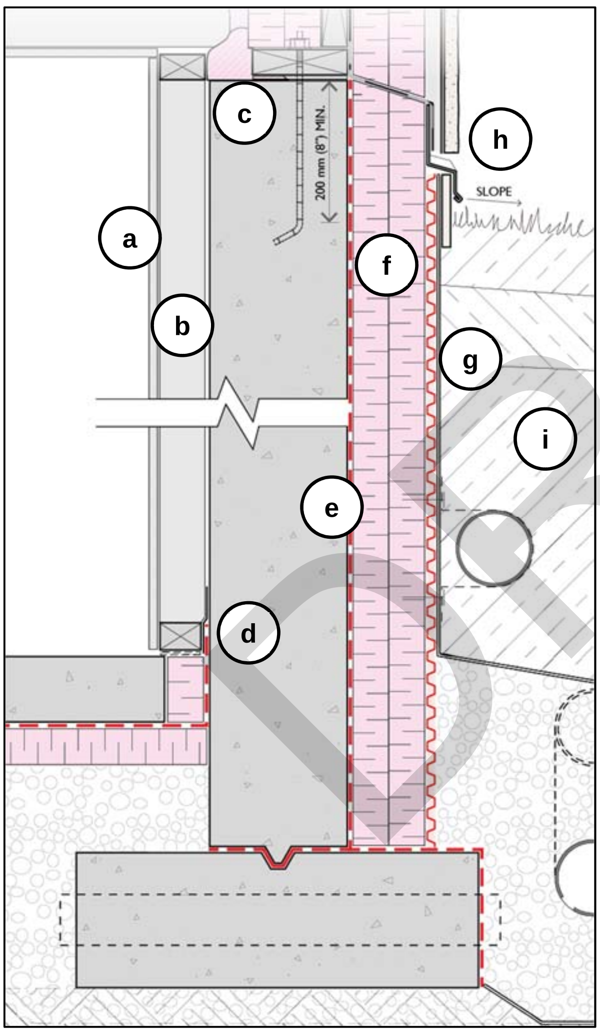


Figure 12: Exterior Insulated Foundation Wall.

A foundation wall which is insulated at the exterior would have the following elements, with assembly described from interior face, through to exterior backfill, as follows:

a. Gypsum board (ideally non paper-faced for enhanced resiliency),
b. Wood framing (including electrical, plumbing services, etc), with
c. Sprayfoam sealed against bottom of wood framing where it sits on supporting concrete foundation wall (i.e., for airtightness),
d. Concrete foundation wall,
e. Damp-proofing / waterproofing membrane applied to the concrete wall,
f. Rigid insulation board – Extruded Polystyrene (XPS) insulation. Alternatively, a below-grade rated expanded polystyrene (EPS), draining rigid mineral wool or closed cell sprayfoam could be used as insulation in this application,
g. Drain mat (with filter fabric side on the exterior) installed on the insulation (i.e., used as a drainage medium and capillary break between the insulation and the backfill),
h. Water- or damp-proofing, insulation and drain mat should continue to the top of the concrete wall, with proper termination in accordance with the manufacturer's recommendations. A durable and UV-resistant cover material should be placed above grade against the otherwise exposed portion of this assembly to protect the materials from UV exposure and physical damage, and
i. Backfill.

6.2 FOUNDATION WALL WITH INSULATING CONCRETE FORMS

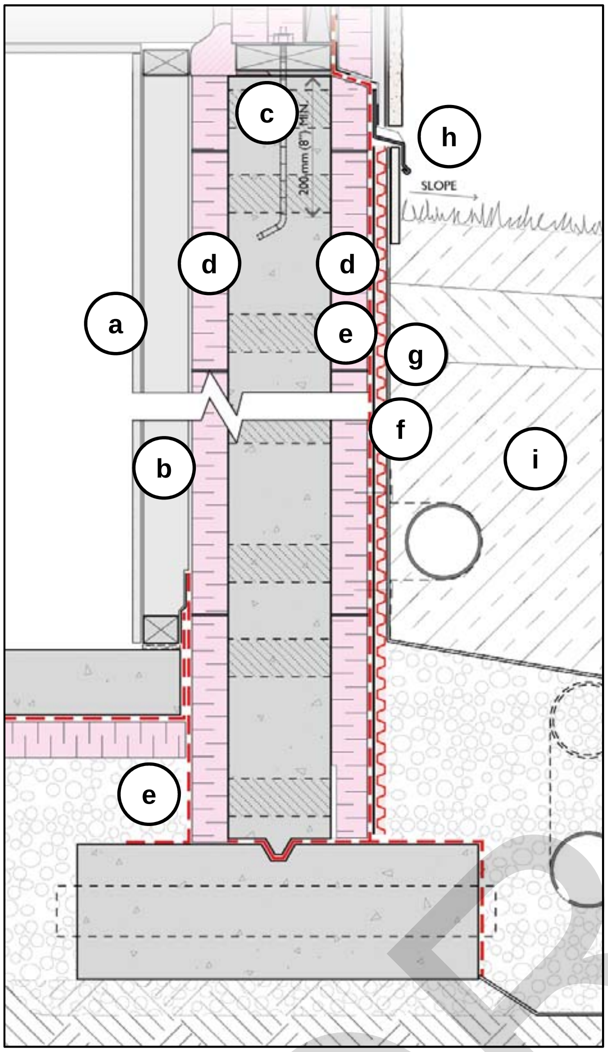


Figure 13: Foundation Wall Formed with Insulating Concrete Forms (ICF).

A foundation wall which is constructed utilizing insulating concrete forms (ICF) would have the following elements, with assembly described from interior face, through to exterior backfill, as follows:

a. Gypsum board (ideally non paper-faced for enhanced resiliency)
b. Wood framing (including electrical, plumbing services, etc), with
c. Sprayfoam sealed at interface of and against both wood framing and ICF (for airtightness).
d. Insulating concrete forms with integral, expanded polystyrene (EPS) insulation and reinforced concrete core,
e. Compatible waterproofing or damp-proofing liquid or sheet membrane is applied to the exterior EPS insulation board
f. Slip sheet (placed between the waterproofing or damp-proofing membrane and the drain mat) to reduce the risk of damage to the membrane by the texture or dimples in the drain mat,
g. Drain mat with filter fabric (installed on the exterior side), installed against the slip sheet (i.e., used as a capillary break to reduce the amount of liquid water that reaches the damp-proofing/waterproofing),
h. The water- or damp-proofing, and drain mat continue to the top of the concrete wall, with proper termination in accordance with the manufacturer's recommendations. A durable and UV-resistant cover material is placed above grade to protect the materials from UV exposure and physical damage, and
i. Backfill.

Building Code Requirement	Best Practice / Comment
Foundation walls shall be constructed so that surface water will not enter the building or damage moisture-susceptible materials (*5.7.1.1.(2)*), except where specifically designed to accommodate such.	

6.3 Interior Insulated Foundation Wall

Below-grade walls with interior wood studs with only batt insulation (no foam insulation) may have been common in the past, but are generally not appropriate for single family dwellings or multi-unit residential buildings. In addition to the relatively low thermal performance achieved for the larger stud space consumed, the interior vapour retarder material used will likely inhibit interior drying of the wall assembly. In some cases, a smart vapour retarder, a membrane with varying low vapour permeance can be used to control outward vapour movement, but still allow for some inward drying from the wall assembly. This approach may be used to address the above issue, but is not a widely used approach to controlling moisture in below-grade wall assemblies.

While many of these insulated stud walls have been constructed and have performed satisfactorily, they are sensitive to even minor amounts of moisture ingress, as well as air movement and related condensation. These assemblies should be used only with good knowledge of site soil moisture characteristics and careful attention to details, as well as to construction compliance.

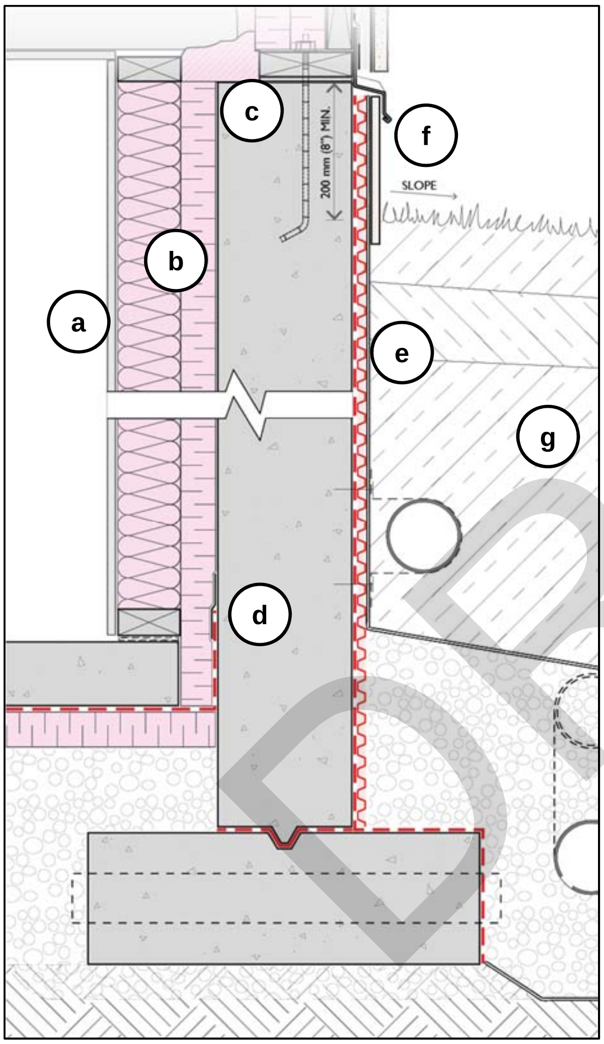


Figure 14: Interior Insulated Foundation Wall.

A foundation wall which is insulated at the interior would have the following elements, with assembly described from interior face, through to exterior backfill, as follows:

a. Gypsum board (ideally non paper-faced for enhanced resiliency)
b. 2x4 framed wall filled with batt insulation and extruded polystyrene (XPS). XPS to be sufficient to maintain the interior surface of the foam above the interior dewpoint. The ratio of batt to foam insulation will depend on the climate zone, interior occupancy and available interior space. Alternately, a closed-cell sprayfoam or a faced expanded polystyrene (EPS) with taped joints could also be utilized in lieu of XPS. Minimum 2" rigid XPS insulation with taped and sealed joints.
c. Sprayfoam applied and sealed between below-grade insulation, wood framing and where it sits on supporting concrete foundation wall (i.e., for airtightness),
d. Concrete foundation wall
e. Water-proofing or damp-proofing applied to the concrete wall with drainage mat (with filter fabric side on the exterior) used as a drainage medium and capillary break between the membrane and the backfill),
f. The water- or damp-proofing, insulation and drain mat should continue to the top of the concrete wall, with proper termination in accordance with the manufacturer's recommendations. A durable and UV-resistant cover material should be placed above grade against the otherwise exposed portion of this assembly to protect the materials from UV exposure and physical damage, and
g. Backfill.

6.4 DAMP-PROOFING OR WATERPROOFING MEMBRANES AND WATER DIVERSION ALONG FOUNDATION WALL

For many walls at "dry" sites, a damp-proofing coating / membrane applied against the concrete foundation wall will be sufficient as the innermost exterior protection against exterior water ingress. However, where partially saturated conditions or hydrostatic pressures exist, more robust assemblies, materials and details need to be used. Three general categories of below-grade exposure conditions must be considered for every project.

Optimally drained: The provision of a damp-proof coating on the exterior of the wall may be adequate in conjunction with appropriate joint and crack control details, provided there is adequate vertical drainage (e.g. gravel drainage chimney comprises portion of backfill closest to foundation wall) leading to perimeter foundation drains. However, more robust membranes may be appropriate even when no hydrostatic pressure is present if backfill does not comprise gravel, even if it is 'free-draining'.

Hydrostatic pressure: The presence of full hydrostatic pressure is associated with a submerged or fully saturated condition, where no foundation drainage is present, such as for a tanked structure. This condition dictates the need for a fully-bonded, robust, waterproof membrane (at walls and below the slab-on-grade). Where hydrostatic pressure is a design consideration, so are buoyant uplift forces and it will be necessary to retain the services of a structural as well as a building envelope engineer.

Partially saturated conditions: Often where backfill against foundation walls is not free-draining, partially saturated conditions may exist adjacent to foundation walls. In these scenarios, it would be suitable to use a higher quality membrane assembly.

Drain mat generically describes either dimpled, high-density plastic or woven or non-woven geotextile membranes that are commonly used as a 3D drainage medium against the vertical foundation walls.

Better products incorporate filter fabrics or redundant layers to ensure they don't become clogged and maintain their drainage ability long-term. These products are becoming more commonly used than the traditional approach of free-draining crushed gravel and filter fabric. Installation and termination details are provided by the manufacturer. Some products may have third party Building Code evaluations to assess performance including testing to promote these products as an alternative to Building Code minimum. However, until these product types are specified in the Building Code, without professional guidance, they should only be used to augment, not replace, Building Code minimum requirements. For example, use of a damp-proofing sheet membrane or dimple mat should not replace liquid-applied damp-proofing unless the overall building enclosure assembly has been considered by a building envelope professional.

Photo 4: Typical drainage membrane installation.

Where Insulating Concrete Forms (ICFs) are used for the foundation walls, ensure that the sheet or liquid applied damp-proofing / water-proofing membranes used are compatible with the materials used in the ICF, as confirmed by the ICF manufacturer. Solvent based bituminous membranes and primers are NOT compatible with the ICF foam plastic insulation.

The table on the following pages summarizes common building damp-proofing and water-proofing strategies, including where they should be used, general requirements for installation, benefits and limitations, and other details.

KEY TABLE

	Dampproofing – Optimally Drained		Non-Tankable Waterproofing – Partially Saturated Backfill		
Where Required	Where exterior finished ground level is at a higher elevation than the ground level inside of the foundation walls (Building Code 9.13.2.1.(1))				
Suitable Environment	Relatively dry soil conditions with well-drained backfill or moist soil conditions with clear gravel backfill		Moderate moisture environments		
Acceptable Foundation Types	Spread & strip footings; piles and grade beams; raft slab with or without piles.		Spread & strip footings; piles and grade beams; raft slab with or without piles.		
Product	**Asphalt Cutback**	**Asphalt Emulsion Dampproofing (Thin Application)**	**Liquid Applied**	**Self-Adhered Modified Bitumen Sheets**	**Asphalt Emulsion Waterproofing (Thick Application)**
Concrete Forming Application	Cast Backfill	Cast/ICF[1]/ Shotcrete Backfill/Blindside	Cast/ICF[1]/Shotcrete Backfill/Blindside	Cast/ICF[1] Backfill	Cast/ICF[1]/Shotcrete Backfill/Blindside
Concrete Cure Time	0 Days	0 Days	Varies product to product	10-28 Days	0 Days
Membrane Reinforcement	Unreinforced	Unreinforced	Varies product to product	Integral reinforcement facer	Fully embedded reinforcing fabric recommended
Description	Solvent based bituminous liquid membrane typically spray or roller applied	Bituminous liquid membrane suspended in water typically spray or roller applied	Liquid or spray applied bitumen membrane modified with polymers for elasticity and puncture resistance	Factory manufactured self-adhered bituminous sheet waterproofing modified with polymers for elasticity and puncture resistance	Asphalt emulsion applied thicker than the dampproofing application with reinforcement to meet waterproofing requirements
Thickness	10-30mils	30-50mils	+50mils recommended	60mils	60-80mils
Benefits	• Can be installed below freezing	• Light crack bridging potential	• Cold weather application available • Light crack bridging potential when reinforced • Can transition onto penetrations	• Can bridge large cracks • Easier to install than head welded membrane • Factory manufactured sheets provide consistent membrane thickness	• Medium crack and bug hole bridging potential • Can transition onto penetrations
Limitations	• Solvent based, releases VOCs • Bug holes and cracks should be sealed before installation • Required thickness sensitive to quality control during installation	• Must install above 5°C • Bug holes and cracks should be sealed before installation • Required thickness sensitive to quality control during installation	• Performance varies significantly from product to product due to different chemical compositions • Required thickness sensitive to quality control during installation • Bug holes and cracks should be sealed before installation	• Attention to penetration detailing required • Must be applied on dry concrete • Bug holes and large cracks should be filled with grout or sealant before installation to support membrane	• Must install above 5°C • Reinforcing fabric installation prone to applicator error Prone to inconsistent application • Required thickness sensitive to quality control during installation

	Tankable Waterproofing – Submerged / Fully Saturated			
Where Required	Where hydrostatic pressure (including buoyancy) occurs, waterproofing is required for the exterior surfaces of floors-on-ground, and below ground foundation walls (Building Code *9.13.3.1.(1)*)			
Suitable Environment	High moisture environments or temporary low intensity hydrostatic pressure anticipated		High moisture environments or sustained hydrostatic pressure anticipated	
Acceptable Foundation Types	Spread & strip footings; piles and grade beams; raft slab with or without piles.			
Product	**Asphalt Emulsion Waterproofing with HDPE Liner**	**Torch Applied Modified Bitumen Sheets**	**Bentonite Sheets**	**Pressure-Adhered Thick HDPE Membrane**
Concrete Forming Application	Cast/ICF[1]/Shotcrete Backfill/Blindside	Cast/Shotcrete Backfill/Blindside	Cast/Shotcrete Blindside	Cast/Shotcrete Blindside
Concrete Cure Time	0 days	10-28 days	0 days	0 days
Membrane Reinforcement	Fully embedded reinforcing fabric recommended	Integral reinforcing within bitumen	Integral geotextile liner, HDPE liner recommended	Continuous HDPE sheet membrane
Description	Asphalt emulsions waterproofing installed with continuous HDPE liner for additional water resistance	Factory manufactured heat welded bituminous sheet waterproofing modified with polymers for elasticity and puncture resistance	Clay composite sheet waterproofing which absorbs water and swells to form an impermeable layer	Fully adhered composite sheet membrane comprised of a thick HDPE liner and a pressure sensitive adhesive
Thickness	80mils + liner	115mils	250mils	30-50mils
Benefits	• High crack and bug hole bridging potential • HDPE liner is waterproofing layer • Can transition onto penetrations	• Fully adhered, can bridge large cracks • Heat welded laps • Factory manufactured sheets provide consistent membrane thickness	• Factory manufactured sheets provide quality assurance	• Laps become continuous with pressure • Fully adhered, can bridge cracks • Factory manufactured sheets provide consistent membrane thickness
Limitations	• Must install above 5°C • Heat welded HDPE laps required, otherwise weak points. • For backfill application, reinforcing fabric installation prone to applicator error • Required thickness sensitive to quality control during installation	• Attention to penetration detailing required • Commonly has adhesion issues due to complexity of torch applied vertical application • Bug holes and large cracks should be filled with grout or sealant before installation to support membrane	• Attention to penetration and lap detailing required • Skilled trade installation required • Shoring wall must be flat to prevent voiding and to contain membrane for shotcrete application	• Attention to penetration and lap detailing required

[1] Solvent-based membranes are not acceptable for ICF installation. Water-based primers should be used where priming is required. Confirm product compatibility with ICF manufacturer prior to installation.

7.0 BACKFILL

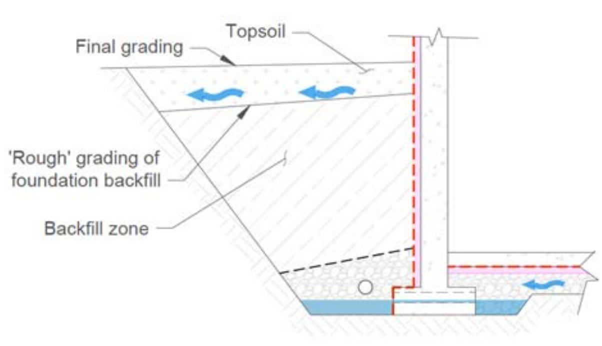


Figure 15: Both surface and 'rough' grading slope away from building.

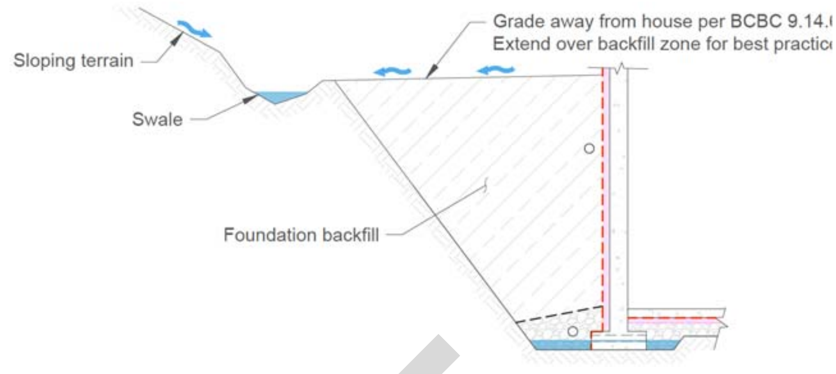


Figure 16: Example of best practice grading on sloping terrain.

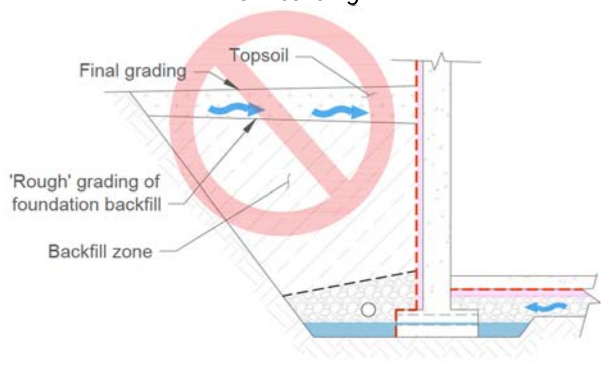


Figure 17: 'Rough' grading directs water towards building.

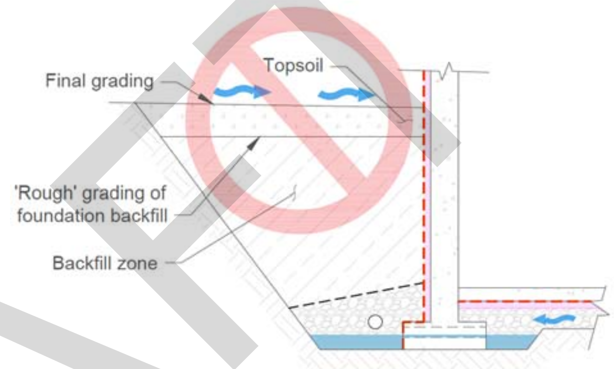


Figure 18: Surface grading directs water towards building.

7.1 FOUNDATION WALLS

"BETTER" PRACTICE: Use "clean" (less than 8% silt content), well-graded sand to backfill against foundation walls. River sand is not considered to be well-graded.

"BEST" PRACTICE: Use clear gravel with a gradation between 1/2 and 1 inch to backfill against foundation walls.

Foundation walls should be backfilled with free-draining materials containing less than 8% fines (e.g., clay or silt) as these particles tend to compromise drainage systems. Additionally, it is noted that soil with greater than 8% fines is considered to be frost susceptible and may heave when temperatures are below freezing.

In areas where drainage is particularly important (e.g., groundwater elevation or hydraulic conductivities are high), clear gravel is best used to backfill foundation walls. Clear gravel may be rounded or angular and should have relatively uniformly-sized particles ranging from 1/2-inch to 1-inch size with a low content of fine materials. Clear gravel is considered to be free-draining and is a proven, excellent, and preferred material for drainage use purposes.

7.2 UTILITY TRENCHES AND OTHER UNDERGROUND CONDUITS

Where utility trenches or other backfilled excavations exist throughout a site, these features can act as underground conduits for the travel of water. Where these conduits are near a proposed building, care should be taken to minimize the risk that these conduits direct water into the backfill zone for a building. This can be done by:

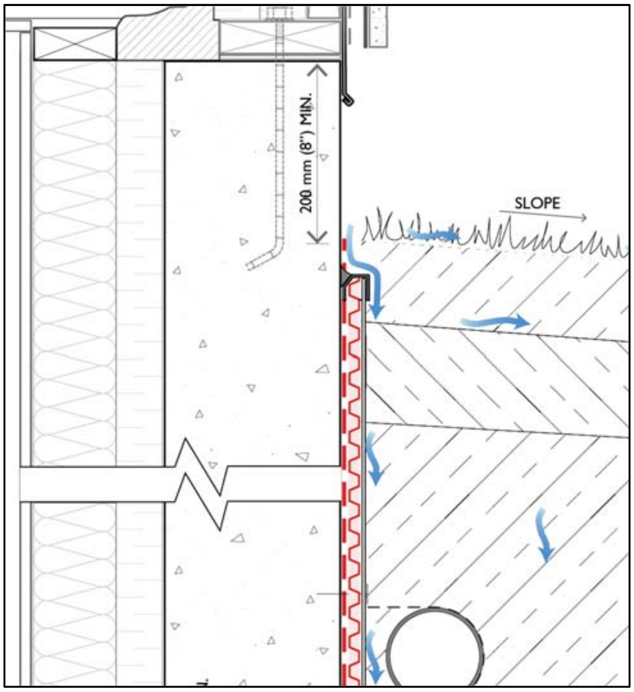
1. Grading the base of the trench excavation or other feature to slope away from the building.
2. Backfilling with well-graded (i.e. includes a range of particle sizes) material including some silt.
3. Compacting using suitable compaction equipment and in appropriate lift thicknesses.

Best Practice / Comment

Ensure both 'rough' grading and final grading is sloped down/away minimum 2% from a building past the backfill zone of the building.

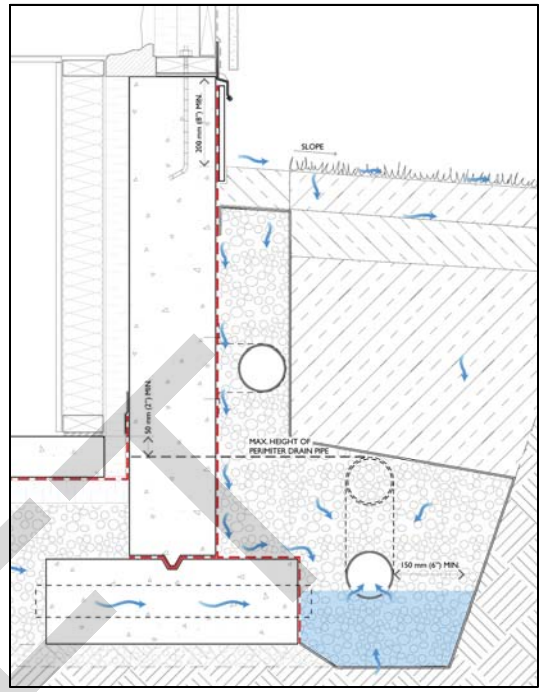
While the drainage layers are porous and free-draining, an impermeable soil layer (e.g. clay cap) or concrete is often used as a good practice on top of the backfill to limit surface water infiltration into the drainage system.

8.0 Exterior Membrane Termination



Alternate Detail A

When the top of a drain mat is in top soil, it is important to terminate the mat with a proper termination bar, sealed to the foundation wall.



Alternate Detail B

Drainage chimney using crushed gravel instead of drain mat.

MOST IMPORTANT:

- The building enclosure components are the last line of defence against groundwater entry. Every effort, discussed throughout this guide, should be made to minimize the amount of water that is able to make contact with damp-proofing / water-proofing of the foundation wall.

Proper detailing of membrane termination assembly, including UV protection, and transition to wood framing at the top of foundation walls, is required to ensure that surface water cannot enter behind the below-grade control layers.

When a drainage mat is utilized for below-grade drainage it should continue up this exposed portion of the concrete wall and be protected from UV and physical damage by a concrete board, flashing or another suitable product.

Alternately if the drain mat is terminated below the finished grading for aesthetic reasons it should be finished with a termination bar and sealed to the foundation to prevent water and debris from getting behind it. Alternate details are shown above for this configuration or where a crushed gravel drainage chimney is used instead of drain mat.

Building Code Requirement	Best Practice / Comment
A damp-proofing membrane is required on floors-on-ground and the exterior surface of foundation walls per Building Code clause *9.13.2.1.(1)*, where the exterior finished ground surface is at a higher elevation that the ground level inside the foundation walls. Damp-proofing is not required on: • The floors of garages • The floors in unenclosed portions of buildings, or A waterproofing membrane is required on the exterior surface of floors-on-ground and foundation walls per Building Code clause *9.13.3.1.(1)*, where hydrostatic pressure occurs.	Where floors are damp-proofed, the damp-proofing shall be installed below the floor. Where a separate floor is provided over a slab, the damp-proofing is permitted to be applied to the top of the slab. Where installed below the floor, damp-proofing shall consist of 0.15mm (6mil) polyethylene or type S roll roofing. Joints in damp-proofing shall be lapped 100mm minimum. The roofs of underground structures shall be waterproofed to prevent the entry of water into the structure. Basement floors-on-ground to be waterproofed shall have a system of membrane waterproofing provided between 2 layers of concrete at least 75 mm thick. The floor membrane shall be continuous with the foundation wall membrane.

9.0 Roof Drainage and From Other Impermeable Surfaces

Photo 5: Example of a well-constructed foundation drainage system: drainage membrane applied over the damp-proofing agent, PVC foundation drain pipes have been bedded in clear gravel wrapped in filter cloth, rainwater leader downspouts directed shallow solid pipes.

Photo 6: Example of a very poor drainage system: rainwater downspout drains to a splash pad which directs water towards building foundation wall and adjacent to poor building enclosure membrane termination

MOST IMPORTANT:

- Best practice is to have foundation drainage and roof runoff managed by separate systems.
- Pipes which will be used to direct roof drainage should be installed as "high" as possible around a building (but below the depth required for frost protection) to allow for discharge via gravity wherever possible.
- Rainwater leader pipe systems should be directed into a sump to collect accumulated sediment prior to discharging into civil infrastructure, or onsite detention / infiltration facilities.

Although not required by the Building Code, it is best practice to have runoff from impermeable surfaces (including roofs) and foundation drainage managed by separate systems (as shown in Photo 5 above). Roof runoff should be directed to a shallow, solid pipe system. There are several reasons for this, including:

- Decrease the amount of water at the foundation drainage level next to the building footing;
- Allow for gravity discharge of rainwater from the roof, as opposed to requiring it to be pumped; and
- Allow for on-site management of rainwater (e.g. via infiltration or detention).

Where solid PVC pipe is used to divert rainwater directly into the storm sewer, it should be installed as "high" as possible around a building (but below the frost line), strapped to the foundation wall, and sloped a minimum of 1% to the sewer connection.

Patio drains and trench drains may also be directed to this shallow, solid pipe network where appropriate.

Sufficient cleanouts should be provided for the shallow, solid pipe system to allow for future maintenance.

Rainwater leader pipe systems should then be directed into a sump to collect accumulated sediment prior to discharging into civil infrastructure.

Some Authorities Having Jurisdiction may prefer that roof runoff not be connected into a pipe system, and that they instead discharge at-grade onto splash pads or extended leaders. Where this is the case, extreme care and thought should go into how to manage this runoff, with consideration given to:

- Local geology with respect to ability for water to infiltrate into subsurface soils;
- Type and quality of building enclosure membranes used on foundation walls;
- Location of rainwater splash pads with respect to the building foundation wall (direct water **away** from building wall);
- Site grading (ensure water does not accumulate next to building);
- Excellent building enclosure materials and installation workmanship including termination details becomes critical; and
- The use of a low permeability "cap" above foundation backfill materials.

Building Code Requirement	Best Practice / Comment
Where downspouts are provided and are not connected to a sewer, extensions shall be provided to carry rainwater away from the building in a manner which will prevent soil erosion (*9.26.18.2.(1)*). Where downspouts are provided and are not connected to a sewer, provisions shall be made to divert the water from the building, and prevent soil erosion (*5.6.2.2.(3)*)	Ensure water is carried away from the building and discharged past the backfill zone.

10.0 WATER MANAGEMENT AND DRAINAGE DISCHARGE

Photo 7: Example of a swale constructed to direct surface water away from a building.

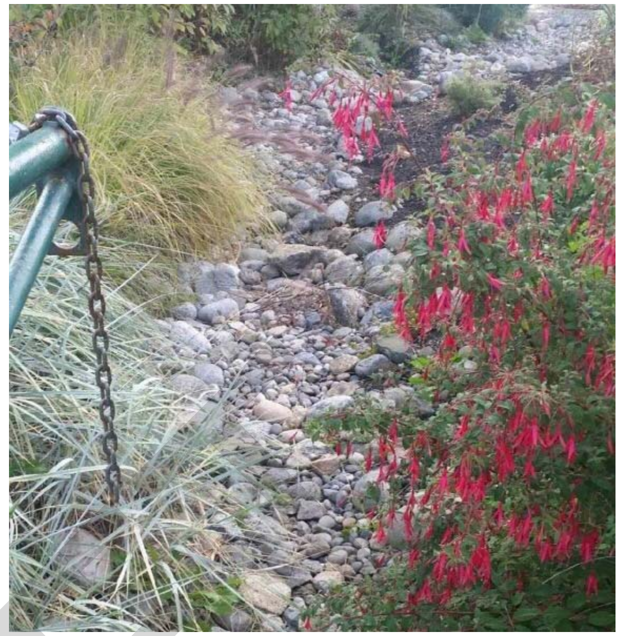


Photo 8: Example of a raingarden or dry creek bed landscape feature.

MOST IMPORTANT:

- Wherever possible, discharge should be by gravity.
- Pipes managing rainwater runoff should be installed as high as possible (but below frost penetration depth) in order to increase the feasibility of gravity discharge.
- Roof runoff should never be directed to foundation drains.

10.1 STORMWATER MANAGEMENT FEATURES

Stormwater management in the context of this guide comprises infrastructure that has been engineered to meet location-specific guidelines, bylaws, and/or regulations for managing stormwater within a property and controlling the amount of water discharged from a property.

In a time when climate change is increasingly challenging the capacity of municipal stormwater infrastructure, consideration could be given to including (and maintaining) backwater valves, alarms, and natural gas powered backup pumped systems for select sites. In evaluating associated risks, it is important to note that, as a rule, municipal civil infrastructure is designed to manage surface water flows associated with certain storm events (with the design events becoming increasingly common), but that there is not excess capacity to conduct excess flows due to groundwater which is pumped to these systems.

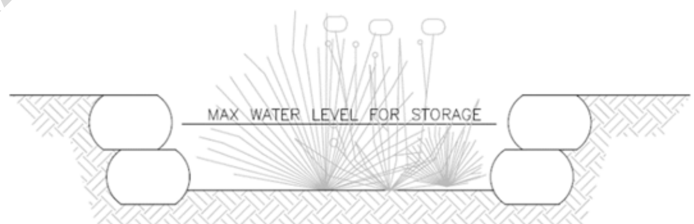


Figure 19: Example section of a raingarden

10.2 DRAINAGE DISCHARGE – GRAVITY

Photo 9: Example of an infiltration tank.

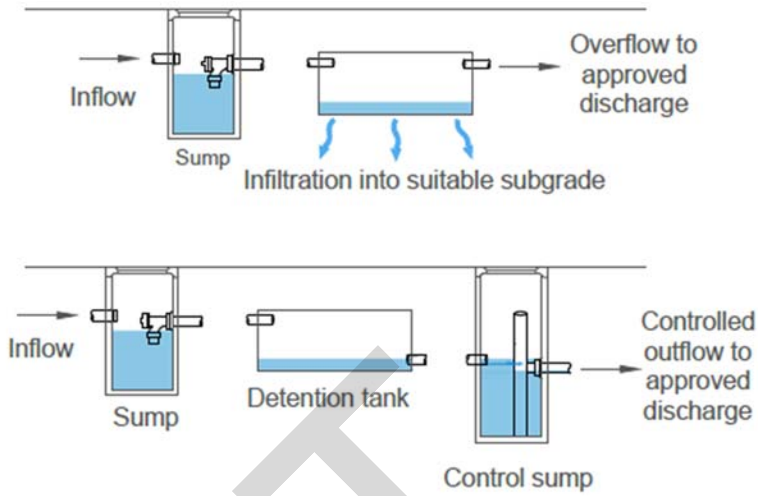


Figure 20: Typical infiltration (top) versus detention (bottom) systems.

MOST IMPORTANT:

- Make sure discharge location cannot become flooded or easily blocked (e.g., by ice in a ditch) and cause discharge water to back-up and cause flooding of basement.
- Make sure underside of floor system is above design flood elevation of closest (i.e., receiving) water body.

Many municipalities in BC now require on-site infrastructure to manage the stormwater runoff from a property during storm events. Two common systems in use today include infiltration systems (i.e. referred to as dry wells, rock pits, and/or infiltration trenches / tanks / galleries / fields) and detention systems (e.g. lined storm tanks). These systems can also be combined or used in series, although not all systems are recommended for all sites. Professional Civil or Geotechnical Engineers are often retained to design and review construction of these systems, and provide sign-off on Item 4.2 of the Building Code Schedule B Letters of Assurance where required.

10.2.1 Infiltration

Infiltration systems such as dry wells, rock pits, and/or infiltration trenches dispose of water by infiltrating it into the ground at a given site. Infiltration systems are preferred by many Authorities Having Jurisdiction as they mimic the natural process of rainwater percolating into the soil, and thus supporting base stream flows and reducing the load on municipal sewers. However, many sites are not suitable for infiltration fields, including:

- Sites with a high water table (note that the water table at a site can fluctuate seasonally and from year to year).
- Sites with unsuitable geology, including relatively impermeable soil such as glacial till, clay, bedrock, or sensitive soils or expansive clays.
- Sites which are steeply sloping, or at the crest of a slope, due to slope stability reasons.
- Sites which are overly confined to allow for adequate setbacks from proximate basements and/or property lines.

We note that the hydraulic conductivity/ permeability used for design must be representative of the site. This can be determined through percolation testing and in consultation with a Geotechnical Engineer).

Note that the Building Code clause *9.14.5.3* requires dry wells (infiltration fields) to be located only in areas where the natural groundwater level is below the bottom of the well, not less than 5 metres from a building foundation, and located so that drainage is away from the building. Where this is impracticable, consultation with a registered professional may be required. Infiltration systems should be engineered to overflow before backing up, in the event of a storm event which exceeds the design capacity.

Finally, sites with septic systems have specific setback requirements from stormwater infrastructure, groundwater or drain pipe break-out points. These setbacks are outlined in the Sewerage System Standard Practice Manual (current: Version 3, September 2014).

10.2.2 Detention

Detention systems manage stormwater by retaining it on-site and releasing at a controlled rate into municipal systems. If located below the water table, they should be designed for buoyant or uplift forces. Detention systems should be engineered to overflow before backing up, in the event of a storm event which exceeds the design capacity. Detention systems could be dye-tested to confirm they do not leak.

10.2.3 Receiving Water Body

BC's Ministry of Environment's Flood Hazard Area Land Use Management Guidelines requires that the underside of the floor system supporting habitable space in a designated floodplain be above the Flood Construction Level (FCL) as specified by the local authority or determined by a hydraulic engineer. The FCL is NOT the "high water level" determined by a BC Land Surveyor, as there are a number of other considerations that go into its determination. Habitable below- or at-grade structures may not be permitted in a floodplain, dependent on the local FCL.

It is noteworthy that sometimes alluvial soil deposits (i.e. deposited by water) can extend beyond the boundaries of designated floodplain areas. Accordingly, habitable basements are often permitted by municipalities in these areas. However, the hydraulic conductivity of alluvial soil deposits could be expected to be high. Thus, constructing below-grade in such areas is illogical and would typically not be recommended by a geotechnical engineer without appropriate flood protection measures.

Where the risk of flooding is not locally managed by regional dike infrastructure, it may be possible to construct local flood-proofing measures. Geotechnical engineering services relating to flood-proofing a site or portion thereof may include raising site grades, designing an on-site flood protection berm or dike, designing scour protection of berms and foundation subgrades, designing groundwater cut-off structures, or providing recommendations for waterproofing and dewatering structures built below the FCL. The design of these elements may be done in conjunction with a hydraulic engineer and should consider off-site impacts. It is noteworthy that in coastal areas, FCL determination includes allowances for sea level rise due to climate change.

Drainage Element	Building Code Requirement	Best Practice / Comment
Drainage Discharge	Storm drainage systems shall be connected to a public storm sewer, a public combined sewer, or a designated stormwater disposal system (*2.1.2.2.(1)*) An overflow from a rainwater tank shall not be directly connected to a drainage system (*2.4.2.2.(1)*). Foundation drains shall drain to a sewer, drainage ditch or dry well (*9.14.5.1.(1)*).	Refer to local regulations/bylaws for regional requirements.
Dry Wells	May be used only when located in areas where the natural groundwater level is below the bottom of the dry well (*9.14.5.3.(1)*). Shall be not less than 5 m from the building foundation and located so that drainage is away from the building (*9.14.5.3.(2)*).	Recommended to be used only in areas where soil conditions are suitable for infiltration. Alternatively, detention tanks could potentially be utilized on sites where dry wells (aka rock pits or infiltration fields) are not appropriate.

10.3 DRAINAGE DISCHARGE – PUMPED

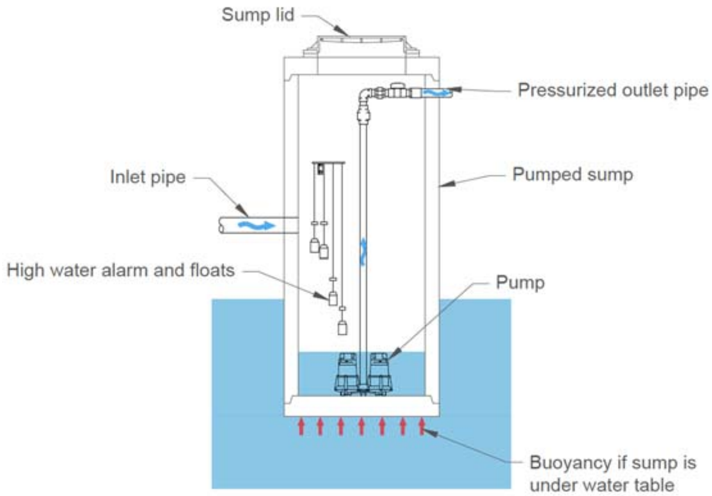


Figure 21: Typical section of pumped sump where bottom of sump is submerged.

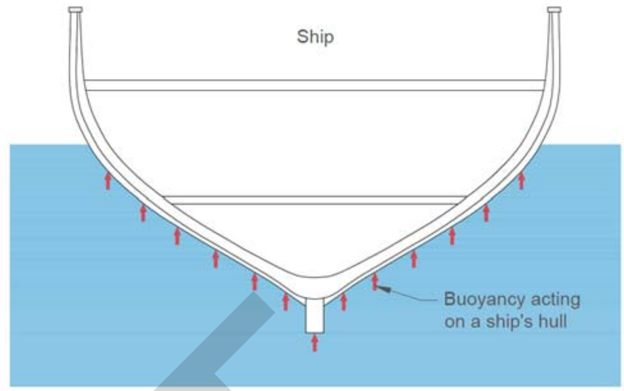


Figure 22: Example of buoyancy acting on a ship's hull; the same forces can act on sumps or basements where they are below the water table.

MOST IMPORTANT:

- Pumped systems should include two pumps, an automatically triggered back-up power supply which does not rely on power supply which may be at risk of outage, and a high water alarm.
- Pumped sumps should be sized, and pumps selected and controlled, so as to cycle both on and off for no less than 1 minute.

Each element of a pumped system should be regularly maintained and tested. The pumped system as a whole should be regularly tested and maintained / replaced as necessary.

The design of a pumped system may be appropriate for a given site in order to manage foundation drainage and reduce the risk of water ingress. This design would include sizing the pump for site-specific groundwater volumes (perched and/or ambient), including for seasonal fluctuations and considering the hydraulic conductivities of surrounding soil. In this case, "groundwater" should include for the rainwater contribution to the perimeter drainage system (i.e. rainwater that infiltrates the backfill zone and adjacent areas. Some Geotechnical and some civil engineers can provide recommendations in this regard.

Sump volumes should be big enough to allow for some storage of water and proper operation of float switches as required to reduce the risk of a pump "burning out". It is best practice to provide a hard-wired, natural gas backup generator to supply emergency power to pumps during a regional power outage, as power outages often occur during large storm events when pumps are most needed. Only certified plumbing and electrical contractors and gas fitters should be utilized during construction.

Pumped systems require regular maintenance and testing to ensure that pumps, floats, backflow valves, electrical systems, and backup generators are operational. However, it is important to note that even if these best practices are followed, pumped systems do have a finite design service life and are prone to failure.

Some municipalities do not allow pumping of groundwater into municipal storm systems, meaning that alternative discharge methods for this water would need to be found (if possible) or the structure must be tanked. [It is noted that tanked structures should be designed to resist buoyancy forces, which could require costly investigations, design fees, and construction costs, including for construction of tie-down elements as may be required to resist buoyancy forces.]

Where it is possible to negate the need for a pumped system, whether through site selection or design of a building, this would be preferred. This will save construction costs as well as operating costs in addition to reducing long term risks of flooding (and possibly insurance premiums). In some residential buildings, the requirement for a pumped system could be completely eliminated if the basement floor slab was to be raised only a few inches, and the potential for future water damage therefore substantially reduced. Where a gravity drained system is feasible, it is recommended that building elevations be carefully selected so as not to eliminate this possibility.

11.0 INTERIOR BUILDING ENCLOSURE – HEAT, AIR AND CONDENSATION CONTROL

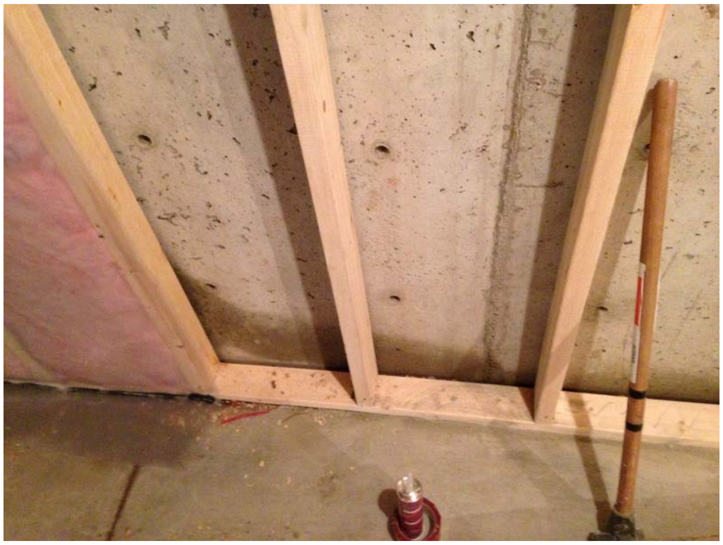


Photo 10: Moisture on the interior of a concrete foundation wall.

11.1 CONDENSATION CONTROL AND DRYING ABILITY

Of importance to the design of below-grade wall assemblies is the ability for the assembly to dry out. Below-grade concrete walls need to dry primarily to the interior because the presence of moisture and damp-proofing or water-proofing on the exterior side of the wall will limit outward drying. The inner layers of the below-grade wall assembly, especially basement interior finishes, should therefore be vapour permeable and allow for drying to the interior. This is particularly an issue early in the life of the building when the concrete itself is still curing. Additionally, it is beneficial in terms of allowing minor condensation events or small leaks in-service to be located and mitigated,

When constructing buildings in low-lying areas or in regions prone to flooding, or where the owner desires a more proactive approach to resiliency, the designer should consider the use of non-moisture sensitive materials in the below-grade portions of a building. This could include non-paper faced gypsum, treated wood or steel framing, and non-moisture sensitive flooring and finishes.

12.0 MAINTENANCE

All elements of a drainage system should be maintained by the owner on an annual basis. Expected maintenance includes, but is not limited to, cleaning up forest litter, debris, accumulated sediments or other deleterious materials which could potentially clog the proposed system at the locations of:

- roof gutters and rainwater downspouts,
- trench drains
- catch basins and lawn basins
- pipes, and
- sumps.

Pipe systems should also be cleaned annually or as necessary through snaking and/or hydro jetting.

For this reason, it is important that sumps, cleanouts, and other drainage features remain accessible for the life of the building. Often, sumps and cleanouts become buried and/or 'lost' over the years if they are not maintained. This makes it very difficult to find and access the drainage system when unplanned remedial measures must be undertaken.

Photo 11: Building sump at a building found buried in the garden area and noted to be full of sediment and vegetation.

Photo 12: Cleanout is blocked by the building and not accessible.

12.1 IRON OCHRE

In areas where iron ochre is known to be a problem, it is particularly important to follow best practices, including consulting the local building or plumbing inspector and suitably qualified professionals. Often iron ochre can be identified in areas where an iridescent 'sheen' is present on surface water, similar to that observable when gasoline or oil is present.

Iron ochre is natural in origin. It is a product of bacterial activity that occurs where groundwater has travelled through organic-rich soil and enters an aerobic environment, where the associated bacteria are present.

The digestive product called 'iron ochre' is gelatinous and can precipitate (i.e. build up) in pipes and the voids of drain gravel. Thus, a shortened service life of drainage systems in these areas may be expected, even with an enhanced maintenance program. Additionally, the presence of iron ochre may nullify the warranties of certain pump systems.

Iron ochre of 'local' origin typically disappears after 3 to 5 years. Iron ochre of 'foreign' origin continues to be a clogging agent for the service life of affected drainage systems.

Photo 13: Example of iron ochre clogging a pipe.

13.0 DRAINAGE REMEDIATION

Photos 14 & 15: Example of camera'ing of a drainage system: relatively clean pipes.

Photo 16: A foundation drainage pipe overgrown with roots.

> **MOST IMPORTANT:**
>
> - The best method to address the requirement for drainage remediation is to employ best practices during original construction and carry out regular maintenance.
> - Drainage remediation is generally frustrating, iterative, and often expensive.

The amount of water leakage into a below-grade structure that is deemed to be acceptable depends on several factors, including the moisture sensitivity of the finishes and items stored within the interior space, as well as the comfort level of the owner with regard to moisture ingress. For example, an owner would likely be intolerant of moisture ingress to a finished basement in a building due to the risks of damaging interior finishes and belongings as well as due to health issues associated with mould growth. However, an owner may be more tolerant of moisture ingress into a garage or an underground parkade (without storage spaces), especially if the small volumes of seepage could be collected by floor drains (although the risk of water corroding/ damaging structural steel in the foundation walls should be reviewed). In any case, the risk of water ingress should be minimized by design first, and by material assemblies and construction methods thereafter.

If a drainage problem is suspected, sources of water should be investigated, and the function of existing drainage systems reviewed. Sources of water could include, but are not limited to, the following:

- High groundwater table and high hydraulic conductivity (permeability) of adjacent natural soil, resulting in seepage into the backfill zone.
- Upward groundwater flow into the underslab drainage layer, including by capillary action if sand, rather than gravel, was used as an underslab support material.
- Flow of perched groundwater into the backfill zone.
- Flow of surface water into the backfill zone, including due to changes in upslope, off-site conditions.
- Plugged drain pipes, including due to iron ochre.
- Under-capacity drain pipes.
- Under-capacity, poorly maintained, or inappropriately triggered pumps (including pumps that burn out because sump volumes are too small).
- Leaking plumbing fixtures in floors above.
- Compromised above-grade building enclosure.
- A storm, tide, or flood event or combination of events that exceeds the maximum design event.
- Collection of water vapour due to building enclosure systems that are inappropriate.
- Shallowly-sloping drainage systems with downstream inverts that are compromised by sedimentation, vegetation, ice, etc.
- Off-site situations such as a poorly-served municipal sewer systems (downstream ditches that are full of ice or have become 'habitat' and are no longer maintained, pipes that are under capacity or that have become under capacity with nearby development, etc.).
- Ultimate discharge elevations being below flood elevations.

These could be exacerbated by cracks in foundation walls or a lack of suitable gravel as bedding under foundation perimeter drainage pipes and/or as an underslab drainage layer. Having a specialty sub-contractor 'camera' and scope existing drain pipes (shown in the photos above) is a useful tool to allow visual evaluation of the function of existing drainage systems. Good record-keeping, including accurate documentation of this work and its findings, is important to maximize the usefulness of this work and it is generally worth the expenditure to have an engineer refer to drawings of the original construction during their full-time field review at the time of camera'ing. Flow tests are not as conclusive, although insight can be gained by introducing tracer dye into discrete downspouts.

The most cost-effective solution for a site with drainage problems will depend on the configuration of the existing drainage system and access. In general, drainage remediation is an iterative process, with least costly potential solutions usually implemented first, and other potential solutions implemented subsequently, based on observations of performance. It makes sense to try the easiest potential solution first. Sometimes a solution can be found which is as simple as re-sloping gutters to drain toward a downspout (rainwater leader) that is downstream of a problem rea or re-directing rainwater leaders that currently discharge into foundation drains to discharge to ground surface. In general, the solutions which perform the best are those which are implemented from the exterior of the building. It is common for several iterative solutions to be necessary to achieve complete satisfaction. Some Professional Geotechnical and Building Enclosure Engineers can provide assistance for sites requiring drainage remediation.

Additionally, drainage remediation often involves excavation in areas where access is restricted. Where it may not be possible to properly slope and/or step excavations in conformance with WorkSafeBC's requirements, shoring in conformance with WorksafeBC can be installed. Alternatively, a Professional Geotechnical Engineer could be consulted with respect to the safety of temporary excavations as required to provide access for remediation of foundation drainage systems.

DISCLAIMER

This document is intended to present some of what are judged to be current best practice guidelines according to industry professionals, as well as to emphasize some basic Building Code requirements for foundation drainage systems and related topics. The recommendations presented herein may not be suitable for every project or building site; therefore, every site must be considered on an individual basis. These best practice guidelines were judged to be current at the time of publishing this document; however, best practice guidelines in geotechnical and building enclosure engineering are ever-evolving and may not be considered best practice in the future. Inclusion of a qualified professional geotechnical engineer on the project team who is current with regard to professional development and industry standards could be expected to lend to a project's success.

ACKNOWLEDGEMENTS

LINKS

REFERENCES

GLOSSARY

Reference: Materials

MOST IMPORTANT:

- Use rigid PVC or ABS for drainage purposes.
- Use clear gravel with a gradation between 3/4 and one inch.
- Make all corners with double-45 degree fittings as opposed to 90 degree elbows.

Pipes

PVC

PVC has been in use for drainage purposes since circa 1980 and is generally white, rigid pipe with glued fittings. It is recommended for drainage purposes as it is the most easily flushed and snaked pipe material commonly in use and is the least prone to breakage. ABS is also occasionally used for drainage purposes, and appears similar to PVC and black in colour.

ABS

Big-O

Big-O pipe is known to crush, "belly," and be more prone to filling with sediment over time. Additionally, it is not easily maintained. These materials are described further in the Glossary.

Clay Tile

Asbestos Cement

Filter Fabric

Filter fabric aperture is function of gradation

Drainage Element	Building Code Requirement (Reference)	Best Practice / Comment
Pipe Size and Materials	Drain tile or pipe used for foundation drainage shall not be less than 100 mm in diameter (9.14.3.2). Materials and equipment used in a drainage system where excessively corrosive wastes are present should be suitable for the purpose (2.2.1.1.2).	Use PVC rigid, perforated, PVC pipe, installed with perforations facing downwards and sloped at a minimum grade of 1% for foundation drainage. For most subsurface soil and groundwater regimes, pipes comprising minimum 100 mm (4 inches) diameter are sufficient.
Installation Methods and Pipe Fittings	A T shall not be used in a drainage system, except to connect a vent pipe. A cross fitting shall not be used. (2.2.4.1)	Make all connections and corners with double 45-degree corners rather than 90-degree corners, to allow ease of future clean out.
Sumps	18” sediment depths Inlet above outlet (except pumped) – min. 2” Diameter vs. depth	Include sumps where building perimeter pipes (rainwater and foundation drainage systems) are directed away from a building to collect any sediment or vegetation which may collect in the system prior to directing stormwater to discharge infrastructure.
Gravel	Specifies coarse clean granular material containing not more than 10% of material that will pass a 4 mm sieve shall be placed beneath floors-on-ground, except in specific circumstances (9.14.2.1).	A gradation corresponding to 100% passing the 2.5 centimetres (1 inch) sieve and 100% retained on the 1.3 centimetre (1/2 inch) sieve is expected to provide greater void volume and a longer design life in many applications where ‘clear’ gravel is a design element
Other		Ensure that drainage installers are certified trades in the area they are working in. In areas where there is significant groundwater seepage or infiltration of surface water into the backfill zone, it would be best practice to continue the drainage gravel around perimeter drain pipes as a ‘chimney’ adjacent to the foundation wall up to near the finished grade. A layer of filter fabric shall separate clear gravel from overlying fine-grained soil such as landscaping medium or sand placed as a levelling course for pavers.