BOOKLET 1: SITE PLANNING AND FOUNDATIONS

TECHNICAL GUIDE FOR NORTHERN HOUSING

House with a steel space-frame foundation

→ TAILORED FOR REMOTE NORTHERN ONTARIO COMMUNITIES

First Nations National Building Officers Association

Association nationale des agents du bâtiment des premières nations

DISCLAIMER

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The story of site planning and foundations for houses in the north

Historically, the site planning and foundation approaches used in northern and remote residential housing have been the source of failures, where the house was damaged and/or the service life of the house shortened. If the foundation of the home is inadequate, then the rest of the home will also suffer and ultimately will not last.

An important factor in selecting the optimal foundation system is having knowledge of the subsurface conditions: What is the house being built upon?

Knowing things such as the type of soils or rock, the maximum depth of frost penetration or presence of and type of permafrost, and the depth of the watertable, will help determine which foundation system is best suited to the location. It is also especially important to know where the floodplain is located.

If there is no budget to complete a borehole site assessment, geotechnical information may be available for the general area from the band council, Natural Resources Canada (NRCan), Indigenous Services Canada (ISC), and others. Surrounding area information can help to give general ground conditions, but conditions can vary over small areas so it is always preferred to get a localized geotechnical analysis.

House with a steel space-frame foundation

The story of site planning and foundations for houses in the north

This booklet addresses foundations for communities with permafrost, as well as northern communities with very deep winter frost penetration, where excavating below the maximum frost depth is not feasible.

A house with a wood cribbing foundation

Wood-framed basements in the north

Wood-framed basements are the most common foundation approach in most communities in northern Ontario.

Many people have a preference for a basement and the added interior space it can provide at a relatively low construction cost, especially compared to other raised foundation approaches that don't provide a basement. Wood-framed basements can work in the north if the ground conditions are suitable and the basement's construction is well planned in advance. However, a wood-framed basement should be approached with caution, as it is the highest-risk foundation approach in this booklet.

It is best not to assume that a wood-framed basement is right for your new house site/lot just because it is common. This guide recommends that the other foundation approaches presented in this booklet at least be considered before proceeding with a wood-framed basement foundation.

House being constructed with a wood-framed basement

Interior view of wood-framed basement under construction

The following factors can make a wood-frame basement a no-go for certain sites:

- If the site has permafrost
- If bedrock or very large rocks are near the surface
- If the site is at a low spot to the surrounding area, it will likely experience pooling water during a rapid snowmelt or heavy rain
- If a lake or river is close enough that it could flood the site in the future
- If the groundwater table seasonally rises within several feet of the ground surface
- If the ground has lots of fine clays, silts, or organic content prone to settlement and/or poor drainage
- If high levels of radon gas are known to be an issue in the homes of a community

BELOW-GRADE APPROACH: Basement Foundation

Wood-framed version shown*

House with a wood-framed basement

* Although basements constructed with reinforced concrete exist in some areas of the north where concrete is more readily available (e.g. near large hydroelectric dams built with lots of concrete and with year-round road access—such as in parts of northern Quebec—refer to the regional overview booklets), wood foundations may be a more reasonable approach.

BELOW-GRADE APPROACH: Basement Foundation

A typical home in the southern part of Canada is built on a basement foundation where there is living space below grade. Today, these systems are typically constructed of cast-in-place concrete. In northern communities, concrete is often not readily available. For this reason, permanent wood foundations (PWF) are more common.

A basement foundation is not advised in all site conditions and locations. If not properly constructed, basement foundations are susceptible to flooding and settlement/heaving issues.

Typical basement constructed with cast-in-place concrete

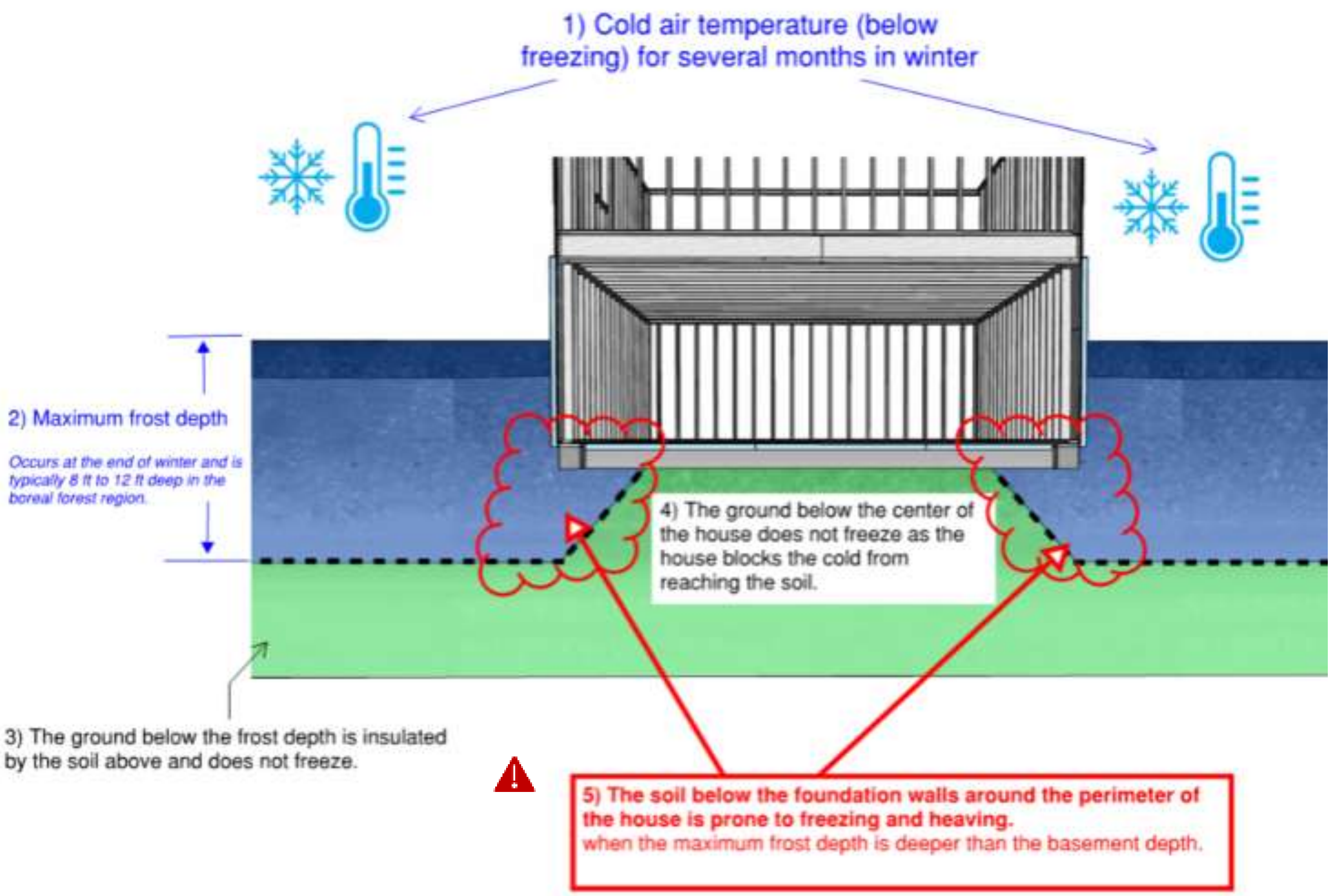
A basement constructed with wood framing

BELOW-GRADE APPROACH: Basement Foundation

In the north, the maximum frost depth is generally deeper than the depth of a basement. This means that the ground below the foundation wall around the perimeter of the house is prone to freezing. Note that the frost depth extends under the foundation wall in the image below.

Soils are prone to heaving when they freeze, which often causes damage to the house (such as cracked windows, drywall cracks, structural damage, and air/water leaks).

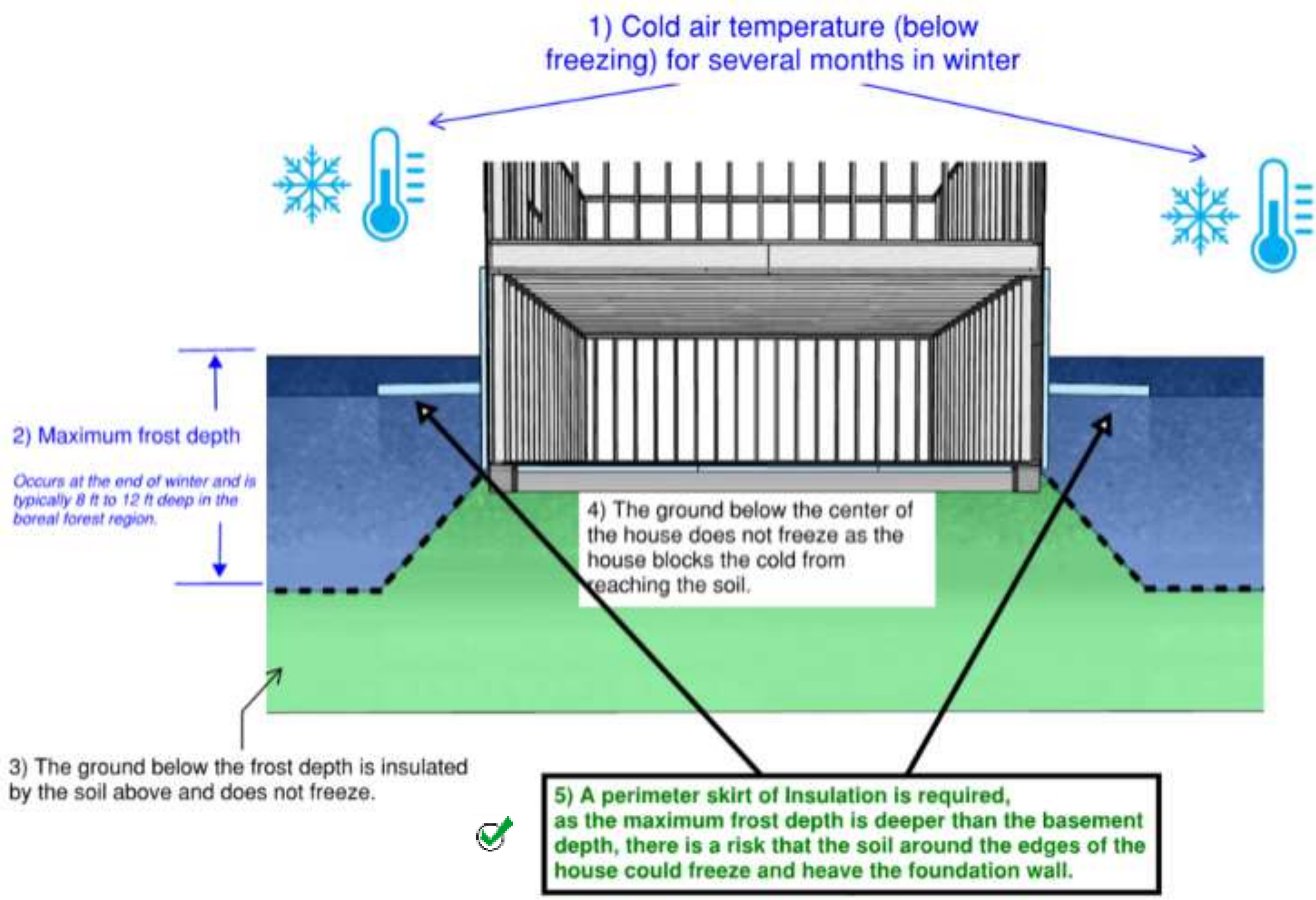
The image below shows the regions of the basement foundation, bubbled in red, prone to freezing and heaving.



A basement without an insulation skirt that is prone to heaving issues

BELOW-GRADE APPROACH: Basement Foundation

A skirt of insulation around the perimeter of the house is required to help prevent the soil beneath the foundation wall from freezing and then heaving. Note that the frost depth is prevented from extending under the foundation wall.



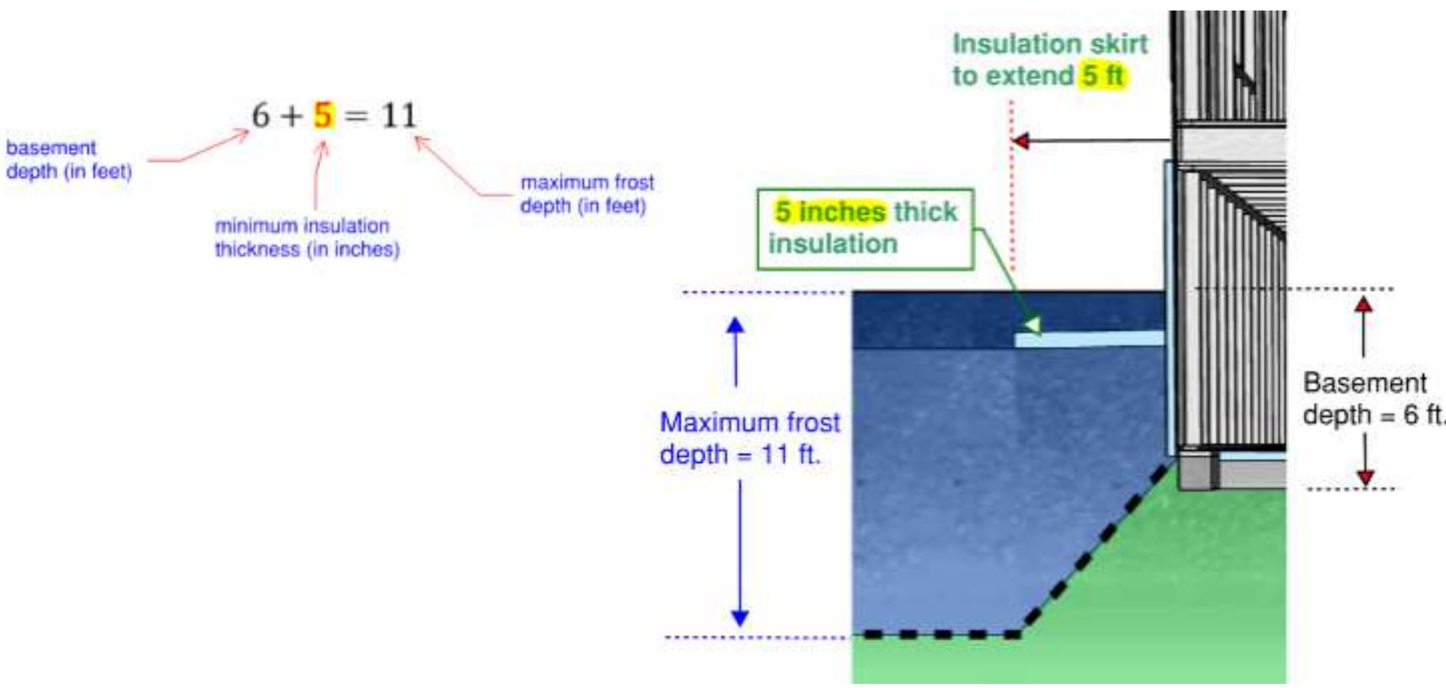
A basement with an insulation skirt to help prevent heaving issues

BELOW-GRADE APPROACH: Basement Foundation

The following is a simplified method to determine the thickness and length of the required insulation skirt. One inch of rigid extruded polystyrene (XPS) insulation is approximately equivalent to one foot of soil depth. Based on this, the depth of the basement in feet plus the thickness of insulation in inches should be equal to or greater than the maximum depth of frost penetration. Also, the length of the skirt in feet should match the thickness of the skirt in inches. See images below.

For example, if the basement is six feet deep and the maximum frost penetration is 11 feet, the insulation skirt needs to be at least five inches thick and extend five feet out from the wall of the house:

(11—6 = 5)



Insulation skirt thickness and extent calculated from basement depth and frost depth

Another example is if the basement is four feet deep and the maximum frost penetration is 11 feet, the insulation skirt must be at least seven inches thick and extend seven feet out from the wall of the house: (11—4 = 7)

BELOW-GRADE APPROACH: Basement Foundation

In areas where a basement is desired, but concrete is not readily available, a permanent wood foundation (PWF) can be installed. This type of foundation system includes constructing a preservative-treated wood structure below grade in accordance with CSA S406, with insulation on the exterior of the walls and below the floor. The basement floor system consists of tongue and groove plywood subfloor over floor joists, polyethylene sheet, XPS foam insulation, and then free-draining gravel, as shown in the image below.

Note the insulation skirt is installed approximately one to two feet below the ground surface to protect it from damage, and should be slightly sloped away from the wall of the house (about 1/4” per ft.)

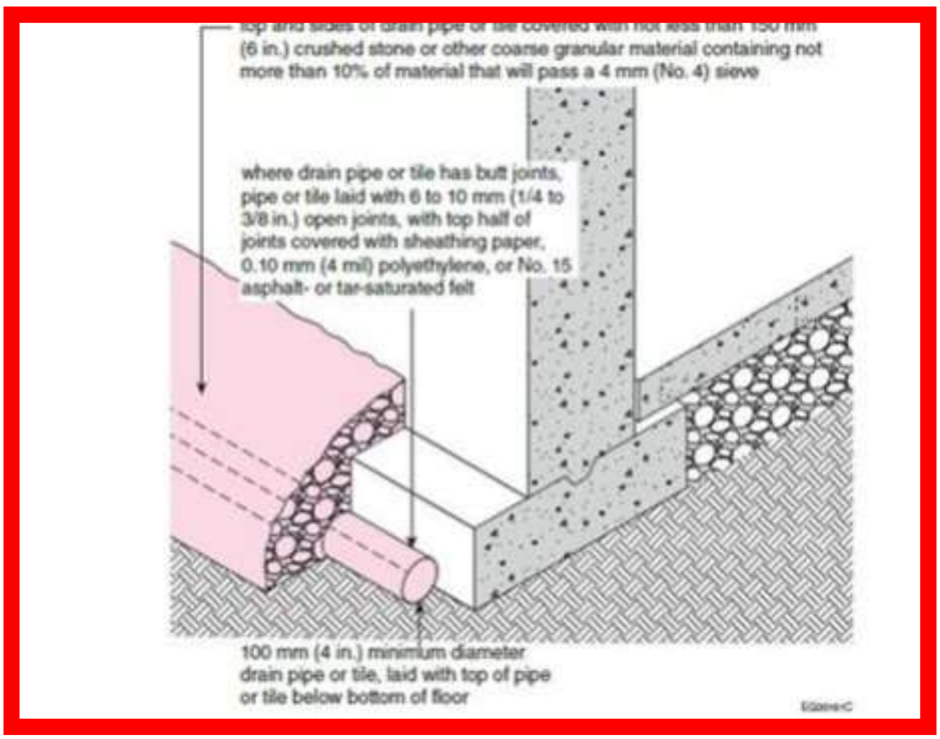
A house with a wood-framed basement

A PWF foundation is to be built according to the CSA S406 standard, where studs and plywood sheathing must be treated with copper chrome arsenate (CCA) preservative, in compliance with CSA O322. Both studs and sheathing must be stamped with the certification mark CSA O322-CCA. Where concrete is available, Part 9 of the *Ontario Building Code* can be referenced for a prescriptive method of constructing a cast-in-place concrete basement foundation.

BELOW-GRADE APPROACH: Basement Foundation

Whether a traditional concrete basement foundation or a permanent wood foundation is used, drainage around the foundation is very important. It is critical to drain water away from the building to reduce the risk of water entering the basement.

Draining water away can be accomplished by installing drain-tile pipe around the base of the foundation and replacing the surrounding soil with more porous alternatives. Sands and gravels provide good drainage. Fine-grained silty and clay containing soils are particularly problematic, since they do a poor job of draining the area around the building.



Drain pipe and drainage gravel at the base of the foundation wall

Note that water still flows downward in the soil, but backs up and floods in poor draining ground. The water needs to be able to easily flow to a *lower point in the ground away from the house.* This can occur naturally if the site is extensively surrounded by well-draining sands and gravels and the water table is much deeper than the basement. However, in many cases a drain pipe and/or a path of drainage sand/gravel will need to be extended away from the house in a trench that is deeper than the basement and has a dropping slope of at least 1/4" per foot (one-inch drop over four feet horizontal). This trench will need to reach a ditch or other point that is lower than the basement and can readily receive large amounts of water without backing up. For many sites, constructing proper foundation drainage is not feasible and this means that a raised foundation must be used.

SOLUTIONS: Recommended raised-foundation approaches in this booklet

Foundation Approach # 1: **The Traditional**

Portable screw-jacks are installed on a built-up support placed on the ground surface.

Foundation Approach #2: **Shallow Foundation**

Piers (steel or concrete) are mounted to bedrock that is relatively close to the surface (within four feet).

Foundation Approach #3: **Space Frame**

Foundation systems are constructed of a three-dimension network of adjustable supports.

Foundation Approach #4: **Deep Foundation**

Steel piles are installed deep into the ground and set on bedrock or sound permafrost.

BASIC CONSIDERATIONS

The following are basic considerations for various site conditions:

- If the ground conditions have not been reviewed by a geotechnical engineer, and there are tight budget and time restrictions, the Traditional approach (#1) is most common. The Traditional is the most risky approach, since it depends on how the ground moves, but for communities with limited housing budgets, it is the least expensive approach. With these site conditions, the Space Frame approach (#3) should generally be favoured over the Traditional, if there are sufficient funds.
- If there is solid bedrock near the surface, the Shallow Foundation approach (#2) is best.
- If the site consists primarily of soil that is relatively level, the Space Frame is best.
- If the site is sloping, and equipment and materials to level the site are not available, the Deep Foundation approach (#4) is best. This is the lowest-risk approach, but also tends to be the most expensive.

READ THIS BOOKLET IF YOU NEED TO:

1. **Select the most suitable location to build new housing on the land around your community.**

2. **Decide what type of foundation to use for a new *sturdy*[1] house in a northern community.**

3. **Learn more about the considerations that drive decisions for site planning and appropriate foundations for a new *sturdy*[1] house.**

[1]Sturdy—The ultimate goal of this guide is to improve the overall well-being and quality of life for community members, by advising on site planning and foundation approaches that will provide a sturdy platform for the house. Avoiding drainage issues, heaving, and settlement will avoid damage to walls, windows, and other parts of the home.

SITE PLANNING

Several site conditions should be considered before planning or building a foundation for a house:

Grading (ground slope and roughness): A site with a large slope could limit the feasibility of some foundation systems. For example, a Space Frame foundation is not suitable for a large slope. Instead, piles should be considered.

Bedrock/soil type: Knowing the soil type or depth of bedrock will allow the structural engineer to design the most efficient and appropriate foundation system.

River flooding and ice damming: Knowing where floodwater and ice damming occurs in the community will prevent building in these areas.

Riverbank erosion: Building close to a riverbed should be avoided to prevent future riverbank erosion problems.

Drainage of surface water: Surface water should always drain away from the house and its foundation. Water should not be allowed to pool around the house.

Wind and snow drifting: Understanding how snow is blown and drifts in your community can help design houses that work better through the winter.

PERMAFROST

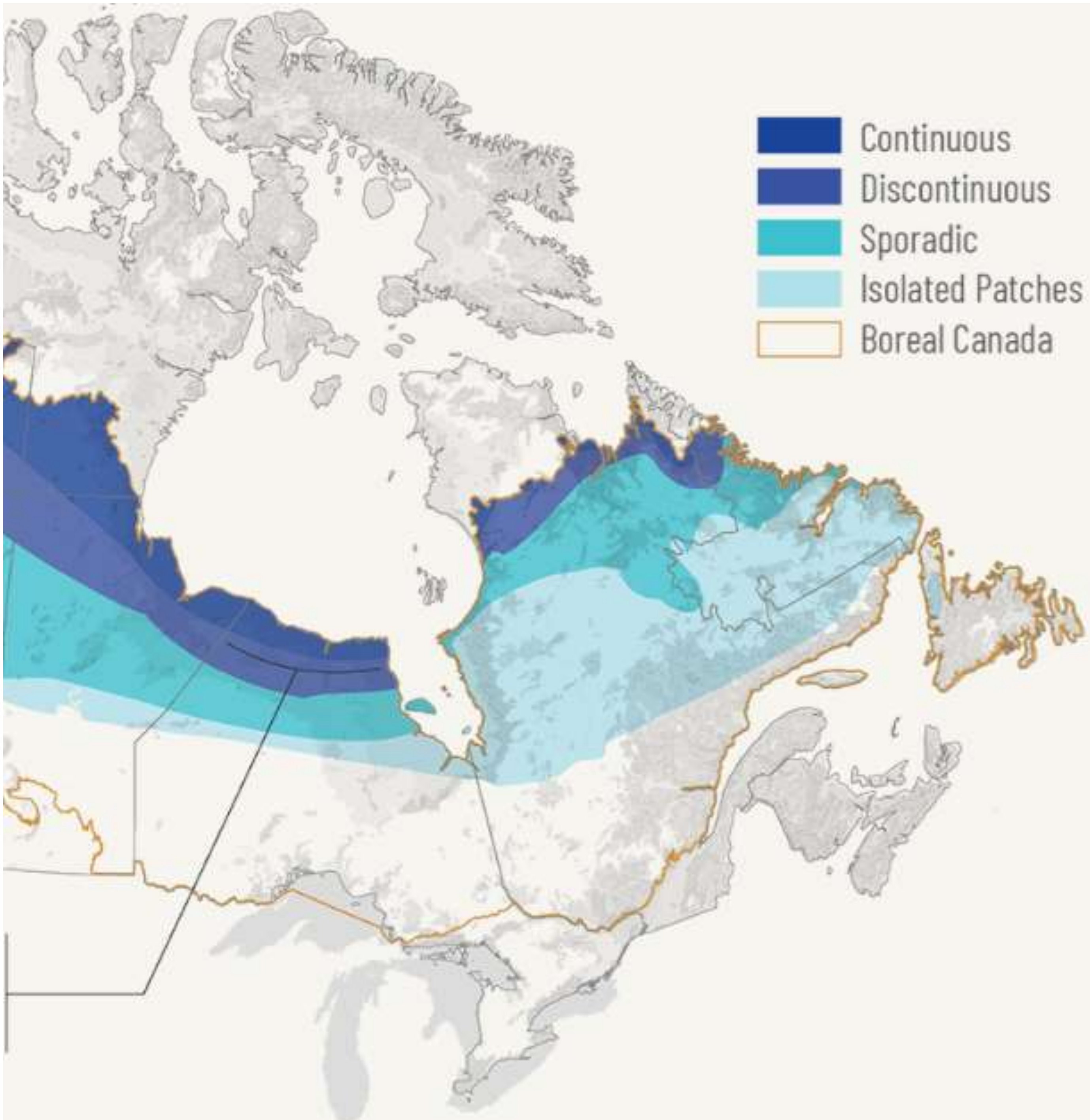
Permafrost occurs when the ground remains frozen all year round for two or more years in a row. No matter what is in the ground (i.e. sand, silt, clay, peat, water, gravel, bedrock), when it is frozen it is referred to as permafrost.

When frozen, permafrost acts like a “solid,” regardless of the different materials. If it stays frozen then it behaves the same, year after year, and can be an excellent basis for a good foundation. If permafrost melts, the solid material reverts to a loose collection of different materials, and each loose material reacts differently under a foundation. If the foundation design and construction have not allowed for this change in the permafrost, the foundation will no longer work without damage to the house.

There are two main types of permafrost in northern Ontario: continuous and discontinuous, shown on the next page. Continuous permafrost is permafrost where more than 90 per cent of the land area is permafrost. Discontinuous permafrost has four subzones:

- Extensive discontinuous permafrost: 65 to 90 per cent permafrost
- Intermediate: 35 to 65 per cent permafrost
- Sporadic discontinuous permafrost: 10 to 35 per cent permafrost
- Isolated discontinuous permafrost: One to 10 per cent permafrost

PERMAFROST—Northern Ontario



ENGINEERING—Geotechnical and Structural

Professional engineers are required for designing foundations. A geotechnical engineer provides the ground and permafrost technical information. A structural engineer completes the foundation design for construction. In some cases, the geotechnical analysis and foundation design can be completed by the same engineer, depending on their experience and skills. The roles of each engineer should be reviewed to ensure that adequate analysis is being completed.

Geotechnical Engineering

The issues surrounding foundation design in permafrost can be complex, and a geotechnical engineer should be consulted. The design of a foundation in permafrost is based on the local temperatures, whether the ground is ice-rich or ice-poor, and what available construction equipment is in the community. Knowing this affects the analysis for determining factors such as the foundation type, depth, location, installation technique, and protection from thawing during construction.

Structural Engineering

A structural engineer should be consulted to complete the foundation design of how it must be constructed. The structural engineer will look at the overall loads imposed on the house, for instance wind, snow, gravity, and occupancy, and then look at how the house is designed to understand how loads are transferred to the foundation and then to the ground. Fewer connection points or posts means higher loads at each point or post, and these higher loads need to be understood in order for the foundation to not shift, crush, or break and cause damage to the house.

CLIMATE CHANGE

Due to climate change, the depth of permafrost in some regions is shifting. This causes housing design and construction challenges. When permafrost thaws, the strength of the soil decreases, and large foundation settlement can occur. It is therefore important to understand current and future predicted conditions of the ground on which any foundation is to be built.

The impact of climate change will vary based on soil types, and their changes in behaviour as they warm up. The geotechnical engineer should design the foundation for predicted future temperatures, since we want the home to be useful for its entire service life. If the service life of the house is expected to be 50 years, the foundation should be designed for predicted temperatures for 50 years into the future for the local area. The design should accommodate predicted settlement and other deformations. Many methods may be considered to help a house adapt to climate change:

- Install adjustable footings/columns/jackposts to allow re-levelling that accommodates changes in the ground.
- If the permafrost is relatively thin, it may be practical to clear the site of vegetation and intentionally thaw the permafrost. Then the house foundation can be designed for non-permafrost conditions from the start.
- Install “adfreeze” piles deeper into the ground, to account for an increased non-frozen layer. This way the foundation will remain as designed longer into the future.

PROTECTION OF PERMAFROST

A house built in direct contact with the ground in permafrost, without any protection against heat transfer from the house to the ground, will lead to melting of the permafrost. This will cause a complete change in the conditions surrounding the foundation, with resulting damage to or failure of the house.

Precautions must be taken to protect the permafrost from thawing due to heat coming from the house:

- Construct the building above ground and leave an open-air space below the building, a minimum of 0.9 meters high. This open space provides a zone that can take the heat loss from the floor of the house and have it dispersed away before it can thaw the permafrost below.

- This open space below the house must be left open for wind and air to freely pass under the house. The space cannot be covered with a skirt or used for storage. Keeping this space clear will help prevent snow drifts from accumulating around and under the house. If this were to happen, the heat loss from the floor could thaw the permafrost below.

PROTECTION OF PERMAFROST

Other methods to protect the permafrost could be considered:

- Adding layers of insulation on top of the ground (to keep the heat out of the ground)
- Installing “thermosyphons,” two-phase closed pressurized systems that cool the ground by extracting any heat in the ground to change the phase of the fluid in the pipes (much the way a refrigerator works). As the pressurized fluid changes to a gas in the pipe, it extracts heat. That heat is then transferred to the air above ground when the pump pressurizes the gas and turns it back into a fluid.

However, these approaches (and others) are more expensive and more common for large buildings that are built in contact with the ground, such as a firehall or water-supply truck garage. For housing, the foundation approaches in this booklet are recommended.

SITE GRADING

Removing materials from the top layers of the ground is sometimes required to avoid problems with the foundation system.

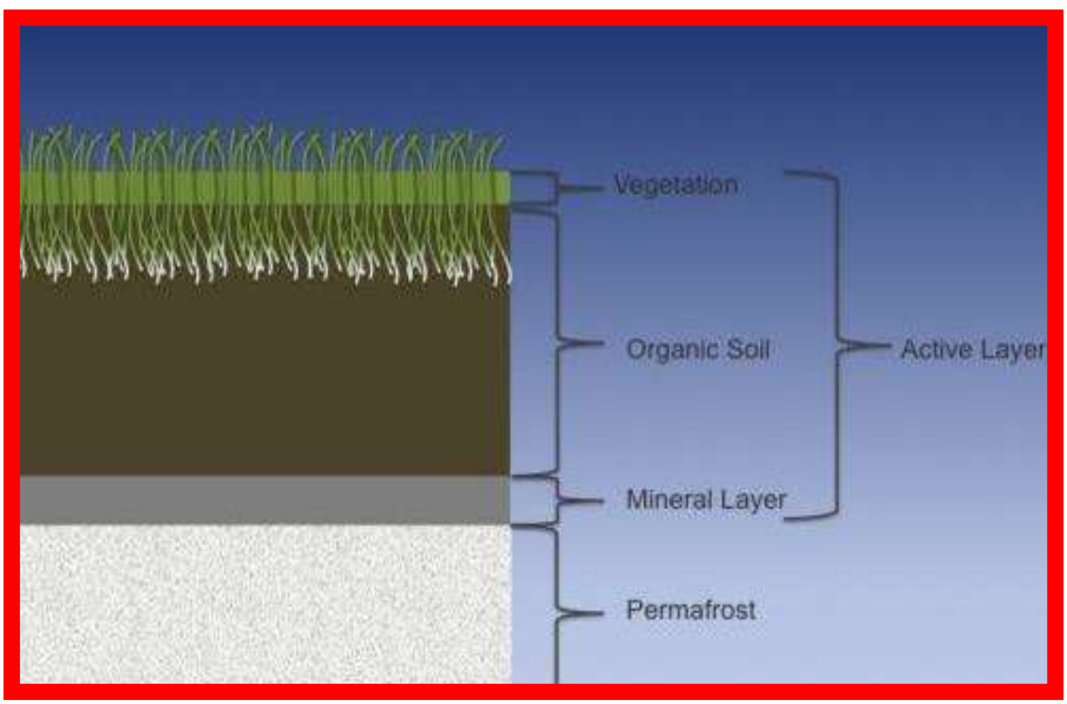
Organic Material

For the Shallow Foundation and Deep Foundation approaches, if possible, organic materials like topsoil and peat should *not* be stripped from the site, as these materials create a layer of insulation and protection of the permafrost.

However, topsoil and peat are not suitable substrates for foundations like the Traditional and Space Frame, since they are built on top of pads on the ground. In these cases, an engineered granular slab should be constructed.

Excavation and Grading

If site leveling or grading is required, excavating into slopes with permafrost should be avoided, as these holes can lead to additional thawing.



GEOLOGY AND BEDROCK

The importance of a geotechnical engineer cannot be ignored. A geotechnical engineer should be consulted to determine the appropriate properties and structural capacity of the existing soils and bedrock at a site.

Bedrock can be present at the surface or far underground. The quality of bedrock can also vary in different locations. As an example, sedimentary bedrock like limestone can be fractured, allowing water and ice to penetrate the bedrock, causing settlement. Even granite bedrock has the potential to be fractured at the surface, which can affect its structural integrity.

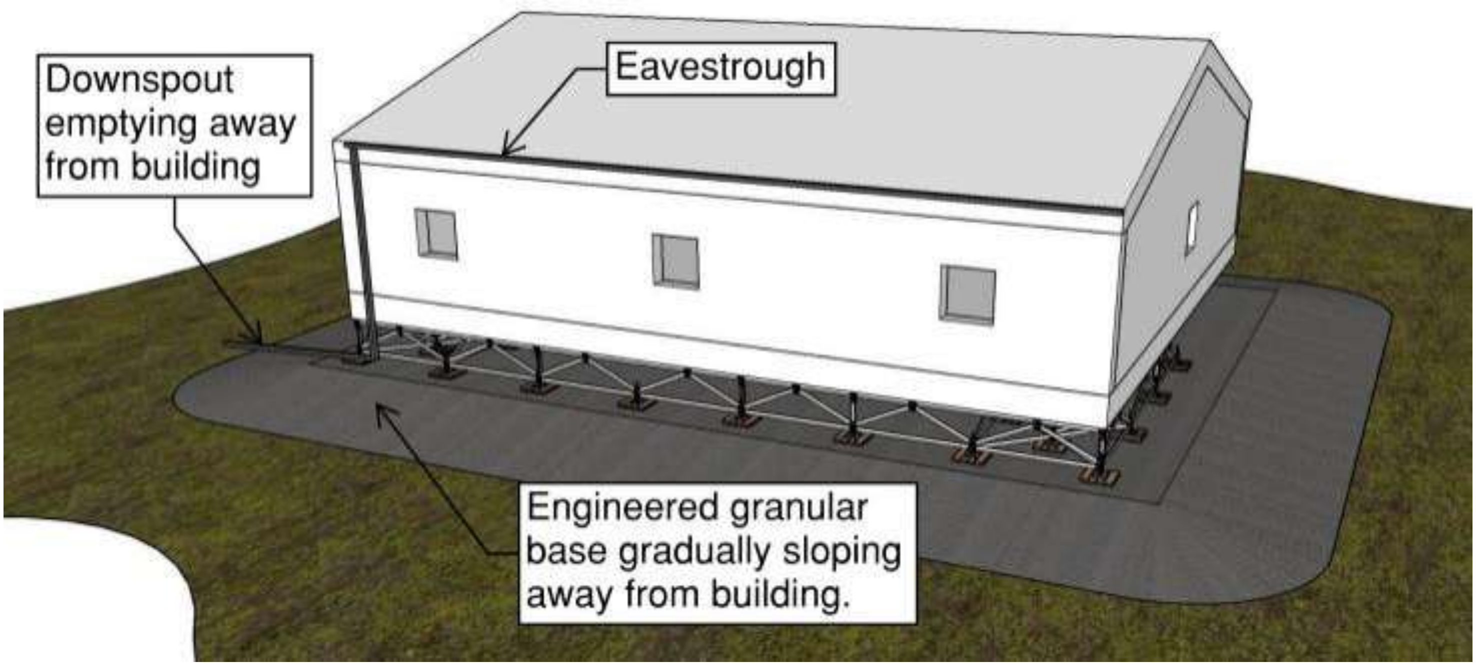
HYDROLOGY—Surface and Groundwater

Surface and groundwater can affect the levels of permafrost and the suitability of certain foundation types. Changes in surface and groundwater can quickly and permanently affect foundation stability. Also, bodies of water, large or small, will affect the temperature of the ground, which can lead to thawing of permafrost.

Surface water around the building foundation that results from poor drainage can also lead to dramatic frost heaving and potential movement of the foundation system.

Surface water is to be controlled through the installation of various systems to divert the surface water away from the foundations. The most successful is proper grading of the ground surface to direct water downhill and away. Water penetration can also be controlled by installing an impermeable geotextile liner in the correct locations, to keep water from getting under the foundation pads.

Surface water should be sent to a drainage ditch that directs the water away from the site and other buildings. Eavestrough and downspouts from the house may need heat-tracing to prevent freezing.



FOUNDATION SYSTEMS

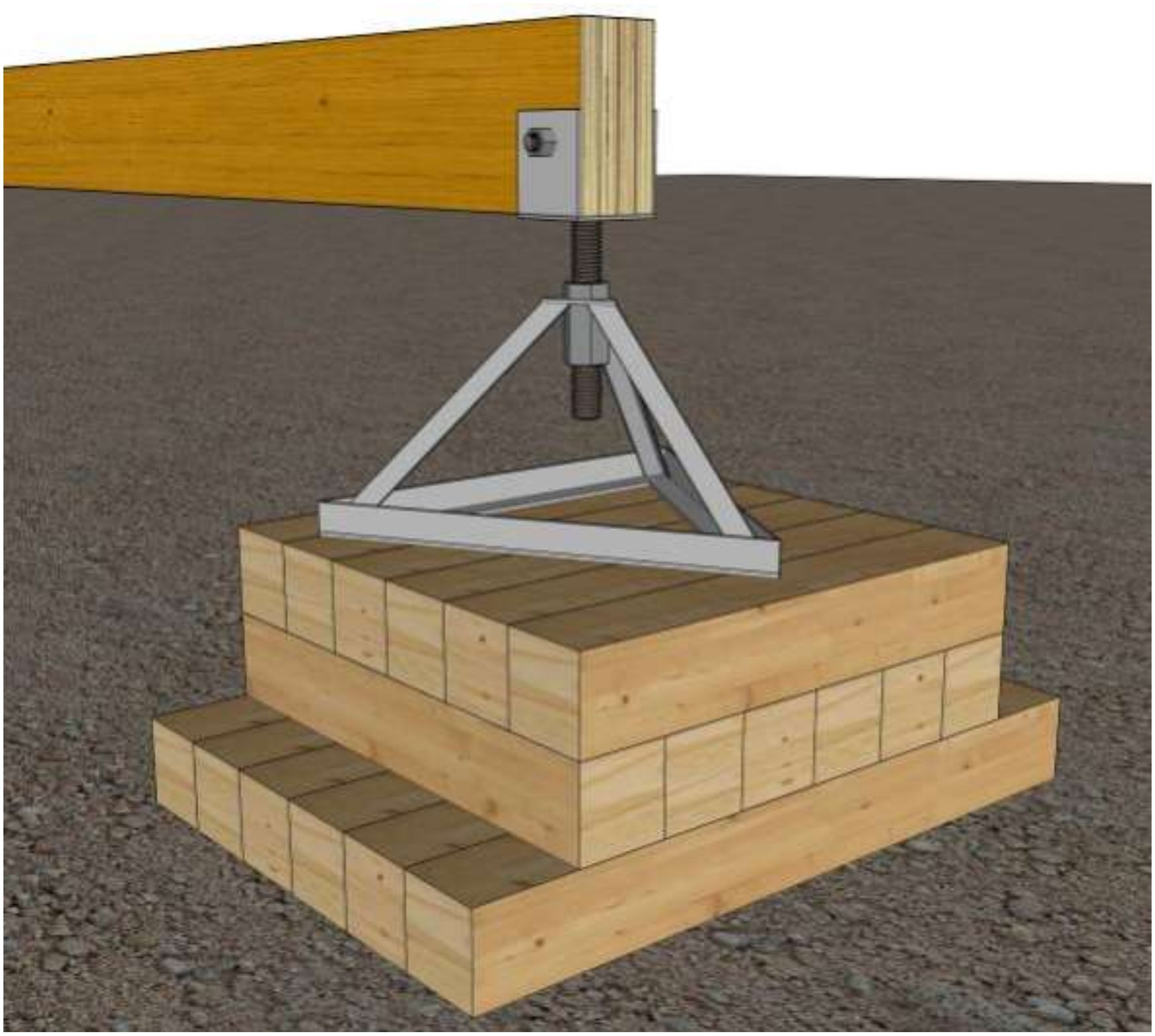
This section outlines the general requirements and procedures for constructing a foundation in northern Ontario's permafrost regions, and remote regions with very deep winter frost penetration.

Several issues should be considered when selecting the most appropriate foundation system for a house:

- Construction equipment available
- Construction materials available
- Construction labour available
- Ground conditions and temperatures
- Groundwater and surface water conditions
- The impact of climate change on soils and permafrost
- The settlement or deformation tolerance of the house

Foundation Approach #1: **The Traditional**

Portable Screw-Jack



Foundation Approach #1: **The Traditional Portable Screw-Jack**

The Traditional foundation system includes beams supported by adjustable screw-jacks or stilts that are surface-mounted on wood or concrete pads with gravel underneath. Because the ground will settle and heave throughout the year, it is essential that this system have the capability to be adjusted seasonally.

Because this foundation system is just sitting on the surface, where required, some form of tie-down is

required to prevent the wind from lifting the house up off the ground. Tie-downs can be achieved by attaching cables from the foundation structure to weights on the ground. An easy method of creating a tie-down is to build a stone gabion, which is a metal cage filled with stone and rubble.

When to use this approach

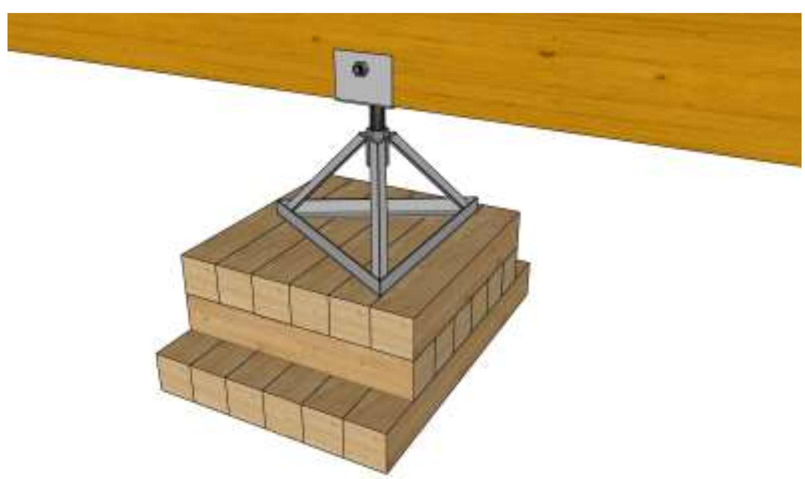
This is the lowest-cost and fastest to build of the recommended foundation approaches, but it is only recommended for use when a house is required to be built quickly at minimum cost. There are better approaches for more long-term foundations.

SITE CONSIDERATIONS—The Traditional

If foundations move during the life of the house, various components that have important functions can be damaged. For example, if the ground moves and the foundations cause different parts of the house to tilt in different ways, the following problems may be found:

- Interior finishes crack or break (drywall, tiles, kitchen counters)
- Sanitary drainage no longer works, due to changes in pipe slope
- The air-barrier layer in the exterior walls get torn or its connections to other materials pull apart (letting in the cold and causing loss of heat)
- The glass in windows breaks
- Doors in the house do not open or close properly
- Drawers slide open
- Windows will not open or close properly

Avoiding these problems in the first place is the best solution. This means having a foundation approach that prevents these movements or allows for simple adjustments to keep the house level. The right foundation will make the house last longer, work the way it was intended to, and avoid future damage to the house.



STRUCTURAL CONSIDERATIONS—The Traditional

With the Traditional approach, a screw-jack post is an example of a surface foundation supported on a surface footing. Screw-jacks can typically allow up to 100 to 150 mm (four to six inches) of height adjustment, which can be used to keep the house level. If there are concerns about ground movement over a longer time frame, then longer posts should be considered to give larger vertical adjustment height.

However, it is important to remember that this system only works if it is regularly “tuned.” The house has to be checked at least once a year (more is better) to make sure it is still level, and adjustments to the screw-jack posts are done if it is not level. If this maintenance activity is not completed, this system is more likely to result in movement and damage to the house. An exchange of lower initial cost versus more long-term maintenance time/cost is required to make this system work.

Because of this dependency on regular “tuning” with the Traditional foundation system, the house design must be able to accommodate a reasonable amount of movement and displacement. The house framing should be constructed so there is more stiffness than in typical houses, because of the expected movement it will experience. More accommodation for movement is also needed in the other house systems, such as plumbing and duct work Refer to the structural booklet (9) for discussion of making the structure more stiff.

As a reminder, the Traditional foundation system needs to be designed by a professional engineer. The structural engineer will determine the building loads, size of the floor beams, spacing of the beams, spacing of the posts, and adjustment height and size of the required footings/base supports for the soil conditions of the house.

Foundation Approach #2: **Shallow Foundation**

Mounted on Bedrock

Foundation Approach #2: **Shallow Foundation Mounted on Bedrock**

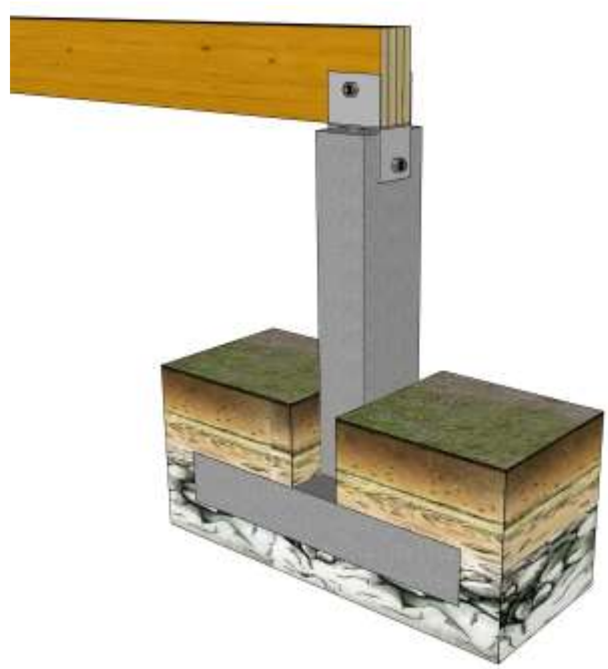
This foundation system consists of a pilaster or pier (column) supported directly on bedrock. The pilaster is normally made of either concrete or a steel post. This foundation approach can be used when sound bedrock is within 1.2 m (four feet) from the surface. This is because it requires relatively short pilasters to allow for thin concrete profiles and because cross bracing is not used. This size of the footing that supports the pilaster is adjusted to accommodate the strength of the bedrock. It is important to have a geological engineer determine the strength of the bedrock.

It is normal to use a concrete bearing pad on the bedrock to provide a level mounting surface.

Use this approach when bedrock is at or near the surface.

Steel Pedestal Versions

Cast-in-Place Concrete Pedestal Versions



SITE CONSIDERATIONS—Shallow Foundation

In theory, the Shallow Foundation system can be installed on permafrost, but it is not recommended, as any warming of the permafrost caused by pilaster contact or climate change will result in unexpected settlement of the foundation. In permafrost zones, the Shallow Foundation approach is recommended only where the foundation can bear directly on bedrock.

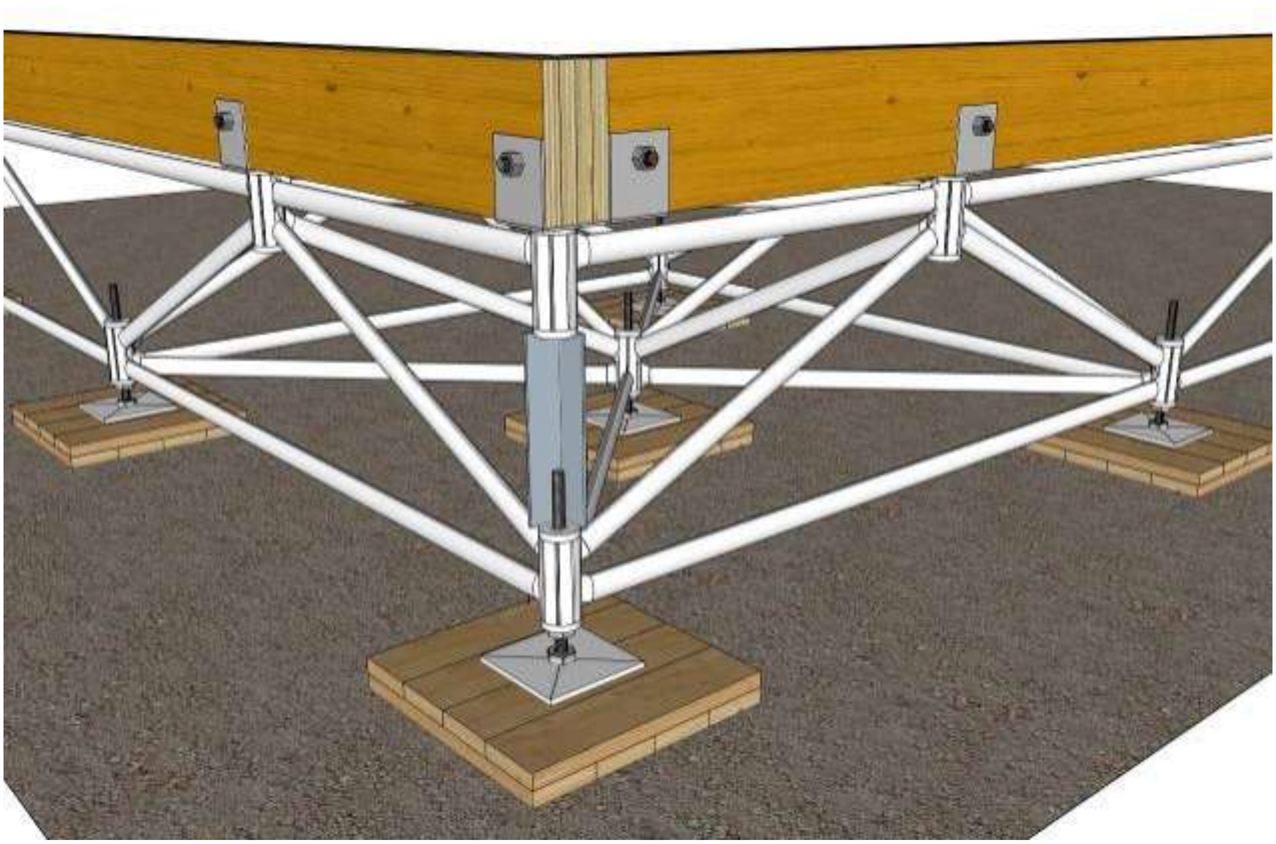
Even in non-permafrost zones, shallow foundations can be risky and prone to settlement and heaving, depending on the soil conditions. These high-risk conditions include sites with fine-grained soils (silts/clays), or organic content, or sites with poor drainage. Shallow foundations should generally be avoided if these soil conditions are present, even if permafrost is not present.

Constructing the Shallow Foundation using cast-in-place concrete should be avoided whenever outdoor temperatures are expected to be +5°C or lower any time over a 28-day period when the concrete is installed. This is because the water in the concrete will freeze before the concrete has properly cured, resulting in permanent damage to the concrete, and a failure of the foundation.

If construction of cast-in-place concrete must take place during cold temperatures, special care must be taken to protect the curing concrete from cold temperatures for a minimum of 14 days after pouring.

Excavation should be completed in a way that minimizes disturbance to the soils and groundcover. This will reduce the risks of surface-water problems. It is recommended that any excavation take place during summer months, so that surface drainage can be properly repaired.

Foundation Approach #3: **Space Frame**



Foundation Approach #3: **Space Frame**

A Space Frame, or triodetic foundation, is an adjustable foundation system with multiple connection points to the house. It is typically supported on surface footing pads. It works by distributing the house loads over many points that contact the ground. The use of many points means the loads on each point are much smaller than for the Traditional or Shallow/Deep Foundations.

A space frame can be constructed of steel, aluminum, or wood, and is specifically engineered by various manufacturers. Space frames are specific to different manufacturers, so care must be taken when comparing different designs, as they may have different features. For example, spacing of connection points and footing pads, access for adjustment of bottom plates, and amount of adjustment.

As with the Traditional, it is essential that this system be adjustable, to accommodate changes in ground conditions. Since adjustments are made after they are noticed, the house frame must be more stiff than in traditional housing.

When to use this approach?

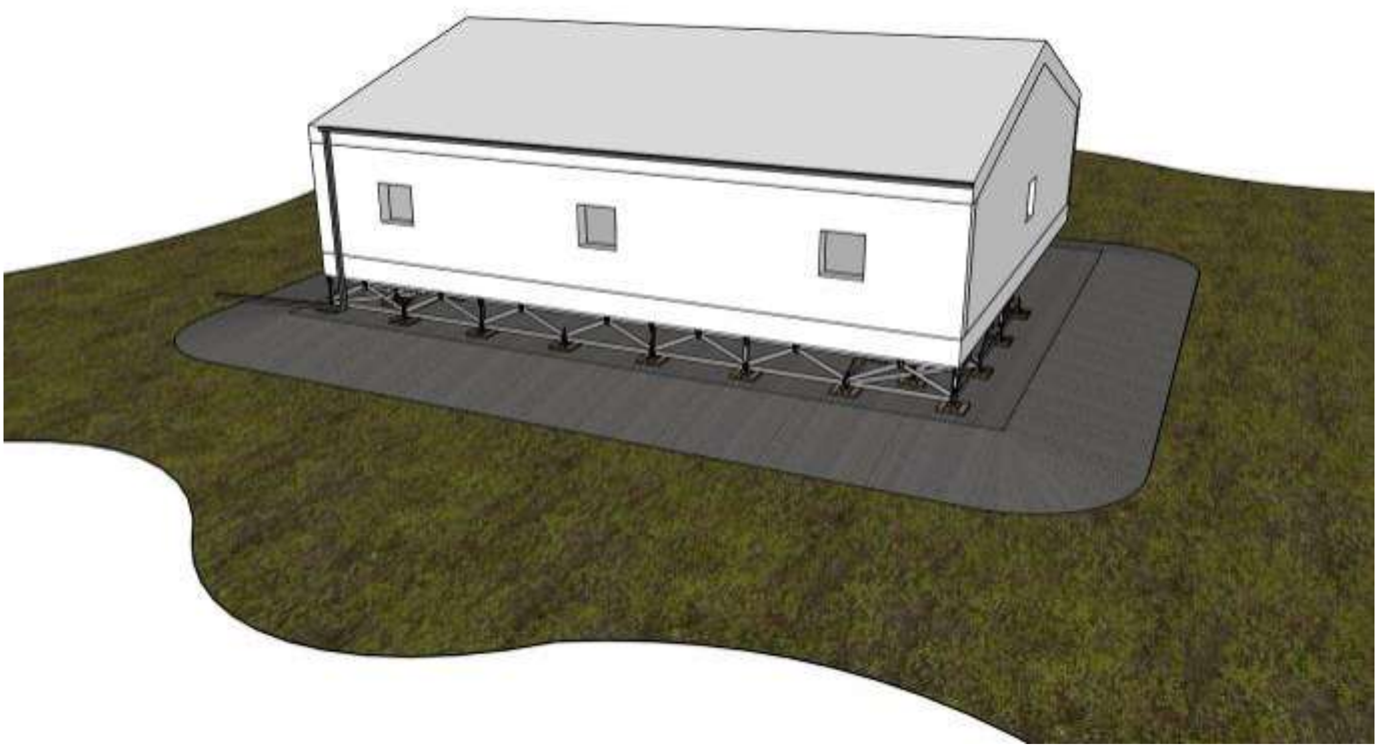
Space frames are typically proprietary (different with each manufacturer), and require more engineering. They can be more expensive as well. Their flexibility and adjustability make them ideal if the geotechnical conditions are unknown. They are an excellent solution due to their rigidity, redundancy, and adjustability. They are forgiving of complex ground conditions and can be installed quickly.

SITE CONSIDERATIONS—Space Frames

The Space Frame can be implemented without an extensive geotechnical study of ground conditions. They are also "pre-engineered" so they can be designed and delivered to site, ready to install.

Space Frames are typically constructed on top of exposed bedrock or a new granular base built up on the existing ground (leaving as much of the native vegetation and earth in place as possible). It is best to construct these granular bases before winter, when the ground is thawed. Most space-frame foundation systems require relatively flat site grading.

The gravel base should be constructed of non-frost susceptible sand and gravel that does not contain frozen materials or ice. In soft soils, a geotextile fabric should be installed below the gravel base. The design and details of the granular base should be provided by a geotechnical engineer. The granular base should normally be at least 300 millimetres thick, installed directly on the existing ground, and extend beyond the building footprint.

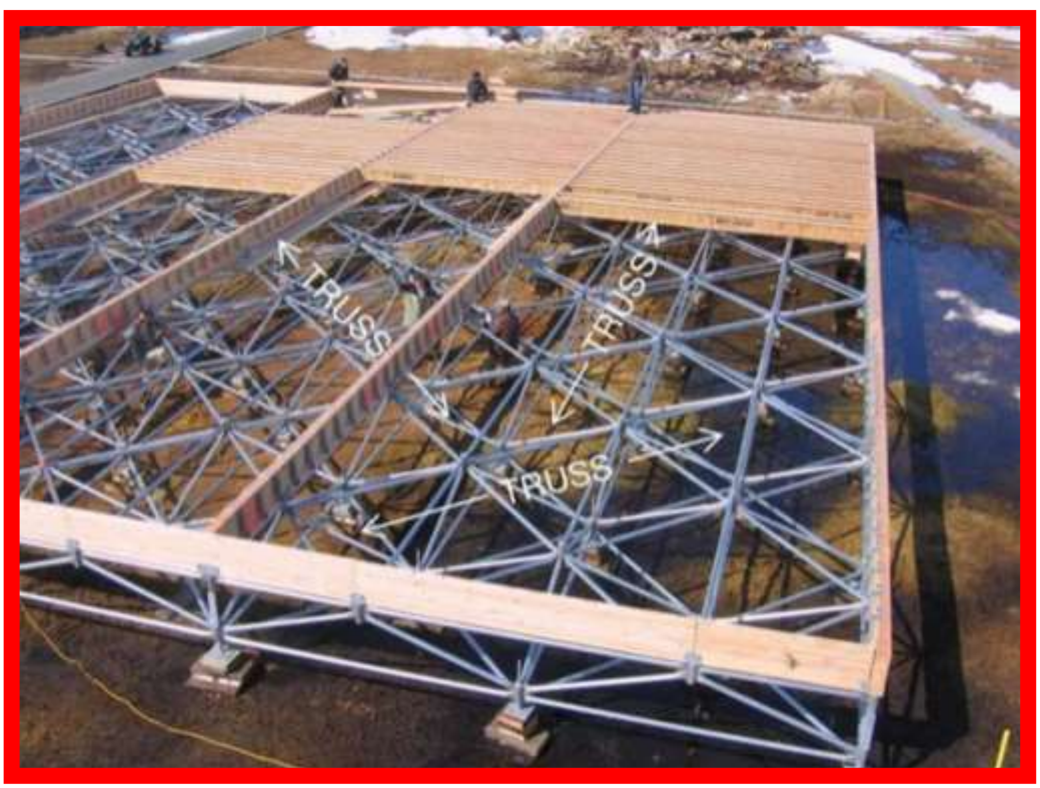


STRUCTURAL CONSIDERATIONS—Space Frames

The design of the space frame will need to be integrated with the design of the house framing, to ensure connection points are properly placed. Proper preparation of the ground/bedrock or gravel base is critical for proper long-term durability of these systems.

Each system is assembled according to specific instructions from the manufacturer and engineer. It is very important that each one is installed correctly. Once installed correctly, they will provide years of low maintenance and good performance. Annual review of the house is needed to make adjustments that keep the house level.

It is important to understand that the space below the house will largely be filled with the components of the space frame.



Foundation Approach #4: **Deep Foundation**

Steel Piles

Foundation Approach #4: **Deep Foundation Steel Piles**

Piles are deep foundations that extend into stable permafrost or bedrock, which is expected to remain stable for the lifespan of the house. These foundations, if constructed properly, require little maintenance and should undergo little to no settlement.

When to use this approach

The Deep Foundation approach will almost always be the most expensive foundation. But when properly designed and installed, piles are almost permanent, and could be re-used for replacement houses over many decades.

These systems are most common in continuous permafrost regions. Costs associated with design and installation make more sense when permanent foundations are desired. Technically, these are the best foundation solutions, but this must be balanced against cost and need.

SITE CONSIDERATIONS—Deep Foundations

A steel-pile system is the most structurally reliable foundation system when dealing with permafrost or very poor soils or bedrock. They work effectively in bedrock that is no more than 10 to 12 meters deep.

Piles must be designed to meet the requirements of the structural section of the Building Code. This means that a geotechnical study is needed and the design has to be provided by a professional engineer. The piles must also be installed by competent contractors with specialized equipment, all under the supervision of the pile engineer.

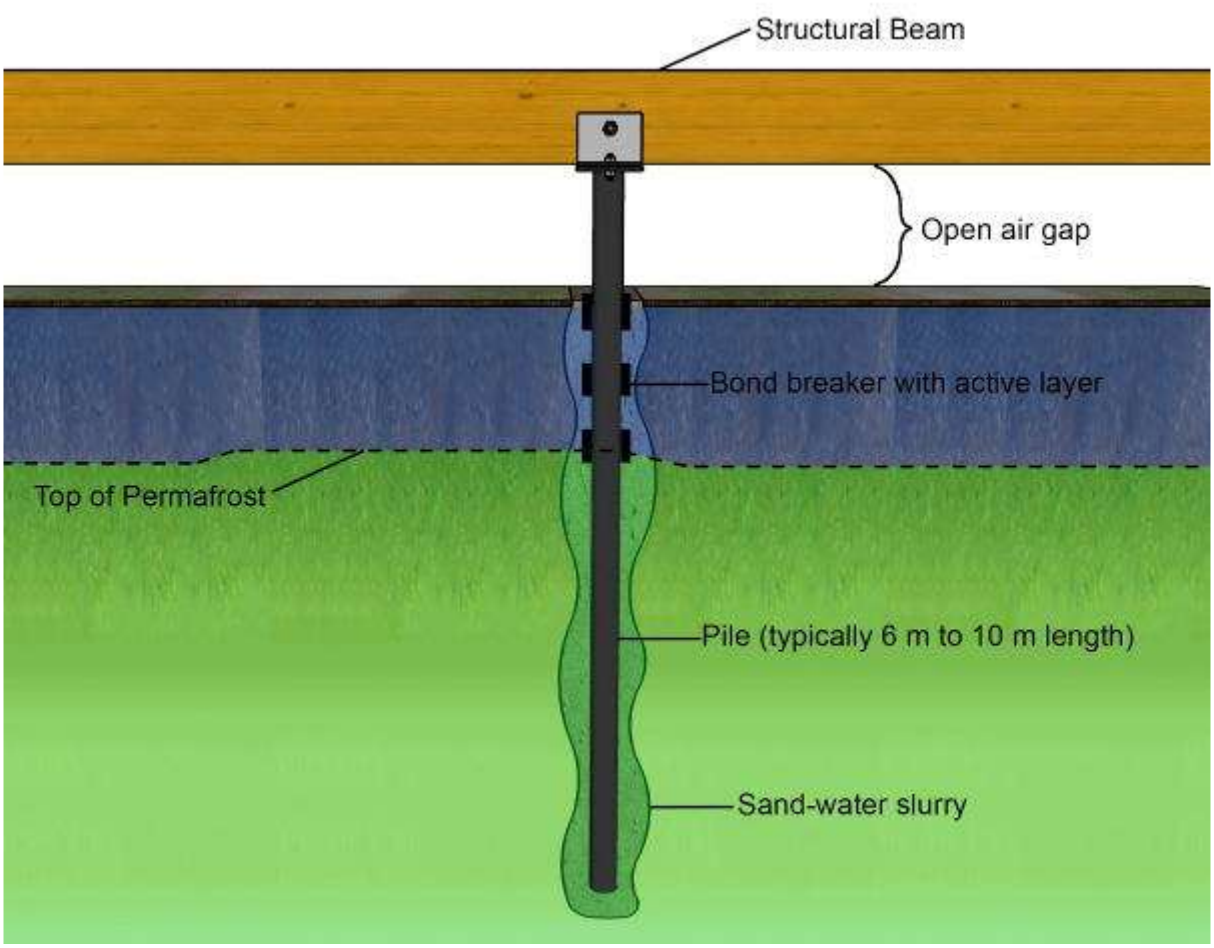
Ideally, the piles will rest on bedrock, but they can also be anchored deep into permafrost. However, future thawing of permafrost needs to be considered by the design engineer.

An extensive geotechnical study of the ground conditions is required with this approach. Steel piles should be used when soil conditions are very poor, or the site has a steep slope.

STRUCTURAL CONSIDERATIONS—Deep Foundations

Pile foundations can be constructed of wood, steel, or concrete. Steel piles are recommended for their durability, ease of transportation, and high structural capacity. Historically, wood was commonly used but modern lumber does not have the same durability or strength as old-growth lumber.

Various styles of piles could be used: sand slurry or adfreeze pipe piles, grouted piles, and driven piles. Regardless of the style, a bond breaker should be installed around the portion of the pile in the permafrost “active” layer. This bond breaker will allow the soil around the pile that freezes and thaws throughout the year to move without heaving the pile. This bond breaker is commonly comprised of multiple layers of heavy plastic and arctic-grade grease.



STRUCTURAL CONSIDERATIONS—Deep Foundations

Sand slurry or adfreeze pipe piles are commonly used for homes in Canadian permafrost regions. This type of pile is installed in a “pre-drilled” hole with a diameter 100 to 200 millimetres greater than the pile. Then the space around the pile is backfilled with a flowable water/sand mixture. During installation of the slurry, the pile should be vibrated in order to minimize the number of air pockets and voids in the slurry around the pile. Sand-slurry piles are often of a stock size, meaning they will be the same from project to project, and can be stockpiled. The size of pile, amount of clearance around, and slurry mixture ratios will be outlined by a pile engineer.

Grouted piles are similar to sand-slurry piles, but instead of a slurry, a structural cement grout is placed around the pile. This style of pile has a larger structural capacity when compared to sand-slurry piles. It is not ideal for northern permafrost regions, and should be avoided if possible, because the curing of the grout around the pile creates heat and could disturb the surrounding permafrost.

Driven piles are made of steel pipe H sections, or sometimes timber. As the name suggests, this piling method involved driving/pounding the pile directly into the ground (no pre-drilling required). It requires specialized piling equipment to drive the pile into the ground. This equipment is located in some locations in the western Arctic but is currently unavailable in the eastern Arctic. Driven piles usually require a small pilot hole to be drilled to start the process. This pilot hole requires the same auger rig that would be used to install a sand-slurry pile.

Of the three common piling systems, sand and slurry adfreeze pipe piles are most common, easiest to install (out of the three pile systems), and can be installed in the widest range of conditions.

ADDITIONAL RESOURCES

Guides and Standards

- CAN/CSA S406-16(R2021), "Specification of permanent wood foundations for housing and small buildings"
- CAN/CSA-S500-14, "Thermosyphon foundations for buildings in permafrost regions"
- CAN/CSA-S501-14, "Moderating the effects of permafrost degradation on existing building foundations"
- CAN/CSA-S502-14, "Managing changing snow load risks for buildings in Canada's North"
- CAN/CSA-S503-15, "Community drainage system planning, design, and maintenance in northern communities"
- CAN/BNQ 2501-500, "Geotechnical site investigation for building foundations in permafrost zones"
- CSA PLUS 4011.1:19, "Technical Guide: Design and construction considerations for foundations in permafrost regions," CSA Group, 2019
- *A Homeowner's Guide to Permafrost in Nunavut*
- Government of Northwest Territories, "Good Building Practice for Northern Facilities," Government of Northwest Territories, 2019

Technical Information

- G. H. Johnston, "Permafrost and foundations," *NRC Publications Archive,* p. 5, 1964
- Stantec Consulting Ltd., "DRAFT Technical Guide for Adaptable Housing in Canadian Permafrost Terrain," Stantec Consulting Ltd., Ottawa, 2019

Building Codes

- *National Building Code of Canada*
- *Ontario Building Code*

This technical booklet was developed to help community decision makers and building officers choose between different technical options in the delivery of residential housing for First Nation communities, in remote northern Ontario.

IMPORTANT NOTE

This booklet addresses general foundation approaches that are suitable for houses in northern communities. Detailed engineering is required in most cases, and should be performed by a Professional Engineer licenced in the Province of Ontario. Detailed engineering of foundation systems is beyond the scope of this booklet; the involvement of a professional is required.

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