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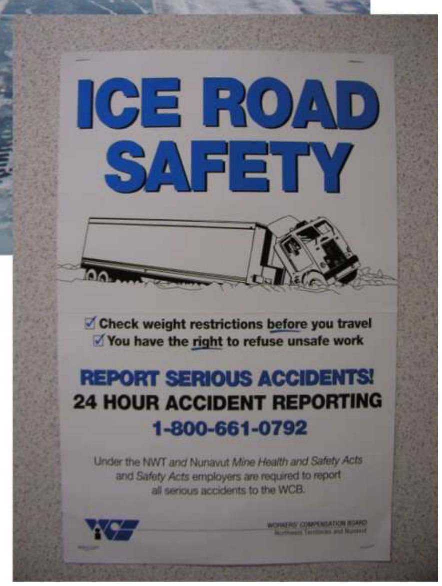
The Tibbitt to Contwoyto Winter Road in the NWT: Identification of Available Data and Research Needs

Paul Dominique Barrette



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ABSTRACT

Information on the Tibbitt to Contwoyto Winter Road north of Yellowknife was acquired by the author during a three-day field trip in March 2008. The construction and maintenance of this road, most of which is constructed over frozen lakes, is managed by the Joint Venture Management Committee (JVMC). It is a major access road to supply several mine sites. Build-up initiation occurs in December. When the ice thickness is deemed adequate, crews get on the ice with light vehicles. EBA engineers are in charge of design ice thickness, so as to ensure they can meet minimum ice thickness criteria. Flooding with pumps is used to improve ice surface quality and also increases the thickness of the ice cover. The ice road is a public-private road. Permitted speeds range from 10 to 35 km/h, but can go up to 60 km/h on expressways. Outstanding issues raised by JVMC include means of extending the season, how to mitigate the effects of blow-outs, and what is the role of load-induced crack accumulation.

RÉSUMÉ

Ce rapport résume les observations recueillies par l'auteur au cours d'un séjour de trois jours en mars 2008 sur la route d'hiver Tibbitt-Contwoyto, au nord de Yellowknife. La construction et l'entretien de cette route, en grande partie sur des lacs gelés, est l'affaire de la « Joint Venture Management Committee » (JVMC). Il s'agit d'une voie d'accès importante pour le soutien logistique de plusieurs sites miniers. Sa construction débute en décembre. Lorsqu'on juge l'épaisseur de la glace suffisante, le personnel a recours à des véhicules légers pour y circuler. À l'aide de certains critères, les ingénieurs de EBA établissent l'épaisseur minimale requise pour un accès sécuritaire. En pompant l'eau sur la glace, on améliore la qualité de la surface tout en contribuant à en augmenter l'épaisseur. Cette route est la fois publique et privée. La vitesse autorisée varie de 10 à 35 km/h, mais peut aller jusqu'à 60 km/h dans les voies rapides. La JVMC a soulevé certaines questions qu'il reste encore à éclaircir. Par exemple, comment allonger la durée de la saison, comment réduire les risques d'éclatement du couvert de glace et quel rôle joute l'accumulation de fractures générées par les chargements successifs.

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1. Introduction

Winter ice roads are an important part of the way of life in the North. They are used to move both people and goods into regions which otherwise would not be accessible in the winter. Ice roads have implications to both an individual's way of life as well as the northern industry. For example, ice roads are used to bring in large quantities of food and material to the diamond mines in the interior regions of the north which otherwise would be have to be flown in at much greater expense (millions of dollars). The government of the Northwest Territories as well as Industry place high value of this and they work together to try to ensure safe roads. A large part of the technology for ice roads was initially developed at the National Research Council (NRC) of Canada in Ottawa by Dr. Lorne Gold. Predictions for safe loads on ice roads are often based on his pioneering research. However, his research was performed many years ago and it did not take into account the possibility of the very large and heavy trucks that are used today.

This report summarizes the information that was acquired by the author during a short field trip this year (March 25 to 27 2008, inclusively) on the Tibbitt to Contwoyto Winter Road north of Yellowknife. This is a major ice road built and operated during the coldest winter months and used to supply several mine sites. The purpose of this short trip was three-fold:

1. To get familiar with the construction methods and operations.
2. To obtain information about establishing design loads.
3. To find out about what their needs are, and how NRC can contribute to their venture.

Much of what is included in this report was obtained through a number of conversations with several people, namely:

- Mr. Erik Madsen, Director of the Winter Road Operations and head of the Joint Venture Management Committee (JVMC), an organization financed by the mining industry to manage the Tibbitt to Contwoyto Winter Road.
- Mr. John Zigarlick, Chairman of NUNA Logistics Limited (the company that builds and maintains the road).
- Mr. Alan Fitzgerald, Senior Superintendant of NUNA Winter Road Services Ltd.
- Dr. Samuel A. Proskin, geotechnical engineering with EBA (the company that JVMC sub-contracts to advise them on engineering issues).
- Mr. Albert Brandl, Superintendant of Lac de Gras camp.

Additional information was retrieved from documents obtained from Mr. Madsen and Mr. Brandl, as well as from JVMC's web site (www.jvtcwinterroad.ca). This report is an attempt to bring the wealth of information thus acquired into a reasonably concise summary of what that venture is about. The author takes sole responsibility for potential oversights, omissions or misinterpretations of the data that may be included herein.

The report is divided into three sections, addressing each of the three objectives stated above.

2. Information related with the ice road

2.1 Background

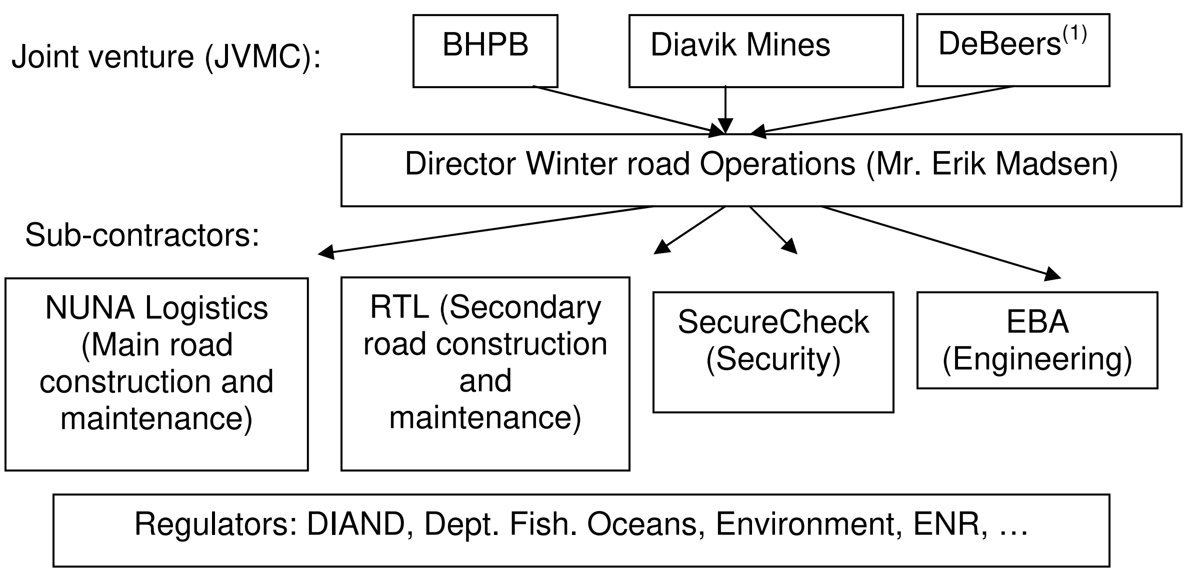
"The Tibbitt to Contwoyto winter road begins at Tibbitt Lake at the end of Highway 4 about 60 kilometres (36 miles) east of Yellowknife, Northwest Territories, Canada (see summary of information in Table 1). From there, it winds its way north linking four diamond mines – Ekati, Diavik, Snap Lake, and finally Tahera at the north end of Contwoyto Lake, Nunavut Territory. The total length is 600 kilometres. It is a region served by no other highways and for 10 months of the year accessible only by air. A secondary segment was built over the last two seasons to accommodate potential closure in the main road." (www.jvtcwinterroad.ca)

Table 1: A few facts about the ice road (from JVMC's web site).

First year – 1982
Original purpose – Re-supply the Lupin Gold Mine at Contwoyto Lake, Nunavut Territory
Length – 600 kilometres (360 miles)
Width – 50 metres (160 feet), narrower on portages (12-15 metres) 25-45 feet
Ice thickness – Engineer proven to support light vehicle loads at 70 cms (27-28 inches) increasing to full highway truck loads as the ice thickens, often exceeding 107 cms (42 inches). In 2008, it exceeded 150 cm.
Speed limits on ice: loaded trucks – 25 kph (15 mph) with some areas 10 kph; empty trucks – 60 kph (35 mph)
Speed limits on land (portages): – Pending portage usually 30-50 kph range because on land and off ice
Manager – Joint Venture Management Committee comprised of BHP Billiton Diamonds Inc. and Diavik Diamond Mines Inc., plus DeBeers soon to join
Constructor – Nuna Logistics Ltd (main route), RTL Enterprises Ltd. (secondary route)
Engineering – EBA Engineering Ltd.
Security –SecureCheck

Most of this road (85%) is constructed over ice. It must therefore be rebuilt each year. The remaining 15% is divided into a series of 64 'portages', that connect the ice segments, and these also need to be maintained throughout the season. The itinerary is modified to some extent from year to year. The winter road is open during 10 weeks. "Diesel fuel is the largest item trucked north on the road. Other supplies include cement, tires, prill (ammonium nitrate) for explosives manufacture, and construction materials." (www.jvtcwinterroad.ca)

JVMC, whose organizational chart is schematized in Figure 1, looks after the construction and maintenance of the road every year. Before each winter season, a budget is assigned for that purpose, and a fee structure ($/ton/km) is established. This year, the fee was $0.21/ton/km. (JVMC is not allowed to make a profit.) This is substantially less expensive than if these supplies were to be shipped by air.



(1) Expected to join within a year

Figure 1: JVMC's organizational structure.

2.2 Construction and maintenance

The initial 60 km segment of that road is a normal gravel road (Highway 4) maintained by the government of the NWT. JVMC got a 'License of Occupation' from DIAND, allowing it to maintain the 64 portages. Other leases from different agencies are also required (to allow quarrying, pumping of water…) from the regulators.

2.2.1 Building the ice cover

Build-up initiation occurs in mid to late December, when helicopters are sent out to drill a few holes. If the ice thickness is deemed adequate, crews get on the ice with light winter vehicles, such as the Hagglunds (Figure 2), a Swedish-built amphibious vehicle, with the purpose of flattening the snow cover. Snow is an insulating material that slows down ice growth considerably. It is the main reason behind strongly fluctuating ice thickness profiles. The Hagglunds can be supported by about 30 cm of ice, and can be fitted with ploughs, though they are not designed for it. This, and probably the low temperatures, may be part of the reason why these vehicles tend to break down a lot (it is a high maintenance vehicle). Snowcats (Figure 2), built by Bombardier, can also be used for that purpose and require about 40 cm-thick ice cover. They are not amphibious but are fitted with side booms connected with a steel cable that is meant to encroach on the ice should the vehicle go through it. These vehicles work in pairs and they are preceded by the ice profiling crew. The roads are located by GPS and follow the same path as the previous year's, except when trouble areas need to be avoided. Heavier vehicles are only allowed on the ice once it has achieved sufficient thickness.

Figure 2: A Hagglund (left) and a Snow Cat (right), two light vehicles used in the initial stages of road construction to clear the ice.

During construction, ice thickness is measured on an on-going basis either by drilling holes through the ice or, more systematically, with a ground penetrating radar (GPR)(Figure 3). More information on this is provided later.

Figure 3: A ground penetrating radar (GPR) system, pulled by a light vehicle (left) or a snowmobile (right), is used to conduct high density ice, thereby closely monitoring ice thickness.

"Based on the minimum ice thickness along the entire route, acceptable load weight limits are set. With each additional inch of ice, the allowable weight increases. When a thickness of 70 cm (27-28 inches) is achieved over the entire road, very light loads known as 'hotshots' are dispatched. When the ice reaches 107 cm (42 inches) along the entire road, it is thick enough for a super B tanker fully loaded with 48,000 to 50,000 litres of fuel. A super B is a tractor hauling two tanks of fuel and weighs approximately 41-42 tonnes when loaded." (www.jvtcwinterroad.ca) In situations where the truck is not fully loaded, the fuel is distributed in the tanks in a specific way so as to spread the weight. Because of a cold winter this year, construction and maintenance went smoothly, with up to 165 cm ice thickness, thereby allowing early access to the SuperB loads.

Following a warm 2005-2006 season, where the road had to be closed earlier than anticipated, Mr. Madsen and NUNA devised new measures to prevent this early closure to happen again:

- A secondary route was built at the south end, built exactly the same way, and used as an alternative or to add flexibility in traffic management.
- More snow cats and Hagglunds were purchased.
- More flooding crews were hired.
- The speeds of the vehicles using the road were reduced, especially on lakes known to cause problems.

Mr. Madsen feels that with these additional measures in place, even if a poor winter season (like the one they two years ago) comes along, they will be able to keep the road operational.

2.2.2 Maintenance crews

About 140 people are working on this road. These people tend to be ranchers, pavement workers, etc., from southern Canada, whose trade typically do not keep them busy during the winter. Aboriginals are mostly hired by the mines because they tend to be good with equipment.

The crew work out of two camps: the Dome Lake camp and the Lac de Gras Camp. An additional camp, the Lockhart camp is also used by truckers to eat, rest and sleep over.

2.2.3 Design ice thickness

EBA engineers are in charge of design ice thickness and of reviewing weight configuration on trailers for heavier loads, to ensure they can meet minimum ice thickness criteria for that point in time. I briefly met with Dr. Proskin one evening as he was coming back from a field day. Although there was little time for a formal discussion on the principles that guide design loads, he will refer us to the work EBA has published regarding that matter. In general, Gold's formulation is agreed upon as being valid, except for the value assigned to the coefficient, which requires verification. Given the significance of the Tibbitt to Contwoyto winter road and Dr. Proskin's extensive involvement in this venture, his work would probably constitute an important component of NRC's re-assessment of engineering standards on ice bearing capacity.

The data gathered by EBA at that time included ice strength, obtained with a manually operated borehole jack. The jack response is used as an index to establish a difference between flood ice and natural ice strengths, which is ultimately used for determining safety factors.

2.2.4 Ice thickness profiles

Thickness profiles are critical. A GPR model SR3000 is used, which records a difference in the dielectric response of two different materials. The ice-water interface can be easily detected, but not the snow-ice interface. This is done by calibrating the device against a representative snow thickness. Drill holes are also done occasionally to confirm readings. The device may be pulled behind a pickup truck and the survey can be carried out at up to 40 km/h. Data is produced in real time and displayed on a screen. This procedure is done along one or more parallel lines running along the road, starting at the centre, then on both sides. The procedure when opening up a road at the beginning of the season is a little more rigorous because the ice is thinner at that time.

EBA uses another type of GPR, which is capable of measuring water depth (in addition to ice thickness), though the snow still has to be carefully accounted for. This instrumentation is in a sleigh and is pulled by a snowmobile.

2.2.5 Snow clearing

This is done whenever required, either after a snow fall or wind-driven snow drift episodes.

2.2.6 Flooding

Flooding is useful to improve ice surface quality and also increases the thickness of the ice cover (though the strength of that ice is known to be lower than that of natural ice). It is either done directly on the ice or with ‘flood trucks’ designed for that purpose (Figure 4). Some light trucks are fitted with a drill which puts holes into the ice at short intervals, and is followed by the pump-hauling crew. The flood trucks are required for the maintenance of the portages. The trucks can be filled by drilling a hole in the ice and inserting the pump nozzle into it. Flooding is often required to smooth the ice near the portages, and is used more often in the southern part of the road than in the north. It is also done more often in areas where the lakes are shallow. When too much flooding is required to fix a long segment of damaged ice, the crew may choose to build a new road alongside it instead. This is more often done in the north. Flooding may take place around the clock with two shifts. It is generally not required for express lanes, because these lanes are used by empty vehicles.

Figure 4: Left) A vehicle fitted with an auger at the back. Right) A pump in action.

2.2.7 Spray ice

Spray icing, an alternative technique to thicken ice covers, is generated by spraying water in the air so that it freezes and falls back onto the ice. Mr. Zigarlick says this technique is not suitable for the ice road, which is too long. It is better adapted for McKenzie Delta operations.

2.2.8 Bathymetry

Much of the bathymetry remains to be done (using EBA's GPR).

2.2.9 Time frame for winter road operations

A decision is made as to when the road opens, taking into account a lot of data and many people's views. This year, the crew got onto the ice as early as mid-December, and the road opened at the end of January. Because of the cold winter, the ice thickness achieved very high levels. The road was to be closed on March 31st, not because it was no longer in good shape (as in other years), but rather because all users got the material they wanted from the south and no longer required additional loads.

The best way to extend the season is to start earlier, as opposed to ending later, since in the latter case, the sun is high above the horizon and is the main source of ice decay. The limiting factor when deciding to close the roads are the portages, which tend to decay earlier than the segments built on ice. The reason may be that sand is used on the portages (since there are hills that the vehicles would not be able to climb otherwise). This sand is available from nearby quarries. But being darker than the ice, the sand absorbs the heat from the sun and accelerates decay. I asked if it would be possible to use another material in critical areas. For instance, clean snow could potentially serve that purpose. But this really comes down to logistics and operational expediency – that material has to be available nearby and in large enough quantity.

The whole 600 km length *must* be usable for the road to operate. Any small segment that is unable to carry the traffic for whatever reason is sufficient for the road to close. Late in the season, for instance, traffic may be allowed night time only, when the road is not submitted to the sun's damaging effects.

For 2-3 weeks after the road closes, some of the staff prepares the camps for the following season (maintenance on equipment, fuel replenishment …). They are then flown out and someone is hired to watch over the installations during the summer. The air strips are also used throughout the winter to move crews in and out.

2.3 How the road is used

The ice road is a public-private road, and the public is allowed to use it (unless they carry a load exceeding 3500 kg, in which case it has to be reported). Since they do not have to check in or otherwise let anyone know of their whereabouts, it is not known how many of them are actually using it at any one time. Fishermen and hunters are amongst the non-commercial users.

A few (4-5) major trucking companies, plus a few other minor ones, are the main end-users (Figure 5). A 'load' is a truck, typically with several axles. What limits the size of the loads that can be hauled on the road is pressure on the wheels (and therefore on the ice). The largest ones are currently about 40 tonnes (while the heaviest ever was about 88 tonnes). But it is also its length, since in order to haul more while respecting the design pressures, the load would have to be too long to handle some of the portages. The road normally sees about 170 loads per day, for a total of about 8000 loads in 2008.

Figure 5: Examples of end-users: Left) A transport carrying ammonium nitrate. Right) A convoy of fuel tankers.

On the normal ice road, speeds range from 10 to 35 km/h, but can go up to 60 km/h on expressways, which are separate lanes made available to unloaded trucks driving back to Yellowknife. In the north, where the ice is thinner, speeds for loaded trucks are up to 25 km/h; to the north, where the ice is thicker, it is 35 km/h. The faster the load, the more damage it does to the ice surface. Extensive road signage is deployed, advising of speed limits, restricted travel lanes, road hazards, etc. Small vehicles (pick-up trucks) are allowed to go much faster.

Trucking companies provide their drivers with training to use the road. This includes:

- An early (December) information meeting.
- A complete review of the 'Winter Road Rules and Regulations'.
- A review of road risks.
- Instruction on the use of tire chains and vehicle troubleshooting.

The 'Rules of the Road' specifies penalties to infractions such as speeding, dangerous driving and other unsafe practices, failure to respect right-of-way, failure to report to designated dispatch points, etc. Penalties range from a written warning, three days (or more) suspension and, ultimately, banning from the road. One of these rules is to travel in convoys (minimum two trucks), in which drivers must maintain a 0.5 km spacing between trucks. Truckers are prohibited to stop on the ice, except in case of emergency. But they can stop their vehicle on portages and spend the night there, as long as they do not interfere with traffic.

Standard winter tires are used by all vehicles. This may appear surprising considering that the surface is often composed of bare ice. But this is allowed because of the low speeds and the fact that the ice road is generally very straight. On the portages, as mentioned earlier, sand is used to maintain traction. Night driving doesn't appear to increase risks of accidents, according to Mr. Madsen. On the contrary, headlights help warning of incoming traffic. A more common cause of accidents is related with truckers failing to radio in their approach to each portage, a procedure implemented to improve traffic safety.

2.4 Safety issues

In order to ensure that the ice is safe, the maintenance crews have to look after two things: 1) <u>Adequate thickness</u>; and 2) <u>adequate surface quality</u>. The former prevents breakthroughs, the latter traffic accidents. The thickness is mostly a function of air temperatures and the ability to either plough away the snow or flatten it, so as to promote heat removal, thereby accelerating ice growth. A reduction in surface quality is induced by the number and size of loads, and by crack formation. It is looked after by flooding.

2.4.1 Safety related with ice thickness

The Tibbitt to Contwoyto Winter Road has an excellent track record in terms of *breakthroughs*. The reason is that, since safety is the first priority for JVMC, ice thickness is closely monitored (as discussed above). Breakthrough-related deaths are not uncommon in the NWT, but they occur with other ice activities – snowmobiles, transport on other roads, etc.

On Dec. 19 2000, Guyle Armstrong died as result of exposure to cold water. His vehicle went through the ice and he was pulled out after being immersed in it for less than a minute. He died of a hearth attack as he was being looked after and having some tea. Last year, another breakthrough occurred in shallow depth, but this happened as the vehicle had been parked on a small pond in a portage. (No casualty resulted from that incident.) This would be an instance of creep failure, but since stopping on ice is strictly prohibited, creep-related ice failure is not an issue.

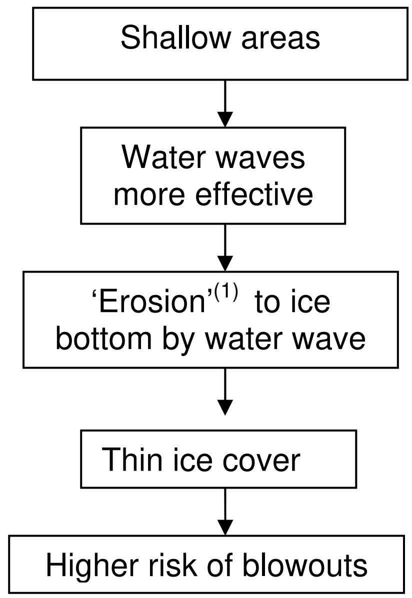
2.4.2 Safety related with surface quality

Surface quality is a main concern, particularly when affected by sudden events such as *'**blowouts**'*. These are the sudden breakage of the ice, caused by water waves produced by the moving loads (Figure 6). For instance, an experiment was conducted once whereby a few holes were drilled into the ice and a truck drove by at speeds of 25, 20, 15 and 10 km/h. They noted that the water spurted out of the hole much more at the higher speeds, while it remained stable at the lowest speed. This argument is used by JVMC to explain to drivers why they have to keep their speed down (bearing in mind that these people are paid – handsomely – by the trip and a cruising speed of 25 km/h is already *very* slow).

Figure 6: Two examples of a 'blowout'. Coat for scale at right.

One way to mitigate the risks of blowouts is to lay out the ice road, whenever possible, so that it does not make a 90 deg. angle with the shoreline. This is based on past experience and observations. For instance, an accident occurred some time ago when the first truck of a two-truck convoy headed toward a portage on an ice road at right angle with the shoreline. Its speed was considerable, thereby creating a wave (so it is believed) that blew out the cover, and caused the second truck to run into the ice fragments.

Shallow areas are thought to be more prone to blowouts because the water waves in these areas are more effective, thereby causing the ice cover to become thinner and thus weaker (Figure 7). But this scheme has yet to be formally documented. Water waves are a form of pressure relief and may not be objectionable as long as they occur away from the ice road. The water waves are more easily 'felt' early in the season, when the ice is not as thick, as they go by and reflect back from the shoreline. One of the reasons unloaded trucks are allowed to go faster (on the express lanes) is that they do not produce water waves. It should be noted that, in places, shallow areas are not a problem. But it is not known why.



(1) Thinning of the ice

Figure 7: Conceptual link between shallow areas in lakes and risk of blowouts.

A second issue are ***pressure ridges***, which are attributed to thermal expansion during warm days. They can be very extensive, especially in large lakes, but are not limited to them. They tend to form at the same location year after year, though not always. On McKay Lake, for instance, there were 3 to 13 of them. On Lac de Gras, there was one last year, and eight this year. The ice road has to make its way around pressure ridges. The reason is that, because it gets reactivated, a ridge that crosses the road may need to be attended to repeatedly, since fracturing is likely to recur. Motion appears to be relatively quick – one time, the crew witnessed the ice cover snap with a thundering sound!

Another feature that can potentially interfere with the ice road concerns the ***longitudinal cracks*** running along the road. Some people link them to the presence of snow banks on each side of the read. Alternatively, they may be induced by the relative buoyancy difference between the thicker ice cover below the road and that surrounding it. This phenomenon is not considered to significantly affect ice road operations, though it may contribute to surface degradation.

General surface conditions deteriorate with time. Potholes and other such damage may result from crack degradation, but overall it is not known for sure what are the processes involved. Wet cracks, which indicate a connection in the crack network between the water column and the ice surface, mostly occur at the beginning of the season, when the ice cover is thinner.

3. Information available from JVMC

Following are the data that can be provided to us by JVMC:

- More information on the few breakthroughs that occurred on that road over its 25 years' existence, and why they happened. The details regarding this matter have not been retrieved during my visit.
- Methodology developed by EBA on stress distribution of the loads onto the ice.
- Ice profiles.
- Statistics on ice loading, traffic, etc.
- SECUREcheck may have statistics on road accidents, relevant to the overall operations of the ice road.
- Meteorological data, notably freezing-degree days from Yellowknife weather station, could be obtained from EBA.

4. What information JVMC is looking for

JVMC was asked about outstanding issues of engineering relevance. Following is what came out of our conversations:

1. JVMC, under EBA's guidance, feels it has a good handle on ice thickness control, thanks to the extensive use of ice profilers. As long as a proper procedure is set in place to remove the snow from the ice surface as early as possible during the season, they should get the 107 cm (42 in) required to allow the SuperB's on the ice by February. However, they are considering potential means of extending the season and improving the itinerary, which will provide them with more flexibility for traffic management in the advent of a warm winter.

2. JVMC also have in mind a few targeted studies on issues they do not fully understand:

    - How to mitigate effects of blowouts, linked with the dynamic behaviour of the ice cover. If they are caused by water waves, as seems to be the case, why are they not observed at Charlie's hill (portage 25-1)? The road at this location is at right angle to the shoreline and, in order to make it up the hill, the trucks are known to carry a lot of speed when they get to that point. These are two features that should favour blowouts at that site. But they do not occur. One possibility is that the water is deep. EBA was asked to look into it.

- There are areas where the ice is intriguingly thin, and it is not clear why. Thin ice has often been attributed by Mr. Zigarlick to water wave-induced ‘erosion’, especially at shallow depth. Currents may also be involved but are not monitored.

- Load-induced crack accumulation in the ice cover, which is directly related with the number of loading episodes it sustains, is an element that is currently not factored in design. Is there a critical density level before the road, even if it has achieved an adequate thickness, becomes too weak? If so, what is it?

- Though pressure ridges are not as objectionable as blowouts, the operations may gain from a better understanding of how they form. Mr. Brandl says this is yet another issue that could be investigated. But this matter is only indirectly linked with the bearing capacity of ice and may not constitute a priority for NRC.

3. Mr. Zigarlick and Mr. Madsen also inquired about the possibility of getting a student to spend a few months (perhaps the entire winter) in the NWT so as to get familiar with the ice road operations, while studying some of these issues. They suggest NRC could team up with JVMC and a university to get that arranged.

5. Conclusion

The information presented in the present report represents the starting point of NRC’s initiative whose objective is to re-assess and update engineering standards on ice bearing capacity. The purpose of this report was to draft a general picture of what is currently involved in making the Tibbitt to Contwoyto Winter Road a successful venture. Its excellent track record on road accidents and breakthroughs is a reflection of the rigorous approach used by JVMC to ensure safe operations, especially considering the demanding requirements that this road has to meet. The data generated by these procedures may in fact constitute an important component of NRC’s study.

At the moment, dynamic loading and associated phenomena are the most important outstanding issues. Ice damage, in the form of crack accumulation and consequent weakening of the ice cover, should also be addressed. On the other hand, time-dependant deformation behaviour (or creep), a critical consideration in other applications relying on the bearing capacity of an ice sheet, is not a significant concern for the Tibbitt to Contwoyto Winter Road, since static loading is carefully avoided.