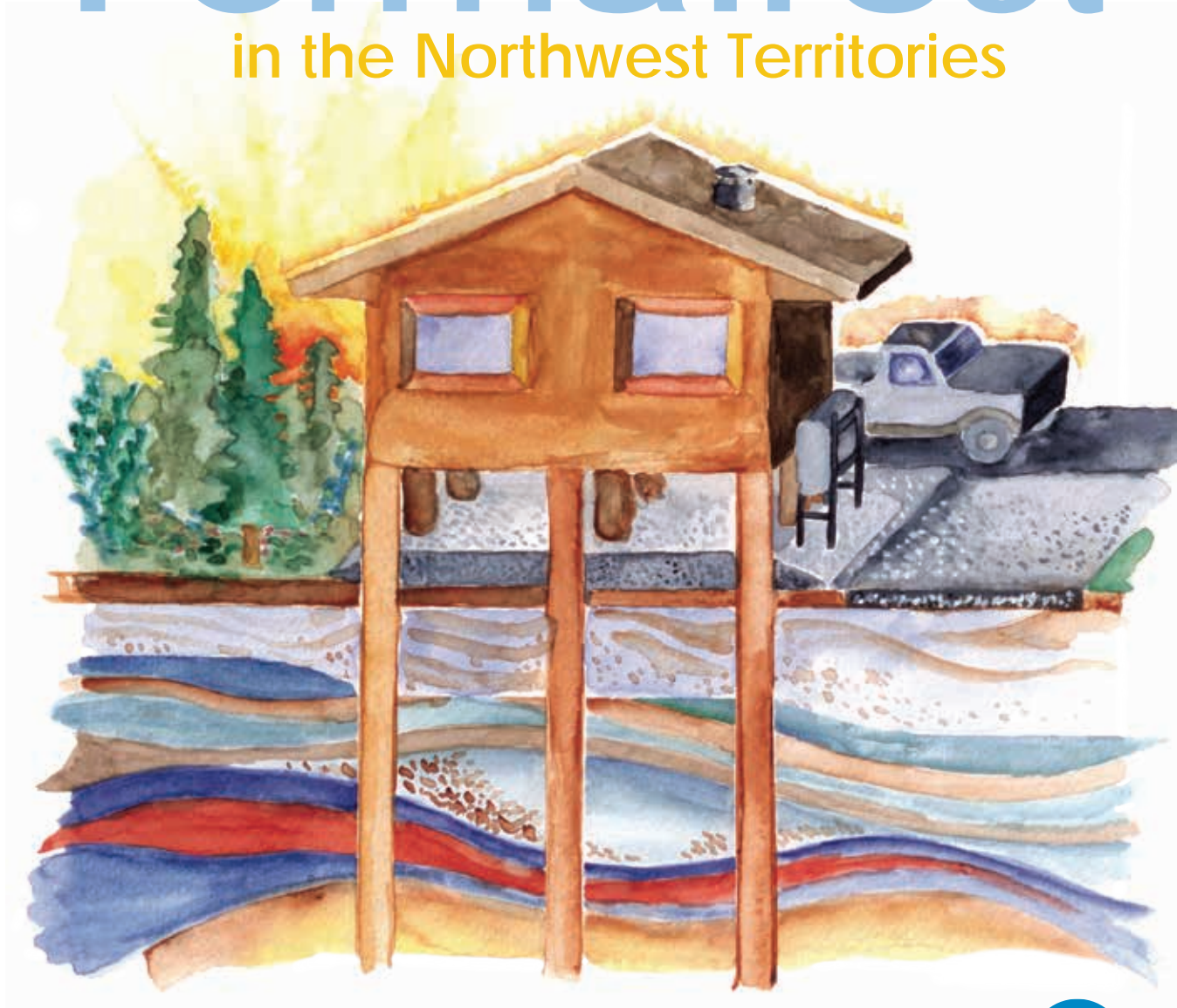


A Homeowner's Guide to  
**Permafrost**  
in the Northwest Territories



Keep Your House on Solid Ground



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**Environment Division  
Department of Environment and Natural Resources  
Government of the Northwest Territories**

PO Box 1320,  
7th Floor, Scotia Center,  
5102 Franklin Ave,  
Yellowknife, NT,  
X1A 2L9,  
(867) 873-7854  
[www.nwtclimatechange.ca](http://www.nwtclimatechange.ca)

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*Permafrost is common and exists under many houses in the NWT*

This Guide is not a legal document nor is it intended to be a complete manual on dealing with problems caused by permafrost to your home. The Government of the Northwest Territories does not assume any responsibility or liability with respect to any damage or loss arising from the use or interpretation of this Guide. It is provided by the Department of Environment and Natural Resources as a courtesy only.

The Guide is intended to provide homeowners with general information on permafrost, the damage permafrost thaw can cause to a house and areas where maintenance or risk prevention is advisable. It is not meant as a replacement for site-specific geotechnical investigations by engineering and / or geoscience professionals.

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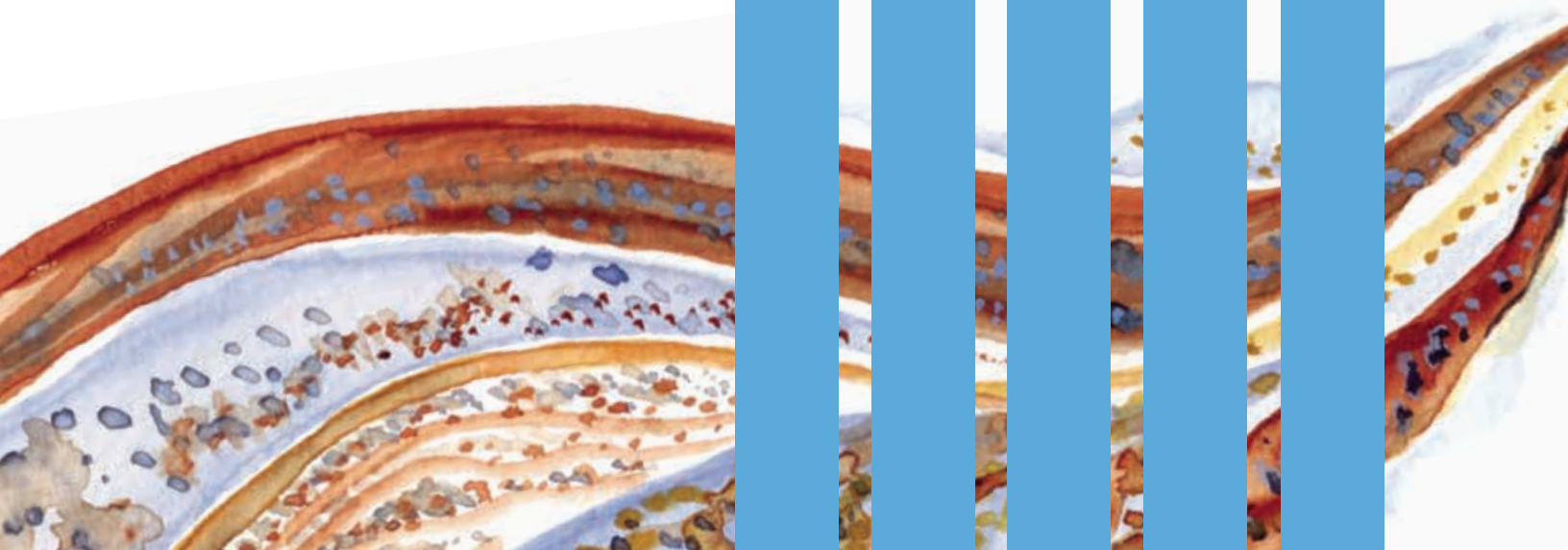
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# Permafrost



*Ice-rich permafrost from a core sample photo by Mike Palmer*

Northern engineers and architects have long developed innovative techniques to deal with the challenges of building on permafrost. However, climate change is causing rapid changes to the permafrost that was once thought would be around for generations. Homeowners in the NWT are starting to realize that their houses rely on potentially unstable permafrost that may lie under their home. Cracking walls and doors that won't close are early indications of bigger problems that may lie ahead.

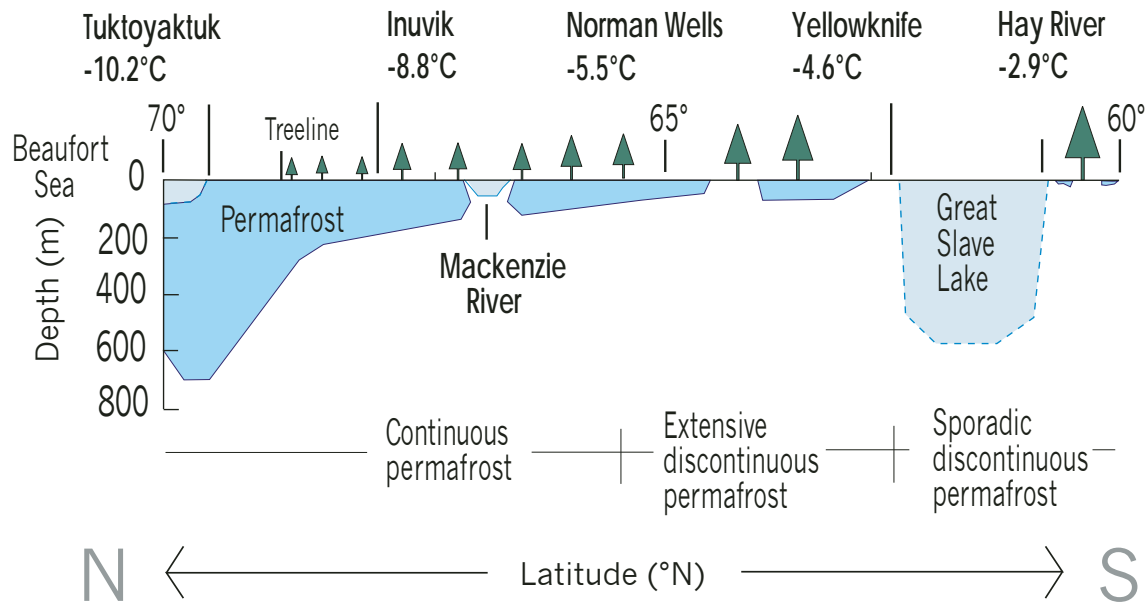
Permafrost is ground that is frozen for two or more years. That ground can be rock, gravel, sand, clay, silt or a mix of these. Ground that contains a great deal of frozen water, or ice causes the most problems for engineers and homeowners. When ice-rich permafrost thaws, the ice melts to water, creating spaces in the soil that lead to ground settlement and building problems.

This Guide contains information on permafrost as it is used in designing a house. It can also help you determine if your home is built on permafrost, the risks related to thawing and tips on how to properly maintain your house and foundation to reduce permafrost thaw. There is also information on other northern foundation issues such as rotting piles and shifting of heating oil tanks.

Keeping your house and foundation in good repair is one way to avoid the risks caused by the thawing of permafrost. Every community and every house faces different permafrost related challenges. Determining what is happening to the ground your house sits on is the best way to figure out your level of risk and how to deal with it.

## Air temperatures and permafrost distribution by latitude (°N) in the NWT

Credit: Modified from Wolfe, 1998



Permafrost is found throughout the Northwest Territories but tends to be more common further north. Permafrost also tends to be thicker and colder in the northern regions. For example, the area around Tuktoyaktuk has cold, continuous permafrost, often hundreds of metres thick. Hay River has sporadic patches of relatively warm and shallow permafrost. Areas between these communities have discontinuous permafrost which can vary from patchy to widespread.

Ice-rich permafrost, the type that can be most harmful to houses when it thaws, is generally found in river valleys, low-lying peaty ground and soil pockets in bedrock areas. Ice-rich areas are found in isolated patches throughout the Northwest Territories but are most common in the Northern Islands, Beaufort Delta area and along the Mackenzie Valley. Mean annual air temperatures are often a good indicator of the presence of permafrost. The average air temperatures from 1971-2000 are shown for some NWT communities in the figure above.



# How can Permafrost

Many houses in the NWT use the strength of permafrost to keep their foundation solid. When permafrost thaws, the house may no longer have a solid base to hold it up. This can lead to uneven floors, cracks in walls and, eventually, serious structural problems.

Many factors affect permafrost stability. It is important homeowners understand how their actions affect permafrost. The good news is you can reduce permafrost thaw and, even re-grow permafrost.

## 1 Permafrost

Ground that remains frozen for at least two years.

## 2 Active Layer

The top layer of ground that is subject to annual thawing and freezing. When the active layer gets deeper, it can thaw the ice-rich permafrost below and cause thaw settlement.

## 3 Ice-Rich Permafrost

Permafrost containing excess ice. Ice-rich permafrost can form thick layers of ice (lenses) in clay or silty soils, which can melt and cause thaw settlement.

## 4 Frost-Heave

The upward movement of the ground surface caused by the formation of ice in the soil.

## 5 Thaw Settlement

The downward movement of the ground due to ice melting in the soil.

## 6 Piles

Wooden or steel building supports drilled into the permafrost are called piles. They are less susceptible to settling, but are subject to 7 creeping (moving down) or 8 frost-jacking (moving up) as permafrost warms.

## Surface Foundation

These adjustable foundations that sit on a gravel pad or concrete footings are more affected by thaw settlement and frost-heave than piles. Examples include pad and wedge, space frames or screw jacks (see page 11).

## 9 Organic Layer

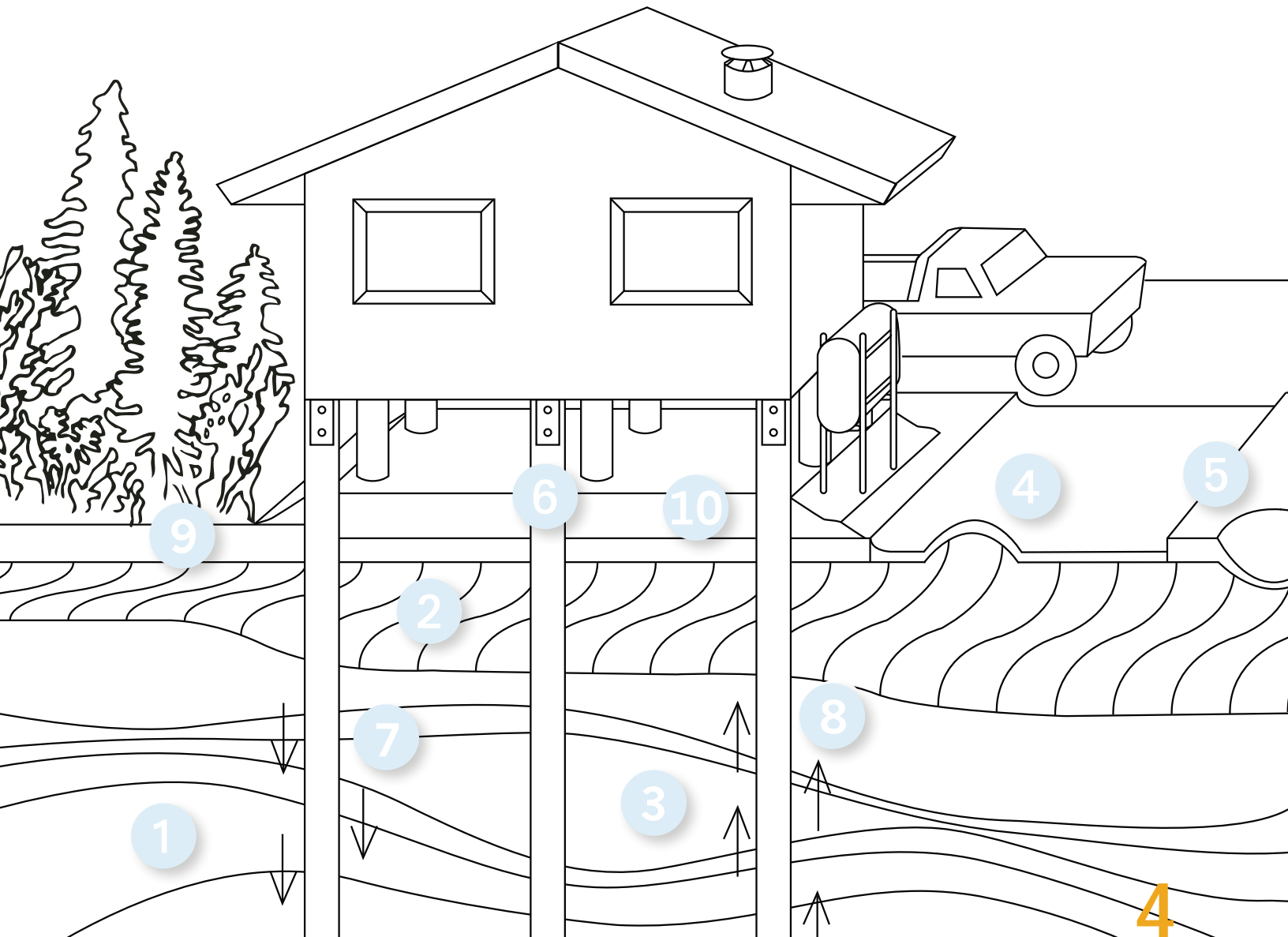
The top layer of dark soil or peat. A thick organic layer insulates the permafrost in the summer. Disturbing the organic layer usually results in rapid permafrost thaw.

## 10 Gravel Pad

The gravel pad is designed to insulate the permafrost and allow water to move through the pad and away from the house.



# Impact My House



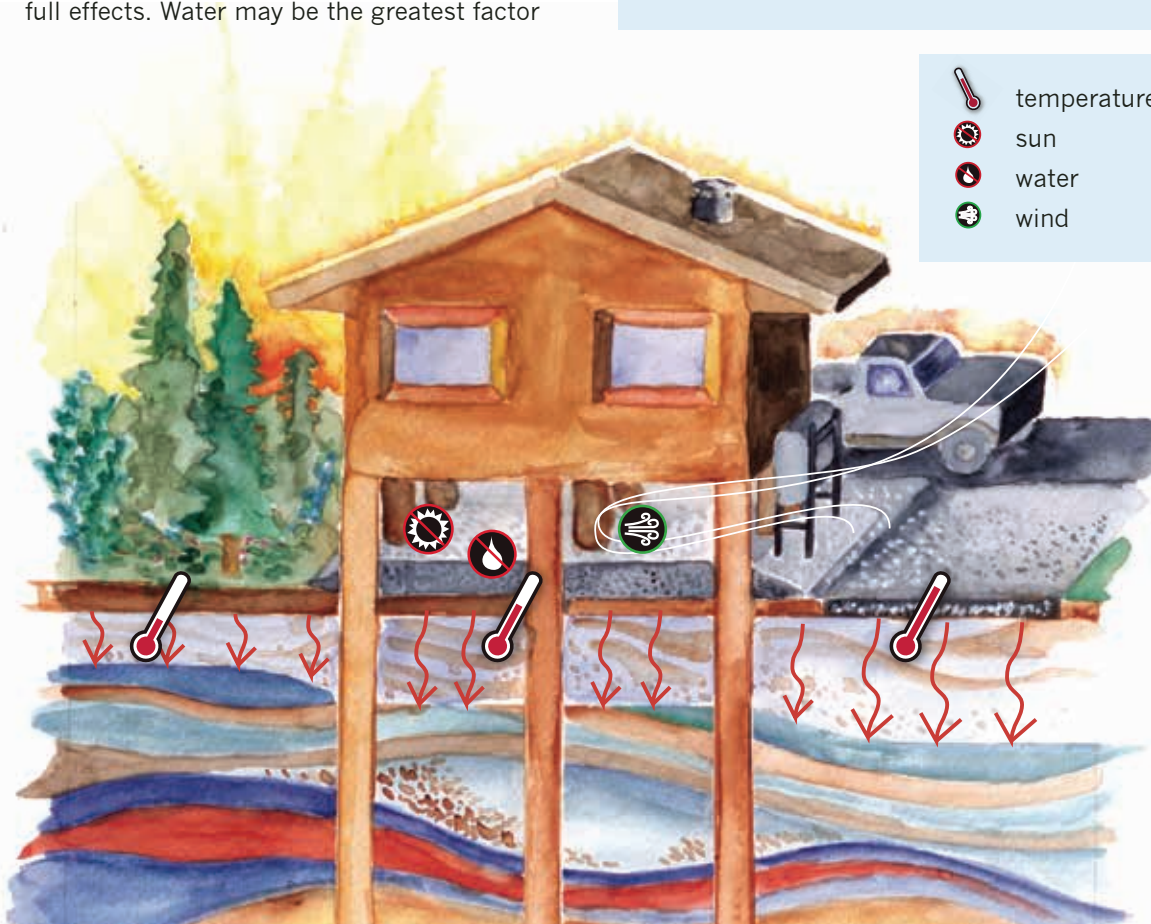
# Permafrost In the Summer

It is natural for the top layer of soil to thaw in the summer. When this active layer gets deeper every year, it is considered permafrost thaw.

Four main factors affect how much permafrost thaws in the summer under your house: temperature, sun, water and wind. The warmer it gets under your house, the more permafrost will thaw. The sun also warms the ground and thaws permafrost, but your foundation is usually shaded from the sun's full effects. Water may be the greatest factor

in causing permafrost thaw, as groundwater transfers heat more easily than dry ground. Wind evaporates moisture under your house, which helps keep the ground dry and prevents permafrost thaw.

Tip: Think of the space under your house. Can you reduce the negative factors of water, sun and temperature while helping the positive factor of wind?






# Permafrost In the Winter

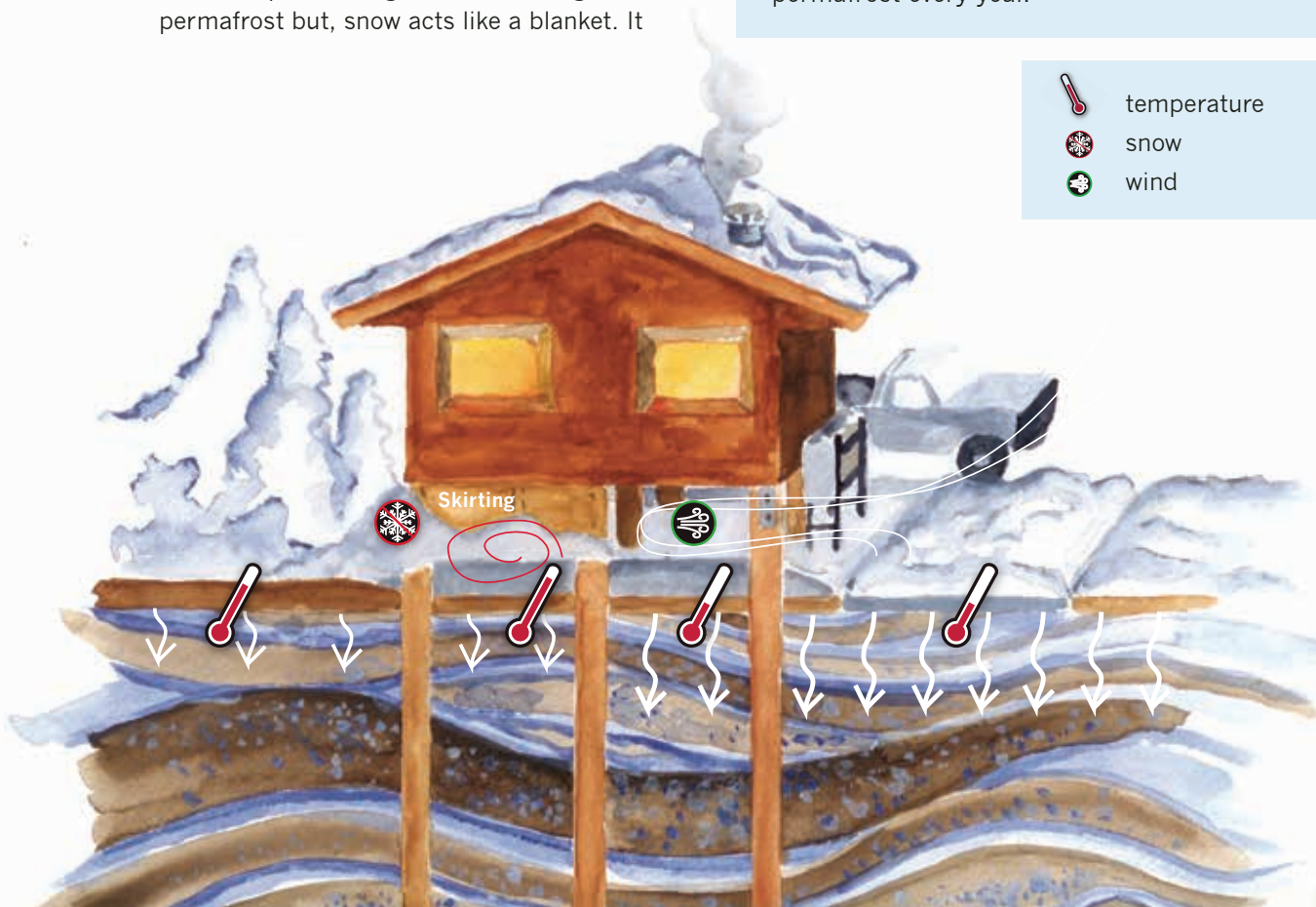
Winter is the season when permafrost rebuilds. The cold temperatures and low snowfall in NWT winters provide good conditions for refreezing the ground that thawed the previous summer.

There are three main factors that affect how much the permafrost will rebuild under your house in the winter. They are temperature, snow and wind. Cold temperatures must reach deep into the ground to recharge the permafrost but, snow acts like a blanket. It

keeps the cold from reaching into the ground and prevents permafrost from re-growing. Wind moves the snow around and deposits it in protected areas while exposing windswept areas.

Tip: Winter winds should be allowed to blow under your house to remove snow build-up. This exposes the ground to very cold temperatures that re-build the permafrost every year.

-  temperature
-  snow
-  wind



# Is My House on Ice-Rich Permafrost?

This is a good question that may not have an easy answer. The following clues and information on the next four pages may help!

Do I live in a community that is sensitive to permafrost thaw? pg 8

Some tree and plant species can be indicators of permafrost. Are these trees and plants around my house? pg 9

What type of soil do I have around my house? pg 9

Does my house have cracks in the drywall, sloping floors, doors that do not close properly, or an uneven roofline? pg 9

Ask around? The local housing corporation, town foreman or a neighbour will likely have information on permafrost in my neighbourhood. pg 9

Permafrost is often not that deep. Dig a hole to find out if permafrost is present. pg 9

Is my house built on a gravel pad with a space frame, screw jacks, pad and wedge, or on wooden or steel piles? If it is, there is a good chance it is built on permafrost (although not necessarily ice-rich). pg 11

**Inuvialuit** communities typically have very cold (-5°C to -8°C) permafrost. While this permafrost is in less danger of thawing, it does contain a lot of ice, which could cause major problems for homeowners.

**Gwich'in** communities are the most at risk of permafrost thaw with warm (-1°C to -3°C) ice-rich permafrost. Minor changes in temperature or surface conditions can cause the ice to melt causing thaw settlement.

**Sahtu** communities have warm permafrost (0°C to -2°C) and enough ice-rich permafrost to cause concern. Conditions can vary within the region.

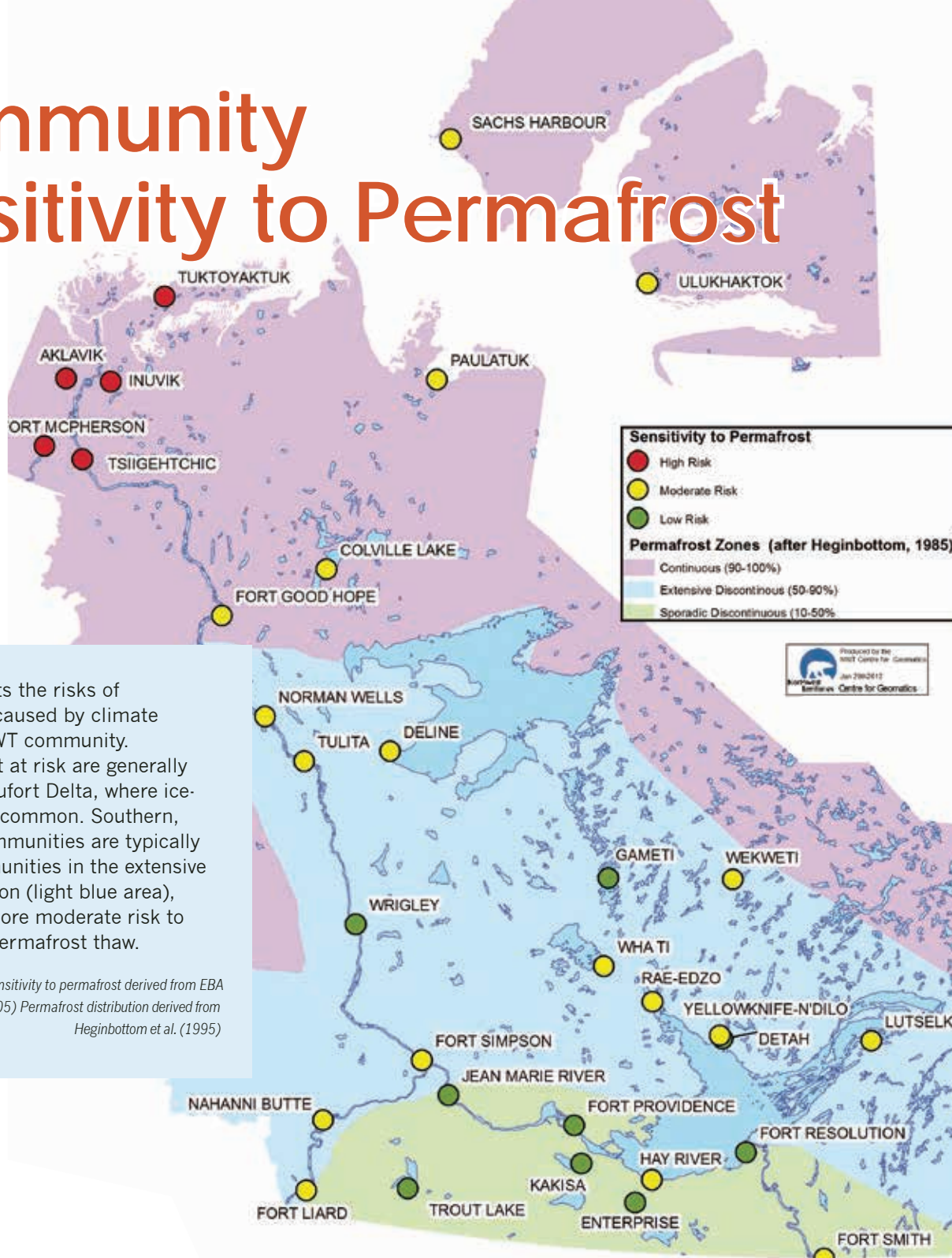
**Dehcho** communities have discontinuous permafrost, which is very warm (0°C to -0.5°C). It is not always ice-rich but isolated ice lenses do pose a risk to some homeowners.

**North Slave** communities often sit over bedrock. There are isolated patches of ice-rich permafrost, which are very thaw sensitive (0°C to -1°C). These lenses are often found in flat areas, which are preferred building sites.

**South Slave** communities are least at risk. There is sporadic permafrost and often sandy soils. The few ice-rich areas are very warm (0°C to -0.5°C) and prone to thawing.



# Community Sensitivity to Permafrost



This map highlights the risks of permafrost thaw, caused by climate change in each NWT community. Communities most at risk are generally located in the Beaufort Delta, where ice-rich permafrost is common. Southern, road accessed communities are typically at less risk. Communities in the extensive discontinuous region (light blue area), generally have a more moderate risk to infrastructure of permafrost thaw.

*Community sensitivity to permafrost derived from EBA Engineering Hoeve (2005) Permafrost distribution derived from Heginbottom et al. (1995)*

Produced by the  
NWT Centre for Geomatics  
Jan 2002/17  
Northern  
Territories Centre for Geomatics

# Investigate Your House and the Area Around It



*Black spruce and willows can be indicators of permafrost*



*Ask around for advice*



*Permafrost is often not very deep*

**Vegetation** provides a good clue about the existence of permafrost in a location. Look for an undisturbed area near your house that looks similar to your lot. Stunted black spruce, willows, labrador tea and peaty or spongy ground often indicate permafrost. Firm, well-drained soil and large trees such as white spruce and pine often indicate a lack of permafrost.

**Soil Type** can also be used to determine the location of ice-rich permafrost. Greyish fine-grained clay or river soil is more likely to contain ice-rich permafrost. Gravel, sand, and coarse soils allow water to drain through and, therefore, are less likely to contain ice-rich permafrost.

**House Shifting** is common in the NWT and is not always caused by permafrost. If you have cracks in the drywall, doors that don't close, sloping floors and an uneven roofline, your house could be built on permafrost.

**Ask your neighbours**, the community foreman, an equipment operator or the town Senior Administrative Officer (SAO). Many people will know about permafrost in your neighborhood.

**Dig a hole** to see if you hit permafrost. The best time to perform this test is in late summer, when the active layer is deepest. You'll know you hit permafrost when you can dig no deeper. Dig in a undisturbed area of your property that appears similar to where your house sits. Pay attention to the soil type as you dig.



Long Lake

# Seasonal Ground Shifting

## LEGEND

### Relative surface displacement

Moderate downward displacement (-3 to -6 cm)

Low downward displacement (-1 to -3 cm)

Stable ( $\pm 1$  cm)

Upward displacement (1 to 6 cm)

Loss of InSAR coherence

Trails

Roads

Transportation right-of-way

Existing buildings

Former building footprint

Water

No data

This map can be downloaded free of charge at [geoscan.ess.nrcan.gc.ca](http://geoscan.ess.nrcan.gc.ca)

Frame Lake

Niven Lake

Yellowknife Bay

Range Lake

This InSAR satellite map of Yellowknife shows changes in the elevation of the ground surface over the summer of 2010. Downward movement (yellow and orange) is most likely a result of thaw settlement and upward movement (purple) is typically caused by frost heave. The GNWT in partnership with NRCan is working to develop InSAR maps for all NWT communities to help with land-use planning.

Kam Lake

Lake

Short, N., et al. 2011

Kilometres

0.5

1

Universal Transverse Mercator Projection



# Foundation Types



## Steel Piles

Drilled six to twelve metres into the ground and permafrost. With a 50-year life expectancy, they should outlast your house. However, permafrost thaw can cause frost jacking and creep.



## Wooden Piles

Wooden piles are drilled into permafrost and have a shorter lifespan than metal. Permafrost thaw may cause shifting. Improperly treated piles are prone to rotting. A combination of moisture and air eat away at the top of piles and leave a weak shell with little strength.



## Pad & Wedge

Stacks of pressure treated lumber hold the foundation of the house off the ground. The blocks should be on a gravel pad and require periodic maintenance to keep the house level.

## Screw Jacks

This system uses adjustable jacks to keep the house level and are typically built on a gravel pad. Annual maintenance is required.



## Space Frames

Space frames are a relatively new technology to deal with unstable permafrost. The web of metal tubes provide strength and adjustability.



## In-Ground Basement

Concrete, or wooden basements, or houses with crawl spaces should not have been built on ice-rich permafrost. If you have a below-ground foundation, frost-heave is your biggest worry. Try to keep water away from your foundation.

# Living on Permafrost

Your house may not be at risk. A number of factors affect how your house will deal with the potential of permafrost thaw. If you have not had any problems with your foundation settling, you may not have to worry about permafrost thaw.

Permafrost does not change rapidly, but it can significantly deteriorate under a house over a number of years due to poor practices and maintenance. Understanding how permafrost is affected by the weather, your house and some of the things you do is the first step in reducing your risk of permafrost thaw.

Many properly-designed, built and maintained houses will outlast their owners and show no wear or tear from permafrost thaw. If your foundation is not very solid, you may want to pay more attention to why it is shifting. The following pages will help you understand how skirting, water, snow, wind and other factors affect the permafrost under your house and what you can do about it.



*A structure with foundation issues due to permafrost*



*Permafrost degradation affecting foundations*

# Water

Moisture or water under your house can promote permafrost thaw. Wet soil transfers heat to permafrost more easily than dry soil and can accelerate permafrost melt. Water in the ground can also cause frost heave and thaw settlement as the water freezes in fall and thaws in the summer.

Houses should be designed to move water away from the foundation. Gravel pads allow water to infiltrate and drain away from the house. If you have water pooling under your house you should take measures to reduce this.



**Tip**

**Moisture, ice or standing water under a house built on permafrost can cause problems. Follow these tips to keep moisture and water away from your house:**

- ◆ Extend the drainpipe from your eavestroughs away from the house.
- ◆ Encourage natural drainage.
- ◆ Encourage airflow under your house so moisture in the soil can evaporate.
- ◆ Add gravel under your house where water pools.



*Ice and water under your house may lead to permafrost degradation*



*Gravel pad should be domed to shed water*

## Ask yourself these questions:

- ◆ Where does the water come from?
- ◆ How can I reduce the water getting under my house?
- ◆ How can I promote evaporation of the water?

# Water Tank Overflow



*Frozen overflow from a water tank  
Photo credit: NWT Housing Corporation*



*Overflow from your water tank builds up  
Photo credit: NWT Housing Corporation*



*Ice and water causes rotting of piles*

If you have a water tank in your home, you should make sure the water tank overflow light is not burned out or missing. Overflow during your tank's regular fill up can lead to water running down the side of the house. If overflow happens frequently, the spilled water can soon become a small lake or a skating rink under your house.

Ice and water under your house contributes to permafrost thaw and can cause piles and blocks to rot or rust. Water seeping under skirting can cause even more problems because the water does not get a chance to evaporate in the summer.

## Here are a few simple solutions

- ◆ Install a water tank overflow light (this can be costly and may require an electrician).
- ◆ Replace a burned out bulb if that is all that is required.
- ◆ Divert spilled water away from your house with a PVC pipe.
- ◆ Place a five-gallon bucket under the overflow and dump it away from the house.
- ◆ If you are home when the truck is filling your tank, flash your porch light when the tank is getting full.

# Snow

Think of snow as nature's blanket. Air spaces in snow act like the air spaces in a down quilt. This means a snow bank will keep the ground much warmer than bare ground. Without a blanket of snow, permafrost will refreeze much deeper and to a colder temperature. When snow builds up under or around your house or you pile snow against the skirting to keep the floor warm, you are robbing the permafrost of the cold air it needs to freeze solid in the winter.



*Snowbanks hinder the cold from recharging permafrost during the winter*



*Storing materials under your house can encourage permafrost thaw*



**Deep snow blocks winter's frost from penetrating into the ground, thus warming permafrost and preventing it from reforming. Be aware of snow patterns around your house.**

- ◆ Instead of banking snow around your house, try shovelling it away from your foundation.
- ◆ Let the cold winter air reach deep into the ground. This will help the permafrost under your house to freeze solid and make it harder for warm summer weather to thaw it.
- ◆ Don't store anything under your house, this encourages snow build-up.

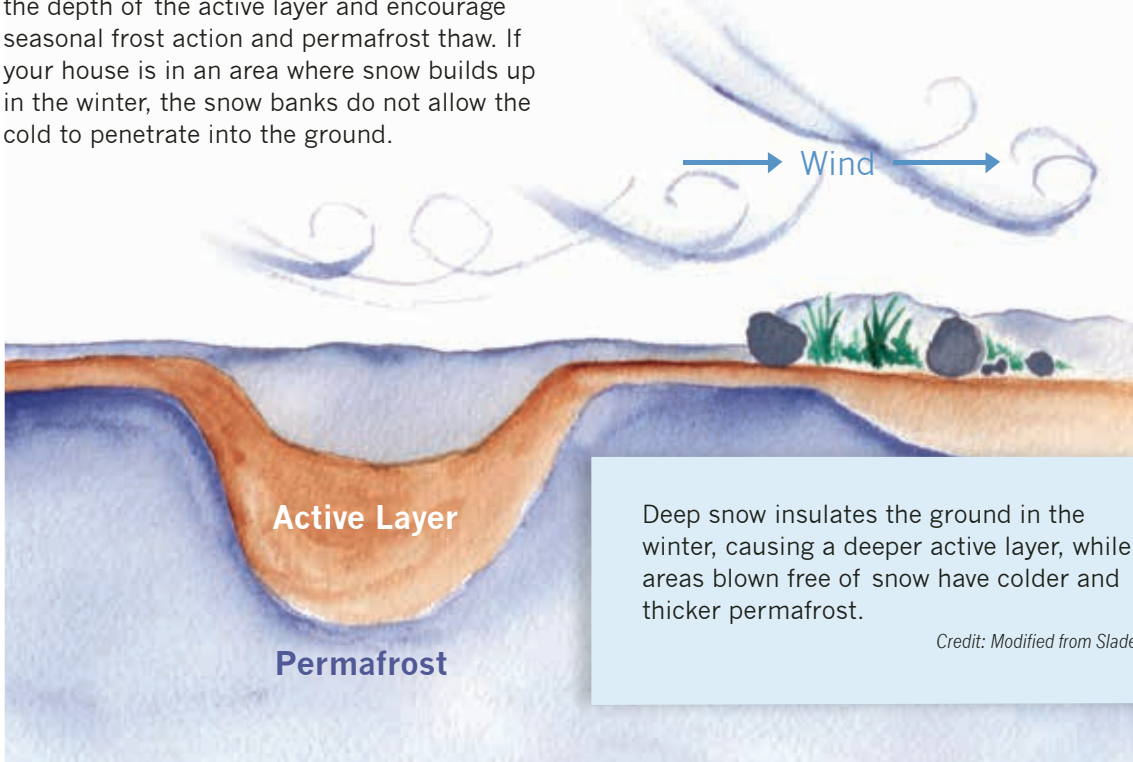


# Wind



*Snowbanks do not allow the cold to recharge permafrost in the winter*

Managing snow is especially important in windy communities above the treeline. Without trees to block wind and collect snow, the wind will deposit snow drifts anywhere there is a low area or obstruction. These snow drifts increase the depth of the active layer and encourage seasonal frost action and permafrost thaw. If your house is in an area where snow builds up in the winter, the snow banks do not allow the cold to penetrate into the ground.



**Tip**

**Good air circulation under your house allows moisture to evaporate in the summer and blows away snow in the winter.**

- ◆ Help the wind blow away snow by removing obstacles to the wind.
- ◆ Can you build a windbreak or snowfence on the windy side of your house (at least 4 metres away).

Deep snow insulates the ground in the winter, causing a deeper active layer, while areas blown free of snow have colder and thicker permafrost.

*Credit: Modified from Sladen*

# Skirting

Skirting is the plywood covering around the foundation of a house. It is usually added to make the house look neater or to keep the floors warmer in the winter.

Houses built over permafrost are generally designed to be raised off the ground with open sides to promote airflow under the house. This airflow helps refreeze the permafrost in the winter and encourages evaporation of moisture in the summer. Skirting limits evaporation and warms the air under the house leading to a slow degradation of permafrost.



*Skirting promotes permafrost thaw*



*Wire mesh allows airflow but keeps foundation clear*



Tip

**If you have skirting and are sure you live over ice-rich permafrost, consider the following general rules for the base of your house:**

- ◆ Remove your skirting altogether  
This will help permafrost to re-establish itself under your house.  
(Skirting should only be removed if you are concerned about permafrost degradation, as its removal may lead to an increase in heating bills.)
- ◆ If you can't remove your skirting, think about adding vents to allow cold air access in the winter.
- ◆ Wire mesh around building foundations allows air to blow through and prevents kids from playing under houses or materials from being stored there.
- ◆ Do not store snowmobiles and lumber or keep dogs under your house. This practice promotes snow build-up that insulates the ground in the winter.
- ◆ If cold floors are a problem, add insulation under the floor.
- ◆ Don't bank snow around your house in the winter.



# Other Factors



*Removing native vegetation can cause permafrost to thaw*



*Dryer vents should not be vented into crawl spaces*

**Vegetation:** Try not to disturb vegetation near your foundation, as dark exposed soil warms in the sun and causes permafrost to thaw.

**Clothes Dryer Vents:** Exhaust heat from clothes dryers can melt snow causing localized frost effects. It can also add extra heat to closed foundations and crawlspaces encouraging permafrost thaw. Properly installed clothes drier vents should be well off the ground on an outside wall and should not be vented into crawl spaces.

## ✓ Tip

### Shade

- ◆ The long days of sun in the northern summer, heat the ground and encourage permafrost thaw. Homeowners can provide shade to the southern side of their house, either through planting trees or shrubs, or by installing seasonal skirting on the southern side only.

# Heating Oil Tanks

Damages caused by a leak or spill in a home heating oil tank can lead to a very costly clean-up for an unfortunate homeowner. Therefore, it is in a homeowner's best interest to inspect and maintain their heating oil tank regularly. Permafrost thaw under the tank or the house can cause movement and put enough stress on fuel lines to cause a break. Homeowners should inspect their tank regularly to watch for signs of shifting and to ensure that it has a solid base, is not wobbly, and is not leaning.



*A wobbly or leaning tank can cause a break in your fuel line*



*Flex hose helps prevent broken fuel lines*

One way to help prevent shifting damage is to install a flexible connection, called a flex connector, between the fuel tank and the house. Flex connectors should be installed in a straight line and should be inspected routinely by the homeowner. If the flex connector becomes bent or is in an S-shape it indicates there has been movement of the tank or house.

More information on the maintenance and upkeep of heating oil tanks is available on the Environment and Natural Resources website at:

[www.enr.gov.nt.ca/\\_live/documents/content/Homeowners\\_Guide\\_Oil\\_Tanks.pdf](http://www.enr.gov.nt.ca/_live/documents/content/Homeowners_Guide_Oil_Tanks.pdf)



**Check your heating oil tank regularly:**

- ◆ Is it leaning?
- ◆ Is it wobbly?
- ◆ Do you have a flex connector?
- ◆ Is your flex connector bent or straight?

# Rotting Pilings?

The Town of Inuvik was built during the late 1950's and early 1960's. More than 70,000 local spruce logs were used as piles. These piles were drilled 15 to 20 feet into the 300-foot deep permafrost.

Building practices have changed since then and today most new houses are built using more durable steel piles. However, old, often untreated, wooden piles still hold up many houses throughout the NWT.



*Wooden pilings rot over time in warm, moist conditions*



*Rotten pilings put your foundation at risk*

More information on dealing with rotting or decaying wooden piles is available on the Public Works and Services website at:

[www.pws.gov.nt.ca/pdf/publications/Deteriorated-Wood-Pile.pdf](http://www.pws.gov.nt.ca/pdf/publications/Deteriorated-Wood-Pile.pdf)



Tip

## Do you have wooden pilings?

- ◆ Reduce water and snow from getting under your house and encourage airflow and evaporation in the summer to decrease the speed of rotting.

The lifespan of wooden piles is rated at 20 to 30 years but many have been around for much longer. If your house sits on wooden piles, make sure they are checked for rot. It may not be visible to the eye. Experts use a screwdriver or knife to detect soft spots in the wood.

Rot is most common below ground level, where moist soil and air meet. Low-lying wet areas and houses with skirting, which can prevent soil from drying out in the summer, are most likely to have rot. Prevent any further deterioration of your piles by decreasing the moisture in the soil around them.

Steel piles have a longer lifespan but rust and corrosion can have a similar impact. Good moisture prevention practices will make them last longer.

# Foundation Checklist!



*Proper maintenance of your foundation is important for your house*

If you are a private homeowner it is in your interest to maintain your permafrost. Now that you understand the basics of permafrost and how it affects your home's foundation it is important that you do some basic maintenance to keep your house in good shape.



*Level your house annually*

These basic maintenance tips will help you keep your house and its foundation in good repair:

- Level your house periodically if you are on a surface foundation.
- Clear snow from around the foundation so the ground can freeze more solidly.
- Check wooden pilings for rot.
- Reduce water and ice build-up under your house.
- Clean your eavestroughs and extend your downspouts so they drain away from the house.
- If snow is drifting or piling up because of the wind, remove the cause of the build-up.
- Check the natural drainage during a rainstorm. Is water flowing away from your house or towards it?
- Remove your skirting or add vents. Be aware, that removing the skirting may cause an increase in your heating bill. Only proceed if you are concerned about permafrost degradation.
- Try to reduce overflow from your water tank or, at least, divert it from under your house.
- Check your fuel tank. Do you have a flexible hose. Does the fuel tank show signs of tilting?
- Check to see if anything is stored under your house? If so can you store it elsewhere?
- Check that your drier vent is located on an outside wall.



In the Northwest Territories, many homes rely on frozen ground or permafrost to keep their foundation solid. Climate change along with improper house design and poor maintenance are leading to widespread permafrost degradation.

Learn about permafrost, how it acts as part of your foundation and what you can do to keep it from thawing. A few minutes and some simple solutions could save you thousands of dollars and help keep your house on solid ground!

This booklet is only meant as a guide and if you are facing serious permafrost related problems with your home you should contact an expert.



*Permafrost issues can be complicated; sometimes it's necessary to ask an expert*

## Sources and Resources:

- 1 Wolfe, Stephen. Living with Frozen Ground A Field Guide to Permafrost in Yellowknife, NWT. Natural Resources Canada, Geological Survey of Canada M41-8/64E. 1998.
- 2 Glossary of Permafrost and Related Ground-Ice Terms, National Research Council Canada. 1988.
- 3 Hoeve, Ed. Assessment of Foundation Sensitivity to Climate Change in the Northwest Territories. EBA Engineering. 2005.
- 4 Heginbottom, J.A. Dubreuil, M.A. and Harker, P.A. 1995. Canada – Permafrost, National Atlas of Canada, 5th Edition. Natural Resources Canada, Ottawa. MCR 4177. Scale 1: 7,500,000 1995.
- 5 Short, N., Stevens, C.W. and Wolfe, S.A. 2011. Seasonal Surface Displacement Derived from InSAR, Yellowknife and Surrounding Area, Northwest Territories; Geological Survey of Canada, Open File 7030, 1 CD-ROM. doi:10.4095/289578
- 6 Sladen, W. E., 2011. Permafrost; Geological Survey of Canada, Open File 6724, 1 Sheet. Doi: 10.4095/288000
- 7 Homeowner's Guide to Oil Tanks, Environment and Natural Resources 2010: [www.enr.gov.nt.ca/sites/default/files/brochures/homeowners\\_guide\\_oil\\_tanks.pdf](http://www.enr.gov.nt.ca/sites/default/files/brochures/homeowners_guide_oil_tanks.pdf)
- 8 Deteriorated Untreated Wood Piles: Cause Detection and Correction pamphlet, Public Works and Services: [www.pws.gov.nt.ca/pdf/publications/deteriorated-Wood-Pile.pdf](http://www.pws.gov.nt.ca/pdf/publications/deteriorated-Wood-Pile.pdf)



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