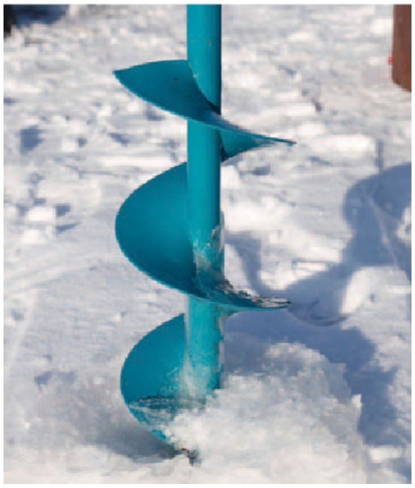
Top Rank Diamond Drilling Ltd.

ICE SAFETY PLAN

Top Rank Diamond Drilling Ltd.



Definitions

Circumferential crack	A crack that forms on an ice cover when it is overloaded. These are rounded cracks that are centered around the loaded area.
Constructor	A person who undertakes a project for an owner and includes an owner who undertakes all or part of a project by himself or by more than one employer.
Deflection test	A field test that determines the load capacity of an ice cover by monitoring deflection of the ice as it is progressively loaded.
Effective ice thickness	Good quality, well-bonded, clear and blue ice that is measured in an ice cover. Poor quality or poorly bonded ice should not be included in the measurement of ice thickness. White ice is considered to have ½ the strength of blue ice. Effective thickness is 100% blue ice + 50% white ice for a well-bonded layer.
Employer	A person who employs one or more workers or contracts for the services of one or more workers and includes a contractor or subcontractor who performs work or supplies services and a contractor or subcontractor who undertakes with an owner, constructor, contractor, or subcontractor to perform work or supply services.
Freeboard	The distance measured from the ice surface to the stationary water level in the hole below the surface. Ice is less dense than water, so it floats.
Global Positioning System (GPS)	A radio navigation system that allows land, sea, and airborne users to determine their exact location, velocity, and elevation 24 hours a day, in all weather conditions, anywhere in the world.
Gold's Formula	A formula developed by Dr. Lorne Gold to calculate the allowable load that can be placed on a floating ice cover.
Gross Vehicle Weight(GVW)	For the purpose of this Best Practice, this is the total weight of a road vehicle when loaded (i.e., it includes the weight of the vehicle itself plus fuel, freight, passengers, attachments, and equipment). Experience has shown that weighing the vehicle on a scale is the most accurate way to determine the GVW.
Ground Penetrating Radar (GPR)	A geophysical technique that uses radio frequency energy to image the earth's subsurface. It emits microwave electromagnetic radiation and then detects the reflections from land formations or objects it contacts below the surface.
Hazard	A hazard is a thing or situation with the potential to harm a worker.
Hazard assessment	An assessment of the worksite to identify existing and potential hazards before work begins at the worksite or prior to the construction of a new worksite.
Ice bridge	A constructed ice crossing over a river or stream.

Definitions

Ice cover	The portion of an ice surface that is floating (buoyant) on a river, lake, pond, or peatland and that is capable of carrying an external load.
Ice crossing	The portion of a floating ice cover that is used to support moving loads for the purpose of travelling from one side of a water body to the other.
Ice platform (pad)	The portion of an ice cover that is cleared or built with ice to support stationary loads.
Ice profiling	Technique used to measure the thickness of floating ice. It can be carried out directly, with a physical measurement, or indirectly, using GPR.
Ice road	A seasonal road built over frozen lakes or along rivers for the purpose of transportation. It usually consists of floating ice and ice that is frozen to the ground.
Operating window	The time during which the ice cover is sufficiently strong to open it to vehicles hauling loads (after construction and before closure).
Owner	Includes a trustee, receiver, mortgagee in possession, tenant, lessee, or occupier of any lands or premises used or to be used as a workplace, and a person who acts for or on behalf of an owner as an agent or delegate.
Professional Engineer	A person who is a professional engineer within the meaning of the *Professional Engineers Act.*
Radial crack	A crack that forms on an ice cover when it is overloaded. It radiates away from the load area like a spoke on a bicycle wheel.
Risk	A measure of the probability and severity (consequence) of an adverse effect to the safety and health of workers, property, or the environment.
Safe Work Procedures	Written instruction detailing all steps and activities of a process or procedure to guarantee the expected outcome.
Water lens	A pocket of water in the ice.
Winter road	A seasonal road built with snow or ice over land and ice for the purposes of transportation. It will normally include ice crossings and ice bridges.

Ice Cover Hazards and Factors to Consider

1 Background

Planning for operations over floating ice covers requires a clear understanding of how the ice sheet must function to ensure a successful and safe project. This is especially important for constructors or employers who have no previous experience building ice covers. The following operational parameters must be identified at the outset:

- **load duration**
  The period that the load will be stationary on the ice cover.
- **Ice cover type**
  Freshwater lake ice, river ice, local flood ice, transported flood ice, or peatland ice.
- **load weights**
  The number and types of vehicles and equipment and their maximum gross vehicle weights (GVWs); this may also include loads imposed by foot traffic for special types of work.
- **schedule and operating window**
  Timing of the start of construction and start of work on the ice cover as well as the operating window required for the work.
- **employer capability**
  Employer experience, equipment availability, and worker training.
- **Hazard controls**
  Controls that reduce either the consequence and/or the likelihood of a hazard; choice of controls depends on the risk level, degree of operator control over the use of the cover, and the user's exposure.
- **Route selection constraints**
  Site access, hydrology, and site permits.

It is also important to consider who will be exposed to the hazards associated with the ice cover: the construction crew, vehicle operators, and members of the public. Normally, the construction crew who builds the ice road faces the greatest risk because crew members go out on the ice with minimal information at the start of the season. This can be dealt with by adhering to controls implemented during the pre-construction and construction phases. Following the construction phase, vehicle operators use the roads to haul loads. Although they may be hauling the heaviest loads, the hazards they are exposed to are minimized through use of the hazard controls.

Members of the public may be at risk if they attempt to access an ice cover when it has been closed by the operator and the operational controls are no longer in place. Consequently, it may be necessary to develop other controls to deal with hazards to the public.

2. Ice Cover Type

Ice type considers how the ice forms, a factor that affects the ice cover's strength, variability, and quality. Freshwater ice, often referred to as blue ice, forms naturally on lakes and rivers and can be similar in strength across all surfaces (Figure 1).

Rivers are more dynamic and subject to currents, so are consequently more variable (Figure 2).

Natural flood (white) ice, which occurs when water floods the surface of natural ice, can be of lesser quality due to the presence of snow and unfrozen water (Figure 3).

Constructed flood ice built by qualified personnel with good practices can generate ice that is comparable to freshwater blue ice in strength and uniformity. The ice types with the least strength and quality are frazil ice (Figure 4) and jam ice (Figure 5).

ICE TYPES (Ashton 1985)

figure 1:
Clear blue lake ice

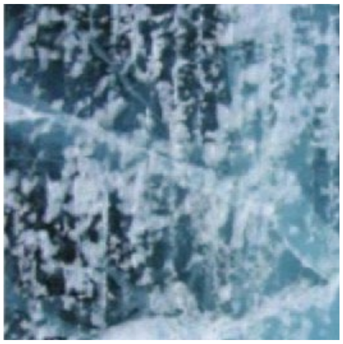


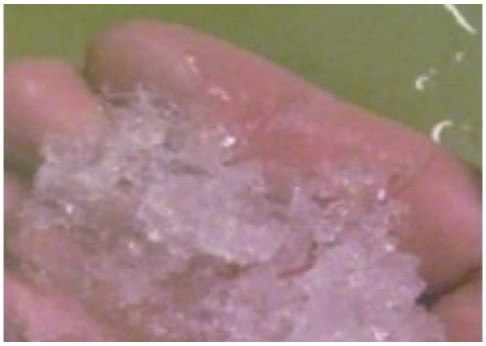
figure 2:
Clear blue river ice

Blue ice: *Ice that grows below the layer of surface ice under calm conditions. It usually forms vertical, columnar crystals that contain few air bubbles. It appears to be blue because it's clear enough to see the water underneath it.*

figure 3: white (snow) ice

White ice (snow ice): *Ice that forms on top of the surface ice by natural or man-made flooding of snow. It's white because it contains a significant number of air bubbles. White opaque ice, or snow ice, is normally considered to be only half as strong as blue ice.*

figure 4:
frazil ice (slush ice)



Frazil ice (slush ice): *Ice made up of disk-shaped ice particles that form and join in agitated water. It is usually found in rivers or streams with turbulent waters.*

figure 5: Jam ice

Jam ice: *An accumulation of ice that often forms on rivers or streams. It occurs when currents move pieces of ice cover to an area where they accumulate and freeze together to form very rough and thick ice covers.*

Peatland ice cover or frost depth (depth at which the peat is well bonded by ice) poses a greater risk because it can be overlooked. The depth of frost depends on the air temperature, composition/depth of peat or mineral soil, and the type of ground cover. The strength of saturated frozen peat depends on the peat's composition, water content, and temperature.

The ice cover type is a key component when conducting a hazard assessment and identifying appropriate hazard management. Higher loads could be used on reliable freshwater lake ice that has good ice monitoring data and a high level of operational controls.

Table 1: Ice Types and Their Variability

Ice Type	Ice Thickness	Quality and strength
Freshwater lake (blue) ice	Low variability over an area	Uniform ice quality
		Higher strength due to low variability
River (blue) ice	Medium to high variability over an area	Fairly uniform ice quality
	More prone to losing underside ice thickness to currents	Variable strength due to variable ice thickness
Natural overflow (white) ice	High variability over an area	Overflow ice, caused by natural water overflowing onto the ice surface, usually contains high air content and should not be relied upon in calculating effective ice thickness. White opaque ice, or snow ice is normally considered to be only half as strong.
Constructed flood ice	Good practices build uniform ice	Uniformity and quality depend on construction practices. If ice is constructed using sound construction practices, which. may include pumping fresh water directly onto the surface of bare ice (flooding), then this ice, once completely frozen and inspected, can be considered as having similar strength to freshwater lake ice. *
Peatland ice	High variability	Strength is highly variable due to water chemistry and temperature.
		Frost depth depends on air temperature, peat composition/ thickness and ground cover.
		Requires specialized analyses and investigation of ice conditions.

*Masterson, D.M., Invited Paper: State of the art of ice bearing capacity and ice construction, *Cold Regions Science and Technology* (2009) 2009.04.002

3. Types of Ice Cover Cracks

Any ice cover will have cracks caused by thermal contraction or movements in the ice cover. Cracks do not necessarily indicate a loss in the load bearing capacity of the ice, except when they are wet or they are radial or circumferential cracks associated with overloading the ice.

Eight mechanisms that cause cracks in ice covers are:

- Excessive loads
- Differences in ice thickness and buoyancy
- Snowbanks
- Thermal contraction of ice
- Thermal expansion of ice
- High winds
- Water level fluctuations
- Dynamic waves.

figure 6

Plan view of radial (spoke-like) and circumferential (round) cracks forming on overloaded ice

Load-induced cracks are those caused by moving or stationary loads that are too heavy for the ice. Field studies have shown that gradually overloading the ice leads to three stages of cracking, as shown in Figure 6:

- Radial cracks may be observed originating from the center of a load, like spokes on a bicycle wheel. This usually occurs at about one half of the failure load. Radial cracks are a warning that the ice is overloaded and the load should be removed immediately.
- Circumferential cracks are those that start forming a circle around the load. Circumferential cracks circle the load like the ripples caused by a stone tossed in a pond. They are warning that the load is about to break through the ice and personnel should be evacuated from the loaded area.
- Circumferential cracks that connect with radial cracks to form pie-shaped wedges indicate the ice has failed at this point and the load can fall through at any time, as experienced by the D10 Caterpillar operator in Figure 7.

figure 7

Breakthrough of a D10 Caterpillar tractor following formation of a circumferential crack pattern

Thicker ice may provide a warning, but thinner ice can fail so rapidly that radial cracking cannot be relied on for any warning.

figure 8

Normal longitudinal cracking caused by buoyancy of the thickened ice over the 20-metre-wide travel lane

Differences in ice thickness and buoyancy cause longitudinal cracks to form along the road in the middle of the cleared lane (Figure 8). As discussed in

The thicker ice in the cleared lane rises above the ice that's depressed beneath the heavy snowbanks. This causes an upward bending of the ice cover that reaches a maximum in the middle of the cleared lane. When the bending becomes severe enough, cracks form on the surface of the ice to relieve the stress. In most cases, the cracks do not extend deep enough to create a breakthrough hazard.

Sometimes several longitudinal cracks can intersect on the surface. Under the right conditions, a shallow piece of ice can pop out (Figure 9). These pop-outs, like potholes on regular roads, are a hazard because they can cause vehicle damage.

figure 9

Longitudinal cracks that have intersected and caused a block of ice to pop out

Cracks can occur under snowbanks that are built by snow piled into windrows along the edge during snow clearing, as shown in Figure 10. These cracks form because the snow depresses and bends the ice cover underneath the snow. Cracks are also more likely to form because the ice cover is thinner here due to the insulating effect of the snow. Most of these cracks start on the bottom and extend upward, but they usually do not reach the surface. However, some of these cracks extend to the top of the cover, creating a wet crack that is a hazard.

These cracks should be monitored, and all traffic kept clear of these areas until these flooded areas have re-frozen. Any activities around snowbanks should be conducted with great care. Consideration should be made in the initial ice design to create enough working space on the ice sheet so that snowbanks do not need to be moved once established. Additional guidance for snow clearing in the vicinity of snowbanks is provided in Section 4.1.6.

figure 10

Evidence of wet cracks underneath a snowbank from water that flowed through the cracks and froze on the surface

Thermal contraction cracks are caused when ice shrinks due to significant cooling. These cracks are usually distributed randomly over the ice and spaced well apart. Snow removal tends to promote thermal contraction cracks because it exposes the surface to rapidly changing air temperatures. Thermal contraction cracks are usually dry but should be monitored because they can become wet cracks if they are subject to further contraction or heavy loads.

figure 11

Pressure ridge about two meters high and several hundred meters long that formed adjacent to a road over lake ice

Thermal expansion can lead to pressure ridges, which are portions of the ice sheet that have moved together to form ridges that can rise up to three meters above the surface and extend for hundreds of meters (Figure 11). These ridges often occur after the formation of thermal contraction cracks that have filled with water and refrozen. If there is a sudden warming of the ice, then the ice sheet expansion is accommodated by upward movements of ice at weak (thin) locations in the ice sheet. These tend to form on larger lakes (several kilometers across) where the thermal expansion effect can accumulate over large distances.

Pressure ridges can challenge operators because they can be areas of reduced bearing capacity or sources of water or be difficult to cross. Pressure ridges can recur over several years and local knowledge may help in identifying potential pressure ridge locations. Upheaved pressure ridges should be avoided due to their unpredictable nature. Pressure ridges should be well marked if in the vicinity of ice crossing alignment and the travel path should be re-routed.

Wind cracks often result in ridge formations that can be parallel or perpendicular to the shoreline. Ice covers should be inspected for wet cracks after experiencing sustained winds of 55 km/h or more early in the season. Wet cracks must either be repaired or avoided by relocating the activities on the ice cover.

Water level fluctuation cracks usually occur in rivers but can occur in lakes when lake levels change. Cracks can also occur in rivers downstream of dams that control water levels. These cracks are almost always wet, tend to follow the shoreline and occur around grounded ice features. In severe cases, the ice cover can separate completely and form a significant drop (Figure 12). It is best to avoid areas of grounded ice features that have water level fluctuation cracks around them. These cracks should be checked before permitting loads to cross them.

figure 12

Hinge crack that became a break along a lake shoreline when the water level dropped

Dynamic waves caused by vehicles travelling too quickly over the ice can cause ruptures in the ice where it is thin or weak. The most common form of rupture is the crown-shaped blowout (Figure 13). These can be two to 20 meters across but tend to occur away from the thickened ice and in thinner ice areas.

figure 13

Blowout caused by speeding vehicles creating dynamic waves that release their energy at weak areas in the ice

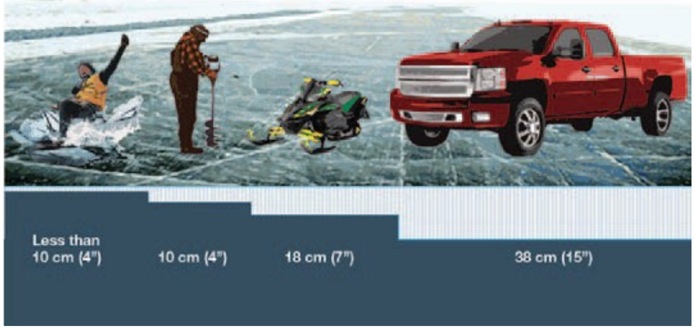
4. Types of Loads

Load types consider the anticipated demand on the ice cover in terms of the number and weight of the loads (Figure 14). Five load types are identified:

1. Foot traffic (total load less than 120 kg) such as workers carrying out initial testing of the ice
2. Snowmobiles (total load less than 500 kg) used at the beginning of the season to pioneer a trail for ice road clearing or for one-time access to a site
3. Light vehicle traffic (total load less than 5,000 kg) to move personnel and light equipment to a worksite across an ice cover that has been cleared of snow to promote ice growth
4. Construction vehicles/equipment including amphibious vehicles (total load less than 22,500 kg) used to clear snow and build ice
5. Heavy vehicle traffic (22,500 to 63,500 kg) for moving heavier equipment across an ice cover that has been cleared/built for this purpose.

Heavier and more frequent loads require greater hazard controls to offset the higher risk of ice failure.

figure 14: Recommended minimum Ice Thickness for blue Ice



5. Load Duration

Load duration must be considered because it affects the success or failure of the ice cover and the way the carrying capacity is analyzed (Table 2). Vehicles moving across the ice cover are analyzed using a different design approach than is used for stationary (immobile/parked) loads such as a drill rig or disabled vehicle sitting on the ice cover.

This provides some specific recommendations for slow-moving vehicles and short- duration (less than two hours) stationery loads on ice covers. For medium-duration loads, some preliminary recommendations are provided; heavier stationary loads require recommendations from a professional engineer.

Table 2: Load Duration

load Duration	observed effects	Design options for Carrying Capacity
Slow-moving loads with stops of short duration (less than two hours)	Initial cracking of the ice cover	Refer to Section 4
Stationary loads of medium duration (less than seven days)	Ice deflection that approaches freeboard	Refer to plan for ice checks
Stationary loads of longer duration (seven or more days)	Excessive creep deflection – water on ice	Professional engineer or client approval by 3rd party ice company professionals (IE. Big Ice)

a. Schedule and Operating Window

Scheduling of ice cover operations depends on ice quality and strength, weather conditions, and traffic requirements.

Weather conditions usually dictate the timing of construction start-up. Air temperatures and snow cover affect the growth of the ice cover (extent of cover, thickness, and stability). Climatic data and local ice conditions are important for evaluating the probable operating period.

A project with a high number of vehicle crossings could require that an ice cover remain open for as many days as possible, so achieving an early start can be very important. For projects with a low number of vehicle crossings, a long ice cover season is not as critical; therefore, identifying a few weeks within a season to safely move a few heavy loads may be the priority.

A preliminary schedule needs to be established to determine what seasonal conditions or constraints exist.

b. Owner/Employer/ Constructor Capability

Experienced owners/constructors/employers may take the overall responsibility for planning, preparing, designing, building and operating ice covers. The owner/constructor/employer's experience can therefore be critical in selecting the route, equipment, and people required to build and operate a successful ice cover. Owners/ constructors/employers of the ice cover may maintain overall project control, but the constructor/ employer's role remains crucial to the successful construction and operation of the ice cover.

The following attributes should be considered when reviewing constructor/employer capabilities:

- Experience in building similar ice covers
- Experience in building ice covers in the same region
- Experience of key staff
- Availability of equipment for construction
- Health and safety plan for working on ice
- Demonstrated knowledge and understanding of this Best Practice
- Knowledge of ice bearing capacity and factors affecting it.

c. Route and Site Conditions

The use of floating ice covers is most frequently associated with seasonal transportation facilities such as winter roads or ice bridges. Winter roads make use of ice covers on lakes and peatlands that will not support traffic loading unless frozen. Winter roads and ice bridges can improve or provide access to remote communities or allow seasonal access for construction or re-supply at remote sites. Use of ice covers for seasonal transportation purposes require route planning and recognition of certain site features that will directly influence the application of this Best Practice. Those features that must be recognized and evaluated in the planning process are discussed in this section.

i. Previous local experience

The first step in planning for use of an ice cover is to thoroughly evaluate previous use of ice covers along the route or at the site. Much of the technology for understanding ice behavior has evolved from field observations and experience. Contractors with prior experience with similar ice covers at the site or at nearby sites can provide field experience that is valuable. However, caution is still advised when considering field experience because water levels, weather, and ice conditions can vary from year to year. Contractors may have to alter their methods and equipment to adapt to changes in ice conditions that differ significantly from what they're accustomed to seeing.

ii. local Climate

Ice growth and capacity is directly linked to the climatic conditions at the site during the time of construction activities. The parameters of importance are mean daily temperature and snow cover. Local climatic variations may have to be considered when applying temperature and snowfall data from a meteorological station near to the project location.

Throughout Northern Canada, warming trends caused by climate change are affecting the function and design of seasonal infrastructure that relies on frozen conditions. The greatest changes are being documented during the winter months in the northernmost part of the provinces and territories. The last published Canadian Climate Normal, a 30-year running average of climatic data to which any individual year is compared, are for the period 1971 to 2000. The last 10 years have included three of the warmest winters on record. What may be of greater significance is the range of variability currently observed between a "warm year" and a "cold year." This variability, coupled with the substantial changes in precipitation that accumulates as snow on the early season ice surface, can impede normal ice growth.

iii. Route selection over lakes, Ponds, and muskeg Terrain

The following factors must be considered at the planning phase when lake ice is used in a winter road route alignment:

- **access onto and off the lake ice surface**
  This must be a technically and environmentally acceptable route. Avoid river and stream outlets/inlets as the lake ice cover near them is usually unreliable.
- **water depth along the chosen lake crossing**
  A rough bottom condition caused by unforeseen shoals and sandbars can initiate lake ice fractures and should be avoided wherever practical.

1. **overall water depth along the route**
   A route that follows continuous deep water is often the most effective alternative, particularly for heavy loads that require severe speed restrictions to manage the ice deflections that occur from movement in the ice and water.

Routing a winter road across frozen peatlands can also expose workers to ice failure hazards that are often overlooked. Open peatland or muskeg terrain can include a mosaic of bog and fen landforms, as shown in Figures 15 and 16. The fens can be ponds that are hidden by a thin layer of floating live vegetation. There are documented cases of construction equipment breaking through thin frozen peat unexpectedly, resulting in operator fatalities

Planning winter routes over peatland requires the same caution as planning routes over rivers. A terrain assessment carried out by a geomorphologist or geotechnical engineer using stereo aerial photos will identify areas at risk. Aerial photography and summer aerial views can provide important information. This assessment should be verified by route reconnaissance, and appropriate plans should be developed to monitor the thickness of ice or frozen peat before construction equipment is deployed.

figure 15

Right-of-way over muskeg terrain

Muskeg terrain is sensitive and there may be requirements to minimize damage from a winter road. A scar of a winter road across this type of terrain is shown in Figure 16.

figure 16

A scar of a winter road across peatland

iv. River and stream Covers

River ice is less predictable than lake ice. It is affected by fluctuating water levels, under-ice currents, and bottom conditions that can shift from year to year. Specific route or site factors that must be carefully considered when planning ice bridges across rivers include:

- **Choose the best site**
  Where several crossing sites are considered practical, choose the site that has the deepest water and most uniform bottom conditions. This is often the widest crossing site, unlike an appropriate crossing for a structural bridge.

Be cautious of the proximity of islands because they are features that are commonly created by active erosion or deposition, signifying channel shifting and unpredictable currents.

- **be aware of variations in ice thickness**
  The presence of naturally drifting snow on river ice combined with under-ice currents can result in highly variable ice thickness. These conditions require a high degree of vigilance to confirm and monitor ice growth and variations in ice thickness. It is recommended to have ice thickness verified with accuracy by technical aids such as Ground Penetrating Radar (GPR) profiling.

- **map the river bottom**
  Sand bars and other features that determine bottom topography can affect ice cover thickness and extent. River bottom topography should be mapped with either manual water depth measurements or with geophysical methods (sonar or GPR).

- **ensure river bank is stable**
  Locations for access to and from the ice surface should be chosen where river bank stability is considered acceptable from hydrological, geotechnical and environmental perspectives.

- **be aware of other factors**
  Water level under the ice can be affected during the operating period by factors that are not common but on occasion have been known to result in unsafe conditions. For example, river estuaries near tidewater affect ice bridges on the James Bay Winter Road in Ontario. River flow data can be obtained from the Water Survey of Canada: **http://www.ec.gc.ca/rhc-wsc/**

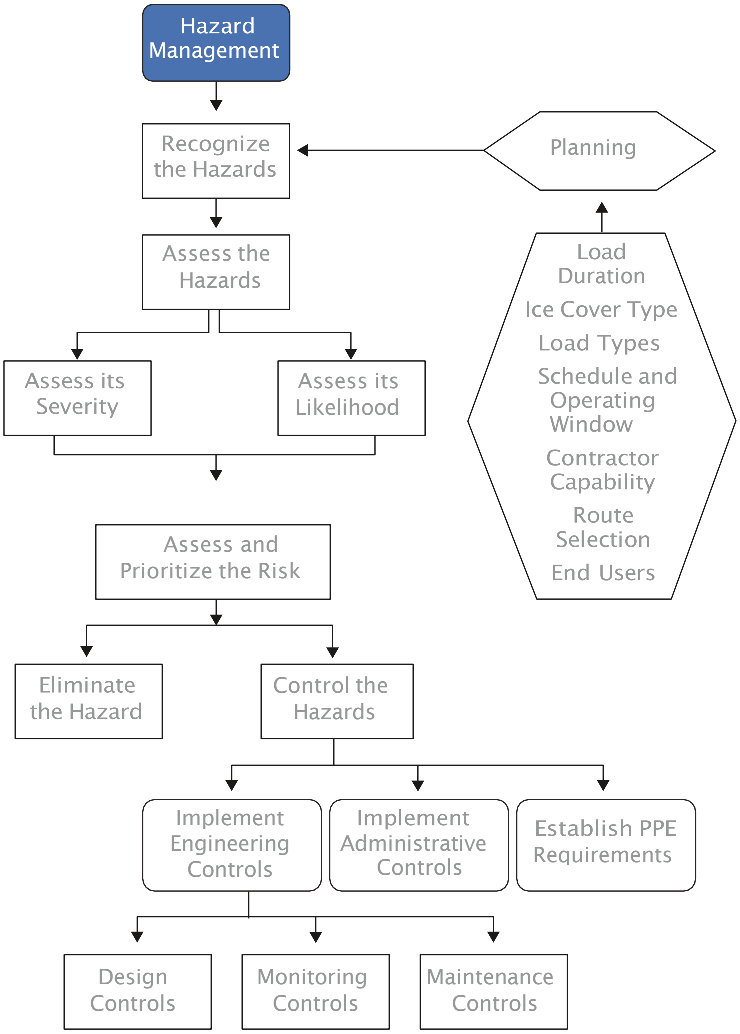
figure 17

Winter road access over a river bank

Ice Cover Hazard Controls

The hazard management approach is shown in Figure 18 and in the following example, where the risk of ice breakthrough and cold-water immersion is assessed for an ice road. (This approach is adopted from the Government of Alberta's *Best Practice for Building and Working Safely on Ice Covers.*)

figure 18: flow Chart for Hazard Recognition, assessment, Control, and elimination



1. **Recognize the hazards:** Failure of the ice cover and breakthrough of a person or vehicle.
2. **assess the hazards** (This approach is adopted from the Government of *Alberta's Best Practice for Building and Working Safely on Ice Covers.*)
   i. Assess the severity of consequences: fatality; loss of property; short-term cover closure and repair.
   ii. Assess the likelihood of consequences: likely to remote with a potential of once in the life of the ice cover.
   iii. Assess and prioritize the hazards based on risk:
      A. Assess: Classify the risk from low risk to substantial risk according to both severity and likelihood.
      B. Prioritize: Choose a load capacity (and equivalent ice thickness) based on risk level and hazard controls that will be implemented during operations.
3. **Control or eliminate the hazards.**
   i. Eliminate the hazard: Choose another route that does not require an ice cover.
   ii. Implement engineering controls (Section 4)
      A. Design controls (Section 4.1)
         - Use appropriate bearing capacity factor.
         - Design lane widths.
         - Adjust road alignment to control speeds.
         - Position snowbanks.
         - Set ice performance criteria.
      B. Monitoring controls (Section 4.2)
         - Define ice quality requirements and restrictions on ice cover use.
         - Monitor ice conditions: thickness and ice cracking.
         - Identify maintenance actions.

C. Maintenance controls (Section 4.3)

- Flooding of thin ice.
- Repair of damaged ice.
- Close ice cover or detour road if conditions do not meet ice performance criteria.

iii. Implement administrative controls (Section 5)

A. Develop ice safety plan for:

- Exploration drill sites
- authorized users
- unauthorized users.

B. Develop and deliver training/hazard awareness programs for:

- Exploration drillers and helpers
- authorized users
- unauthorized users.

C. Develop rules for construction and operation

- Minimum ice thickness for equipment and workers
- Safe work practices.

iv. Establish personal protective equipment (PPE) requirements (Appendix C)

- Identify PPE needed.

Engineering design controls: These are controls that are considered during the design phase so that they can be incorporated during the construction and operation of the ice cover.

monitoring controls: These controls are used in conjunction with the monitoring criteria set out during the design phase to determine when the ice cover is ready for construction or operations, or when there is a need for repairs or maintenance. They involve measuring the ice thickness and regularly observing ice cover quality (cracking).

Maintenance controls:
These controls are used in conjunction with the performance criteria and monitoring programs to address portions of the ice cover that may be compromised by poor ice conditions (e.g., cracking or thin areas).

Administrative controls: These controls, documented in an Ice Safety Plan, must be explained to workers who will work on the ice, including the hazards they may encounter and the steps they need to take to reduce their exposure to the hazard.

d. Design Controls

i. Gold’s formula

All guidelines currently in use in Canada are based on a technical paper published by Dr. Lorne Gold in 1971 entitled “Use of Ice Covers for Transportation”. Gold’s Formula is

$$P = A \times h^2$$

where:

- **P** is the allowable load in kilograms.
- **A** is a risk factor that determines the likelihood of failure (as described in the next three paragraphs and chart on page 17).
- **H** is the effective thickness of good quality ice (cm).

Gold suggested a range of A-values for lake ice that corresponds to a range of safe ice thicknesses for a given load or a range of acceptable loads for a given ice thickness. However, at higher A-values within these acceptable ranges, additional hazard controls must be implemented to reduce risk of breakthrough. Table 3 identifies allowable loads for a measured ice thickness for various A-values that are in common use together with an interpreted level of risk. Table 4 describes the hazard control procedures to be used for the A-values and interpreted level of risk.

For example, if your task is to move a 15,000-kg load across an ice cover, you may choose A-values of 3.5, 4, 5, or 6. If you need to get the load across the ice and have a very short schedule and operating window, then you could select an A-value of 6 because it requires a minimum ice thickness (h) of 50 cm. However, this is a substantial risk that would require you to implement the hazard controls identified for substantial risk in Table 4. For a more conservative approach, you may select a low risk A-value of 3.5, where the minimum ice thickness (h) is 70 cm. This A-value requires the hazard controls identified for low risk in Table 4.

In between these two A-values are two other choices: A of 4 and A of 5. An A-value of 4 is tolerable risk and the minimum ice thickness for 15,000 kg is 65 cm. An A-value of 5 is moderate risk and the minimum ice thickness for 15,000 kg is 55 cm. Both require you to implement the corresponding hazard controls in Table 4 for tolerable and moderate risk.

Table 3: Allowable Loads In kgs. for a-Values and Effective Ice Thickness

low Risk ← allowable load (P=kg) → substantial Risk

h=effective Ice Thickness (cm)	a=3.5	a=4	a=5	a=6
	low Risk (kg)	Tolerable Risk (kg)	moderate Risk (kg)	substantial Risk (kg)
20	1,400	*	*	*
25	2,200	*	*	*
30	3,150	*	*	*
35	4,300	4,900	6,120	7,350
40	5,600	6,400	8,000	9,600
45	7,100	8,100	10,100	12,100
50	8,750	10,000	12,500	15,000
55	10,600	12,100	15,100	18,100
60	12,600	14,400	18,000	21,600
65	14,800	16,900	21,100	25,300
70	17,100	19,600	24,500	29,400
75	19,700	22,500	28,100	33,700
80	22,400	25,600	32,000	38,400
85	25,300	28,900	36,100	43,300
90	28,300	32,400	40,500	48,600
95	31,600	36,100	45,100	54,100
100	35,000	40,000	50,000	60,000
105	38,600	44,100	55,100	63,500
110	42,300	48,400	60,500	**
115	46,300	52,900	63,500	**
120	50,400	57,600	**	**
125	54,700	62,500	**	**
127	56,450	63,500	**	**

Limitations: This table must be used in conjunction with the hazard controls identified in Table 4.

*Refer to Table 5.
**Seek the advice of a professional engineer.

Gold's Formula has been used extensively since 1971 and forms the basis for all infallible measure of the carrying capacity of an ice cover and must be combined with ice monitoring, maintenance, and administrative hazard controls.

The required ice thickness for a given vehicle load must be determined in conjunction with the hazard control process outlined in Section 3. An appropriate A-value is chosen based on balancing risk level against operational controls. Those controls are usually linked to project requirements. For example, if the project requires heavy vehicle traffic and a high traffic volume, then it may not be feasible to design and build an ice cover based on a conservative (low) A-value. However, the risk posed by choosing a higher A-value can be balanced by implementing hazard controls to reduce the risk of the breakthrough hazard. Table 4 shows how A-values are used with appropriate controls to maintain the safety of the ice cover.

Table 4: a-Values and Hazard Controls
(Not To be Used for Loads less Than 1500kG – Use Table 5)

a-value lake Ice	a-value River Ice	level of Risk	Hazard Controls		
			monitoring Controls	**maintenance Controls**	**administrative Controls**
4	3.5	Low	Manual ice measurements and checking of ice quality	Repairs and maintenance as needed	Orientation and instruction for workers and operators Routine worksite observations to enforce rules of ice cover
5	4	Tolerable	· Program of regular manual ice measurements · Ice quality monitoring program	Repairs and maintenance as needed	· Ice safety plan · Orientation and instruction for workers and operators · Routine worksite observations to enforce rules of ice cover
6	5	Moderate	· Daily program of regular ice measurements or program for regular GPR ice profiling plus manual ice measurements · Ice quality monitoring program	Regular repairs and maintenance	· Ice safety plan · Orientation and training for workers and operators · Daily enforcement of rules of ice cover
7	6	Substantial – special provisions	· Program for regular GPR ice profiling plus manual ice measurements · Ice quality monitoring program – flexibility for alternate measurements	Daily program of repairs and maintenance	· Ice safety plan · Orientation and training for workers and operators · Daily enforcement of rules of ice cover

ii. effective Ice Thickness

Effective ice thickness (h) as established in Table 3 is defined as the good quality, well-bonded clear and blue ice that is measured in an ice cover. White ice is considered to have ½ the strength of blue ice. Effective ice thickness is 100% blue ice + 50% white ice for a well-bonded layer (refer to the Treasury Board document for further information). Poor quality or poorly bonded ice should not be included in the measurement of ice thickness. The following are examples of ice that should be excluded from the measurements if they are encountered:

- Ice layer with water lens (>5 mm diameter) with a cumulative volume greater than 10% of the total volume.
- Ice layer with visible, incompletely frozen frazil (slush) ice.
- Ice layer that is poorly bonded to the adjoining layer.
- Ice layer that has been found to have a strength less than 50% of good quality blue ice (a number of specialized methods are available for determining ice strength).
- Ice that has wet cracks.

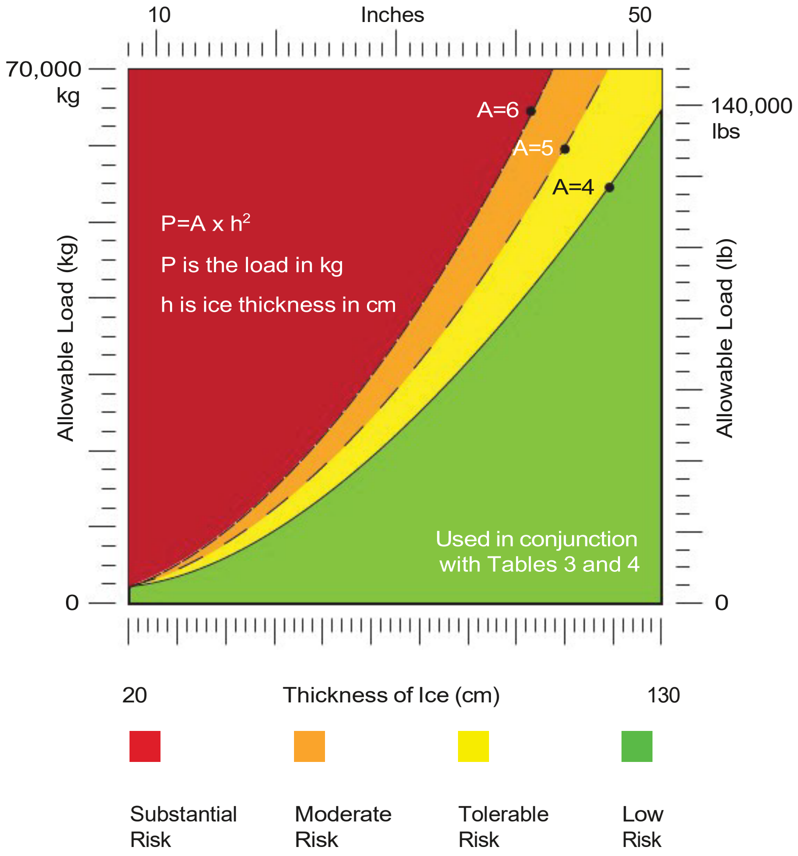
The number and coverage of the ice thickness measurements can also factor into the calculation of the allowable loads—more measurements increase the confidence of ice measurements, as does taking the measurements over a wide area. Follow the procedure described in Ice Monitoring Controls (Section 4.2) to determine the minimum ice thickness. Table 3 and Figure 19 show the calculated loads for A-values. Table 4 describes the hazard controls to be used with the A-value and interpreted level of risk.

iii. Recommended short-Term working loads on Ice Covers

It is important to determine the weight of the equipment or vehicles before they are placed on the ice cover. Although equipment/vehicle manuals often provide weights, these often do not include the weight of fuel, extra equipment, or personnel. When in doubt, equipment or vehicles should be weighed to determine actual weight.

A professional engineer should provide recommendations for loads greater than 63,500 kg.

figure 19: Ice bearing Capacity Chart



Gold's Formula, Table 3, and Figure 19 should not be used to estimate the minimum ice thickness for loads less than 5,000 kg. Instead use Table 5.

Table 5: Minimum Ice Thickness for Lighter Loads

load/situation (slow-moving loads)	minimum effective Thickness (cm)
Person walking (120 kg)	10
Snowmobiles (Maximum weight machine + rider <500 kg)	18
3/4 ton 4x4 vehicles (Maximum GVW of 5,000 kg)	38

Limitations: Must be used in conjunction with hazard controls outlined in Table 4 for A=4 for lake ice or A=3.5 for river ice.

iv. effect of sudden and extreme Temperature Changes

Rapid Cooling of the Ice

Sudden temperature drops (e.g., more than 20°C over a 24-hour period) produce severe thermal stressing as ice contracts (shrinks). During ice contraction, dry cracks (Figure 20) can form or existing cracks can grow and these could become wet if they extend through the entire thickness. The ice cover should be checked for cracks that may affect load capacity. Determine what, if any, steps are necessary to maintain load capacity. Snow cover on the ice may slow down thermal changes and can hide cracks.

figure 20

Longitudinal ice contraction crack

warming of the Ice

A warm period when the air temperature remains above freezing for 24 hours or more allows the ice to warm rapidly from the surface down. These effects are greatest on bare ice and are reduced by increasing depths of snow cover. Even though the ice may have adequate thickness, ice strength can be substantially reduced the longer it is exposed to sunlight and above freezing temperatures (Ashton 1986).

If the average air temperature exceeds 0°C for more than 48 hours, then the following steps should be taken:

1. Determine the minimum ice thickness.
2. Calculate the allowable weight for the measured ice thickness using Table 3 and reduce it by 50%.
3. Monitor ice conditions for signs of decay, cracking, and water.
4. Re-evaluate the allowable weight if the average air temperature remains below 0°C for more than 24 hours and the ice conditions meet the requirements for strength and cracking.

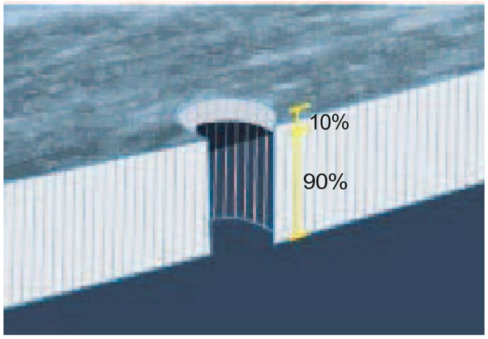
If circumstances dictate, consult with a professional engineer to assess the load capacity of the ice cover.

Ice bearing capacity can be reduced rapidly if the ice cover is subjected to warm air temperatures in combination with the longer daylight conditions that develop. Operations on the ice should be terminated well before this condition begins.

v. stationary loads

There is a fundamental difference between the behaviour of ice under short-term loads and long-term stationary loads. Under long-term loads (more than two hours but less than seven days), the ice continues to sag or deflect until it fails. Different methods are used to estimate the required ice thickness under stationary loads. There are also differences in how the ice cover is monitored and operated under stationary loads.

figure 21



Water level in an auger hole showing positive freeboard and no ice deflection

figure 22

Water level in an auger hole showing no freeboard and water is collecting on the ice because the ice has deflected under the load.

The safety risk in placing stationary loads that are heavier than 5,000 kg onto ice should be analyzed by a professional engineer. Table 6 provides recommended minimum ice thicknesses for vehicles weighing up to 5,000 kg. Under these conditions, ice deflection should be acceptable. Ice deflection can be checked by drilling a hole through the ice and measuring the freeboard. Freeboard is the distance measured from the ice surface to the stationary water level in the hole below the surface, and it arises because ice is less dense than water so it floats. If freeboard is less than 10% the ice thickness (Figure 21), then the ice is deflecting and should be monitored while the load remains on the ice. Loads should be removed before freeboard reaches zero (Figure 22), to prevent water flooding the ice surface through an opening in the ice cover.

figure 23

Stationary load (bulk sampling drilling rig) on constructed lake ice about two metres thick.

Figure 23 shows a 200 metric ton bulk sampling drill rig operating on floating lake ice that was 2 metres thick. An extensive ice monitoring program was in place during the 14 days of drilling operations to determine if the ice deflection and ice quality were consistent with performance requirements. The pad area on the ice should be twice the size the of the drilling rig to distribute the weight on the ice during operations.

Table 6: Minimum Ice Thickness for Stationary/Parked Loads UP To 5,000 kg. (For More Than Two Hours But less Than Seven Days)

load/situation	minimum effective Thickness (cm)
Person standing	15
Snowmobiles (Maximum weight machine + rider <500 kg)	25
Loaded vehicle >500 kg but <1,000 kg	32
Loaded vehicle >1,000 but <2,000 kg	41
Vehicle >2,000 but <3,000 kg	46
3/4-ton 4x4 vehicle (Maximum GVW of 5,000 kg)	55

Limitations: Must be used in conjunction with hazard controls for a low level of risk as identified in Table 4.

If a vehicle or equipment becomes disabled on ice that does not meet the requirements of Table 6, the occupants must be prepared with the necessary emergency kits and supplies and be ready to abandon the vehicle within two hours. The occupants should have a communications device so help can be dispatched in the event of an emergency. Workers must be evacuated immediately, and arrangements made to move vehicles offshore in accordance with the emergency plan.

vi. lane Dimensions

It is widely known that removing snow from the ice surface leads to thicker ice compared to areas that remain covered in insulating snow. Consequently, the snow that is on the ice must be removed or tamped down and snowbanks must be built along the sides of the road to build a cleared lane width.

However, there are two consequences when removing snow and building snowbanks: (1) the thicker ice in the cleared lane rises because it is more buoyant and (2) the thinner ice under the snowbanks depresses the ice cover because of the weight of the snow. As shown in Figure 24, this can lead to longitudinal cracks on the ice surface of the upward bending ice in the cleared lane and to cracks on the ice bottom of the downward bending ice underneath the snowbanks. The cleared lane cracks do not tend to be a hazard and can be managed through repairs. However, the cracks underneath the snowbanks can be hazardous if they extend upwards to the surface (Figure 25). These cracks are discussed in more detail in Section 2.3.

figure 24: effect of Cleared Road on Ice Thickness

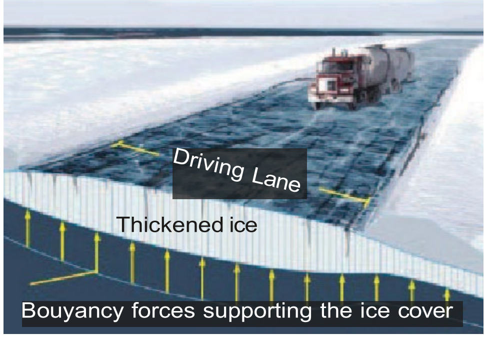


figure 25

Grader partially broken through thin ice beneath a snowbank

Table 7 recommends minimum dimensions for the cleared road width (bank to bank) and cleared driving lane width. In most cases, these recommended dimensions should provide enough snow storage space so that snow clearing equipment can clear snow into this space without needing to move the older snowbanks and travel over the thinner ice that would be beneath those snow banks.

Table 7: Recommended Minimum Road Dimensions

operating Vehicles	Cleared width – bank to bank (m)	Driving lane – width (m)
Light vehicle traffic (5,000 kg)	20	10
Construction (22,500 kg)	25	15
Super B Train (63,500 kg)	30+	20

figure 26

Haul truck on a 40-metre wide lane with low snowbanks

vii. Dynamic effects of Vehicle speed on Ice Covers

When driving on floating ice, a deflection bowl moves with the vehicle, generating waves in the water below the ice. If the speed of these waves is the same as the vehicle speed, the deflection of the ice sheet is magnified and this may overstress the ice cover. The speed at which the maximum magnification of the ice deflection occurs is known as the critical speed. Field studies have shown that vehicles travelling at critical speed increase ice stresses by about 50%, which can lead to extensive cracking, blowouts in thin ice, or breakthrough.

The critical speed for an ice cover depends on water depth below the ice and ice thickness. For example, for one meter of ice and 15 meters of water, the critical speed is approximately 50 km/h. Therefore, in this example the maximum speed should be set at half that value, 25 km/h. In shallower water, the critical speed is less.

Consequently, it is important to control vehicle speeds to reduce the chance of travelling at critical speed and cracking the ice cover. Speed limits need to be set to prevent overstressing. Speed limits depend on water depth, length of the ice crossing, hazard controls and project requirements.

Speed limits and vehicle spacing are discussed further in Section 5.2.

27: Dynamic waves

A slow-moving vehicle causes the ice to bend and forms a deflection bowl under the vehicle

A fast-moving vehicle causes the ice to bend and creates dynamic waves in the ice ahead and behind the vehicle

Dynamic Waves Caused by Speeding Vehicles

- At low speeds, the ice deflection bowl under the vehicle moves with it.
- As speed increases, the water flows away and generates secondary waves in the ice.
- As speed increases, the ice cover stresses and deflections are increased by the waves.
- At critical speed, the full energy of the water waves is trapped under the vehicle.
- At critical speed, the risk of overstressing the ice is higher.
- The vertical deflection of the waves in the illustrations is exaggerated to show the concept.

Other load Capacity methods

Other load capacity methods require more advanced field measurements and analyses. For example, the deflection test involves monitoring the deflection of an ice cover as it is gradually loaded, then analyzing the data to calculate the load capacity. Another example, the borehole jack test, provides a field measurement of the strength of the ice cover. Because these methods rely on field measurements of the ice properties, they can provide load capacities for specific vehicle configurations or ice conditions that cannot be accounted for using Gold’s Formula.

e. Ice Cover Monitoring Controls

i. Measuring and Recording Ice Thickness

Ice thickness is the primary measurement required to determine the safe working load that can be put on the ice (allowable load bearing capacity). Measurements are made in a regular spacing or pattern to provide sufficient coverage and verify the thickness of the ice cover (Appendix A and Appendix E).

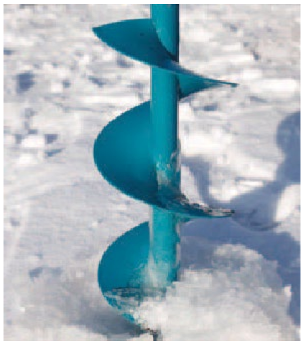
figure 28

Marked pine trees cut and placed as reference markers along an ice road

Ice tests must be completed before work begins and periodically during the work to ensure the safety of workers. It is imperative that a systematic procedure be implemented to document all ice thickness measurements.

Measurement locations should be taken either with a Global Positioning System (GPS) receiver or marked with stakes, or another reliable system (Figure 28) so that these locations can be tracked in future measurements or identified for repairs. This information is a key element in the ice safety plan. These measurements are vital to investigating any ice cover failures that may occur.

figure 29



An auger being used to drill a hole through the ice cover

Manual measurements are made by cutting a hole in the ice cover with an auger, a saw, or an ice chisel and then directly measuring the ice thickness (Figure 29).

Over the past 20 years, Ground Penetrating Radar (GPR) ice profiling has become a more common method, providing a continuous, non-destructive measurement of ice thickness over large areas or distances. GPR profiling can be combined with GPS to retrieve the data (Figure 30). GPR ice profiling should be carried out by trained personnel and the results reviewed by qualified professionals.

figure 30

Dual channel GPR ice profiling equipment (being pulled behind a snowmobile) measuring ice thickness and water depth in a single pass

Pre-Construction Ice Thickness measurements

An ice cover hazard assessment must be conducted and reviewed by field personnel before starting any ice thickness measurement. Suitable equipment and personal protective equipment must be provided and used as prescribed.

Initial testing should be conducted by at least two trained crew members travelling separately over the ice. The work could be carried out by travelling:

- on foot
- by snowmobile
- by amphibious vehicle.

The safe ice thickness limits for fully loaded vehicles must be known and followed at all times. During pre-construction ice measurements, calculate the minimum ice thickness required for fully loaded vehicles being used during pre-construction, using a conservative value of A=4 in Gold's Formula for initial use of the ice cover. Ice thickness can be measured using either the manual method (see Appendix A) or GPR method (see Appendix B).

Amphibious vehicles such as the Swedish Hagglund have been used to transport personnel on the ice during initial measurements. Light snow machines can be used (in pairs) as long as the ice is checked ahead of them to verify that it is thick enough for safe operation.

Procedures for measuring ice thickness before construction should also include the following:

- Testing should be representative of snow-covered and non-snow-covered areas.
- While testing, the crew should also be checking the ice for cracks and noting the snow load.
- If vehicles are used, two separate vehicles must be used at all times and must be separated at a safe distance unless ice conditions are known.
- Wheeled vehicles should be equipped with a winch.
- All vehicles must have two-way radios and/or satellite phones, as well as survival supplies.
- An agreed-upon call-in procedure must be followed with a safety contact in the base office.
- High-visibility (orange or red) survival flotation suits and other required PPE must be worn at all times (preferable to Personal Flotation Devices/PFDs).

- The route should be recorded on a map or with GPS coordinates; if others follow the tested route, it should be marked so it is easily identified. Use items such as high-visibility stakes or pylons, or flagging tape.
- Outfit all vehicles with appropriate safety equipment (Appendix C) and fuel for a full day's work.
- Follow safe operating speed guidelines (refer to Table 8 on page 30).
- A standard operating procedure should be prepared to document these requirements.

Some projects, such as hydrotechnical measurements or water sampling, involve working on foot on thin, floating ice. A hazard assessment must be undertaken, and special training, PPE, and safety protocols are required for such work. For example, working on river ice near open water requires water and ice safety training, PPE, and an emergency plan that takes into account the higher risk of breakthrough and immersion.

During Construction – Ice Profiling

Periodic ice thickness measurements should be conducted as the ice grows, to monitor its progress and approve the use of heavier vehicles. Ice thickness measurements can be carried out using either manual or GPR methods. The choice of a profiling vehicle depends on the minimum ice thickness required for the given vehicle weight.

In addition to procedures listed for pre-construction, consider the following when carrying out ice profiling:

- Calculate the required ice thickness limits for fully loaded vehicles (maximum of 22,500 kg) using A=4 in Gold's Formula for initial use of the road, when ice is measured by manual methods as described in Appendix A.
- Calculate the required ice thickness limits for fully loaded vehicles (maximum weight of 22,500 kg) using A=5 in Gold's Formula for initial use of the road, when ice is measured by GPR method as described in Appendix B.
- Follow safe operating speed guidelines (refer to Table 8 on page 30).
- Mark approved or tested lanes.
- Communicate with other personnel who have tested, travelled, or worked on the ice (check prior to starting work).
- Establish a procedure to ensure the field crew calls in to the safety contact.
- Outfit all vehicles with appropriate safety equipment (Appendix C) and fuel for a full day's work.
- Document these steps by preparing a standard operating procedure.

During operation – Ice Profiling

Ice profiling should continue for quality assurance purposes after the ice cover is opened to traffic or for other purposes. The ice cover would normally be open to vehicles used for patrol and reconnaissance such as heavy-duty pickup trucks. Ice covers used as work platforms and used recreationally may be serviced by snow-clearing and ice-flooding vehicles. The purpose of operational ice profiling is to confirm operational load limits over time and to allow those limits to safely increase with ice growth.

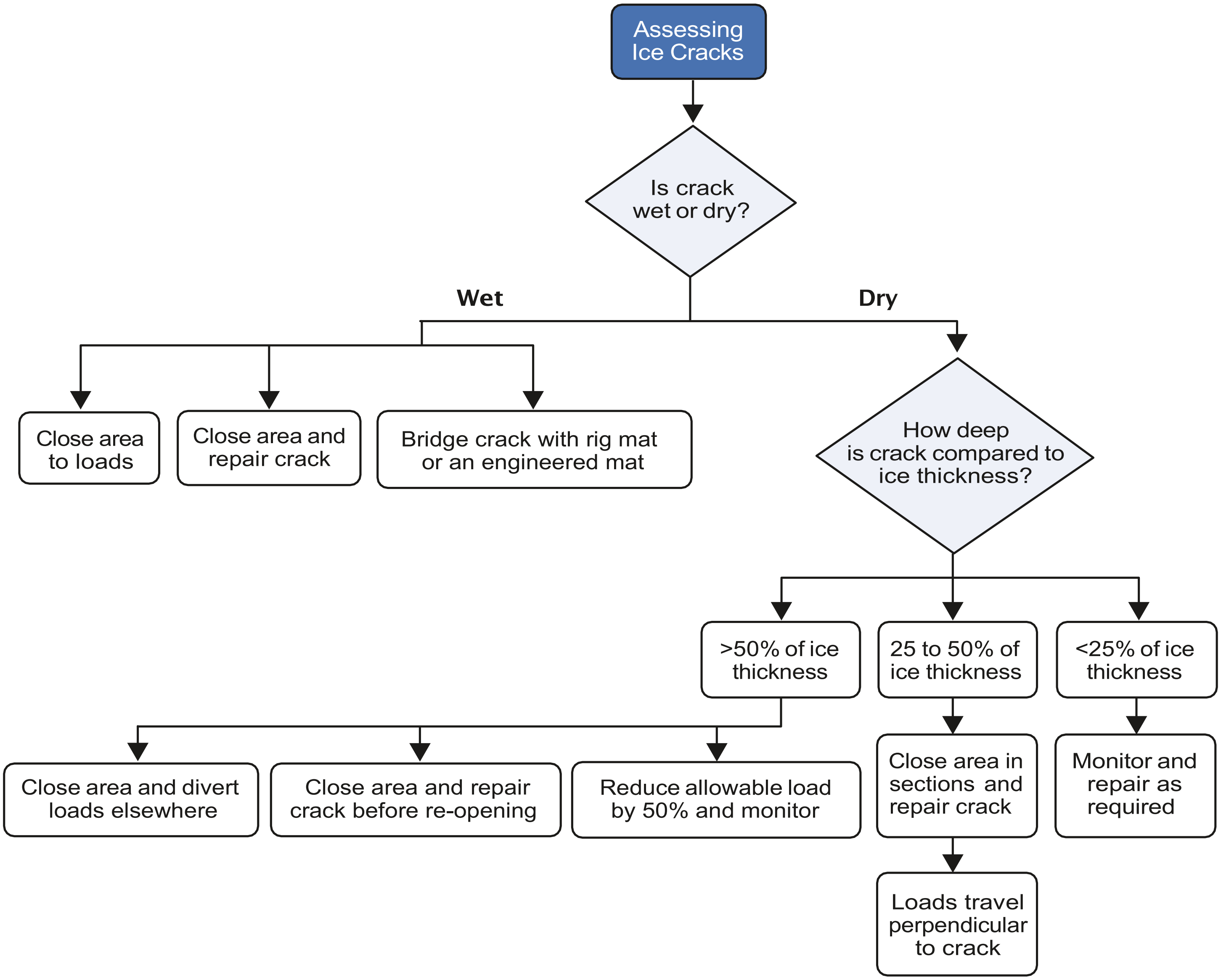
See Table F-1 in Appendix F for a sample ice cover inspection template.

For more information on ice measurements and ice profiling, see Appendix A—in particular, Table A-1: Recommended Maximum Spacing of Auger Test Holes, Table A-2: Recommended Minimum Frequency Of Auger Test Holes, and Table A-3: Ice Cover Profile Template. Also, see Appendix B: Guide for GPR Ice Profiling and Table F-1: Ice Cover Inspection Template.

ii. monitoring Ice Cracks

Surface cracks should be checked by noting their appearance, determining if they are wet or dry, and assessing their width and depth. The process for assessing ice cracks is shown in the flow chart below.

figure 31: assessing Ice Cracks



The water in wet cracks indicates that the cracks reach the bottom of the ice cover. Wet cracks that extend over the ice cover for several meters reduce the bearing capacity of ice. Theoretical studies show that the presence of one wet crack reduces the bearing capacity of the ice by 50% (Ashton 1986). Areas with wet cracks should be flagged off and workers kept away from them. These areas should also be repaired, bridged, or closed off completely to people and equipment/vehicles.

Dry cracks show that they do not penetrate the ice sheet and are not an immediate problem. Dry cracks that extend more than 50% of the ice thickness should be repaired immediately or avoided. Dry cracks may be hard to detect when covered by snow, and this is another reason to keep the ice cover clear of snow.

The following are recommended modifications to ice loads given the nature of the crack.

- Single dry crack (>2.5 cm thick): reduce load by one third or to 66% of allowable
- Intersecting dry cracks (>2.5 cm thick): reduce load by two-thirds or to 33% of allowable
- Single wet crack: reduce by one-half or to 50% of allowable
- Two wet cracks meet at right angles: reduce to one-quarter or to 25% of allowable

See Table F-1 for a sample ice cover inspection template.

f. Maintenance Controls

Repairs and maintenance should be undertaken to address cracks, thin zones, or other damaged areas that may compromise the load-bearing capacity of the ice cover. Snow clearing may also be required to keep the surface clear and to promote natural ice growth. Some ice conditions may require temporary closure of the ice cover to equipment or vehicles, as discussed in Section 5.3.

All cracks that extend more than 50% of the ice thickness should be repaired or traffic diverted around them. Major cracks that have been repaired should be checked once they have re-frozen. Rig mats can be used to bridge cracks that will not heal (re-freeze) or that have a change in elevation that prevents vehicles from crossing. Detours may need to be built around severely cracked areas.

figure 32

Flooding crew repairing an ice road

Safe Work Procedures for Working on Ice

Ice Safety Plan

When working on ice covers, there is always a risk of ice failure and breakthrough that can have potentially fatal consequences. Employers and constructors must conduct a hazard assessment. An Ice Safety Plan is essential to ensuring the health and safety of workers. The site specific ice safety plan should be written in conjunction with the employer and the professional ice crew (IE. Big Ice) to ensure all parameters are being met and complied with.

The Ice Safety Plan should be written and the employer must effectively communicate it to all supervisors and their workers who are affected or potentially may be affected by the ice cover hazards. The flow chart (Figure 33) provides guidance on how to develop an Ice Safety Plan and effectively communicate it to workers and supervisors.

g. Safe Work Procedures for Working on Ice

Standard operating procedures are an effective means of controlling hazards through administrative controls and are related to the actual operation of the ice cover. The most important operating procedures pertaining to ice covers are discussed below. The

h. Approved Use of Ice Covers

Traffic should be restricted to vehicles with a gross vehicle weight (GVW) that meets the requirements for bearing capacity of the current ice conditions. Furthermore, traffic should be restricted to ice covers that have been monitored and ice conditions that have been assessed, documented and approved by the owner (or their designate).

figure 33: Ice safety Plan

Identify existing or potential hazards and determine how to eliminate or control them.

- Start before work begins at the ice cover.
- Involve the affected workers.

1. Follow the flow chart in Section 3: Ice Cover Hazard Controls.

- Develop an Ice Cover Emergency Response Plan in conjunction with the Ice crew and employer

Develop an Ice safety Plan that incorporates:

1. Hazard elimination
2. Hazard controls
3. An Emergency Response Plan.

Inform and instruct all workers and supervisors about the Ice safety Plan and safe work procedures.

- Confirm their understanding.
- Discuss the Ice Safety Plan before work begins and when there are changes to the plan.
- Communicate details of the Ice Safety Plan at new worker orientations, daily pre-job talks, and work group and safety meetings.
- Make written copies of the Ice Safety Plan readily available to all.

Periodically review the hazard controls in the Ice safety Plan and update it as needed.

- Review at reasonable intervals to prevent the development of any unsafe working conditions or when there are changes in work.
- Review when there is a sudden, significant change in weather.
- Inform workers and supervisors of changes

Approved traffic areas should be identified with markers such as barricades, pylons, and signage (Figure 34).

figure 34

Barricade markers

i. Verifying Vehicle and equipment weights

The gross vehicle weight and the minimum ice thickness should be determined before deploying any vehicle or equipment on the ice cover. If necessary, the vehicle or equipment should be weighed with all of the components, fuel, tools, and gear that will be included with it. This information should be affixed to the vehicle or equipment where the operator can read it to make sure it is safe to go on the ice.

figure 35

Portable vehicle scale

ii. stationary loads on Ice Covers

Parked vehicles and equipment should be spaced no closer than two vehicle and equipment lengths for durations less than two hours. Parking for more than two hours on the ice cover should be prohibited unless the construction of the ice cover meets the requirements specified by the crew constructing the ice roads and surfaces. Otherwise, arrangements should be made to move disabled vehicles off the ice cover as soon as possible.

iii. minimum Distances between Vehicles and equipment

For light vehicles (up to 5,000 kg), the distance between vehicles should be at least 200 times the thickness of the ice. For heavier vehicles (greater than 5,000 kg and up to 63,500 kg), the distance should be increased to 500 times the ice thickness. If the water body is smaller than these limits, then only one vehicle or piece of equipment should be permitted on the ice cover at a time (Figure 36). A loaded vehicle should never overtake and pass a moving loaded vehicle going in the same direction.

figure 36

Sign that limits travel on the ice bridge to one vehicle at a time

iv. maximum speed when Travelling on Ice Cover

The maximum speed for loaded vehicles travelling across ice covers is 15 km/h for ideal ice and driving conditions. The speed limit when approaching shorelines is 10 km/h. Speed limits should be adjusted to local conditions by considering weather conditions, ice quality, vehicle loads, proximity of vehicles, and the hazard controls in place. Speed limits must be posted and may be lowered depending on ice conditions and vehicle loads.

> *The observations showed that vehicle speed was a factor for some of the failures. Particular caution must be exercised when approaching shore, or travelling close to it, because of more severe stressing of the cover due to reflections of the hydrodynamic wave. Vehicle speeds should always be strictly controlled when operating on ice.*
> Gold (1971)

Table 8: sUGGesTeD maXImUm sPeeD lImITs

Vehicle/Ice Conditions	suggested maximum speed limit (km/h)*
Vehicle profiling during construction	10
Vehicle approaching shore line	10
Vehicle passing flood crews	10
Load vehicles travelling in opposite directions	10
Meeting oncoming vehicles	10
Vehicle operating at the minimum ice thickness for its weight	15
Vehicle operating at ice conditions that are two times the minimum ice thickness for its weight	20

* Speed limits higher than these should be approved by a professional engineer. Heavily loaded vehicles should never pass each other.

erosion of ice, extensive cracking, or excessive wear due to use can increase the risk of breakthrough. Owners should suspend ice cover operations until these hazards can be eliminated or controlled.

Normally, ice covers are closed before spring thaw begins and the ice cover begins to decay. Decay of ice covers is affected mainly by solar radiation and by the reflecting properties of the ice surface. For example, ice decays more rapidly when its surface is bare and/or exposed to long hours of sunshine. Ice growth stops and ice decay starts before air temperatures rise above the melting point of the ice. Ice temperature and ice quality should be monitored regularly—especially during spring thaw—to determine if the ice cover has adequate bearing capacity to support ice operations.

i. Emergency Response Planning

All construction projects must have a written emergency procedure that complies with section 17 of Ontario Regulation 213/91 – Construction Projects. The plan should include the following:

- Identification of potential emergencies
- Procedures for dealing with the emergencies
- Procedures for rescue and evacuation
- Identification of emergency responders and evacuation workers

Using an Auger to Measure Ice Thickness While on Foot

Field crew members must walk in pairs when carrying out pre-construction manual ice profiling. Both members should wear flotation suits and remain at least 10 meters apart. Both members should be trained in rescue and self-rescue techniques and be equipped with appropriate equipment.

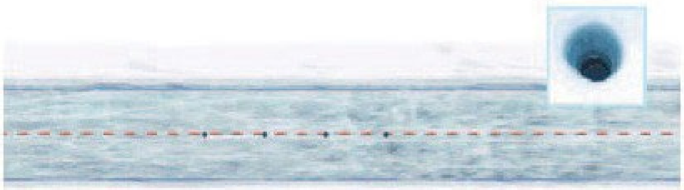
An ice auger should be used. Alternately, an ice chisel or axe may be used to test ice up to 30 centimeters thick. Over unknown water or known moving water (i.e., river, area of springs, etc.), the lead crew member should check for thickness in accordance with Table A-1.

Measurements should be taken using an ice thickness measuring stick, which has a foot to hook the underside of the ice cover. This allows for an accurate measurement of the ice cover and reduces visibility problems caused by poor lighting. The distance may be increased over known calm water and decreased for known currents or eddies. If the distance between test locations is increased, then the trailing crew member must trail further back and remain behind the previous satisfactory test hole. The locations of the test hole measurements should be recorded on a map and/or with GPS coordinates.

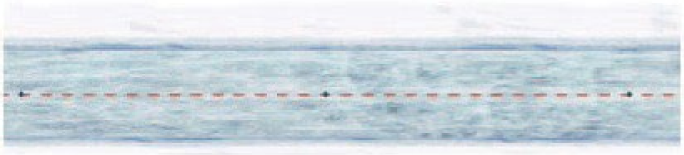
On lakes, the distance between test holes may be substantially increased with the trailing crew member remaining well behind. Extra caution needs to be exercised along shore, as the floating ice cover may actually be thinner near the shore. In addition, as progress is made across the lake, sampling distances will need to be shortened as the ice thickness begins to decrease. If any sample reveals clear blue ice less than 10 centimeters thick, the crew members are to leave the area immediately.

Using the procedures previously outlined, test crew members should establish a boundary for the project area. Ice thickness measurements should be taken at locations throughout the area, and the thinnest measurement of ice cover should be used as the measurement for all bearing and load-bearing capacity calculations.

figure a-1: examples of auger Test Hole spacing Patterns for River Ice with slow-moving Currents



Pre-construction: 10-metre spacing between auger test holes along centre line



Construction: 50-metre spacing between auger test holes along road centre line

Operations: 100-metre spacing between auger test holes along alternate sides of the road centre line

Guidance on Spacing and Frequency of Auger Test Holes In Ice

The number and spacing of manual auger test holes to check ice thickness depend on:

Table a-1: Recommended Maximum Spacing of Auger Test Holes for Measuring Ice Thickness

water body Type	Pre-construction	Construction	operations
Rivers – fast moving or high currents	5 m between test holes along center line or a minimum of 5 holes	25 m between test holes along alternating sides of center line	50 m between test holes along alternating sides of center line
Rivers – slow moving and within 250 m of shore	10 m between test holes along center line	50 m between test holes along center line Check known thin areas.	100 m between test holes along alternating sides of center line Check known thin areas.
Rivers – slow moving and more than 250 m offshore	20 m between test holes along center line	100 m between test holes along center line	200 m between test holes along alternating sides of center line
Lakes – within 250 m of shore	10 m between test holes along center line	50 m between test holes along alternating sides of center line Check known thin areas.	100 m between test holes along alternating sides of center line Check known thin areas.
Lakes – more than 250 m offshore	20 m between test holes along center line	100 m between test holes along center line	200 m between test holes along center line

Note: These are maximum spacings for ice auger measurements. Additional measurements may be required in thin areas.

Table a-2: Recommended Minimum Frequency of Auger Test Hole Measurements

Pre-construction	Construction	operations
Check every 2-3 days to monitor ice growth until minimum ice thickness is achieved to deploy heavier pieces of equipment.	Check every 4-7 days or more frequently to monitor for specific ice requirements for construction equipment and operations.	Test entire route or exploration drill pads area. Monitor thin areas as recommended by ice cover supervisor (e.g., every 2-4 days).

Note: More frequent measurements may be required to monitor changes in ice conditions due to environmental effects (e.g., warming, currents) or changes in loads (e.g., heavier, or more frequent loads).

Safety Equipment

Suggested Equipment To be kept In a Vehicle

Equipment to be kept in a vehicle should include:

- Thermometer to monitor air temperature
- First aid kit (checked and fully stocked)
- Fire extinguisher
- Warning devices (pylons, reflectors, flags, etc.)
- Waterproof matches/lighter and material to start fires
- Candles
- Sleeping bag or warm blankets
- Backup cold weather clothing
- Metal or ceramic coffee mug
- Flashlight
- Snow shovel
- Two-way radio, cell phone, or satellite phone
- Emergency rations: food (energy bars) and beverage mixes (water and instant coffee, tea, or hot chocolate powder)
- Spare gasoline
- Booster cables
- Extra belts and fuel filter
- Antifreeze
- Gasoline antifreeze
- Radiator antifreeze

Employers should inform workers if their vehicle or equipment is equipped with special safety features that would assist them when working on ice.

Suggested Personal Protective Equipment and Safety Equipment

Protective clothing and safety equipment should include:

- Axe or ice chisel
- 30 m (minimum) of 10 mm buoyant polypropylene rescue rope
- Belt or harness with D-rings
- A lifejacket or personal flotation suit such as a survival flotation device
- Ice rescue picks
- Whistle
- Warm clothing
- Insulated gloves (waterproof)
- Rubber-soled felt pack boots
- Sunglasses
- High-visibility clothing

Refer to Ch 7: Cold Stress of IHSA's *Construction Health and Safety Manual* (M029) for more information related to preventing cold-related illnesses.