

17 May 2018

To
Ken Boam
Design Manager
Mt Messenger Alliance

From
Dr Michael John Revell

By email

Dear Ken

ISSUES SURROUNDING FOG AND BLACK ICE

Issues to address

- 1 You have asked for:
 - (a) an explanation of the conditions necessary for black ice and fog to form;
 - (b) my expert opinion on the likelihood of fog in the tunnel and black ice and fog on the new road in the Mangapepeke Valley being a problem; and
 - (c) my view on whether black ice and fog are likely to be more of a problem on the new bypass than elsewhere in Taranaki.

Conditions for ice to form

- 2 To get ice on a roadway requires moisture and freezing temperatures (below 0 °C) at the surface, a combination that can occur in several ways (the first being the most common in this region of New Zealand):
 - (a) Frost;
 - (b) Freezing of groundwater seepage or prior rain; and
 - (c) Light rain falling on a frozen roadway surface.
- 3 **Frost:** During the day when the sun is out and is warming the surface, the air temperatures near the surface are usually above the dew point (the temperature to which air must be cooled to become saturated with water vapour), and water in the atmosphere remains in the form of invisible vapour. However, as the sun sets on cold, still (mean wind speeds less than 10

km/hr), clear nights, the surface temperature drops (as the earth radiates heat into space), and the air near the surface can cool to the dew point temperature. If the roadway temperature and dew point temperature are above freezing, liquid water forms on the surface (dew), but if the temperature is below freezing, frost forms instead. Based on a weighted interpolation of grass minimum temperature records at the four nearest stations at Mokau, Te Whera Forest, Tokirima and Tikorangi, shown in Figure 1, I estimate that there are about 60 frost days a year in the area of the proposed new road. Frost generally accumulates slowly and rarely accumulates more than 2 mm, lessening the icing threat in these conditions.

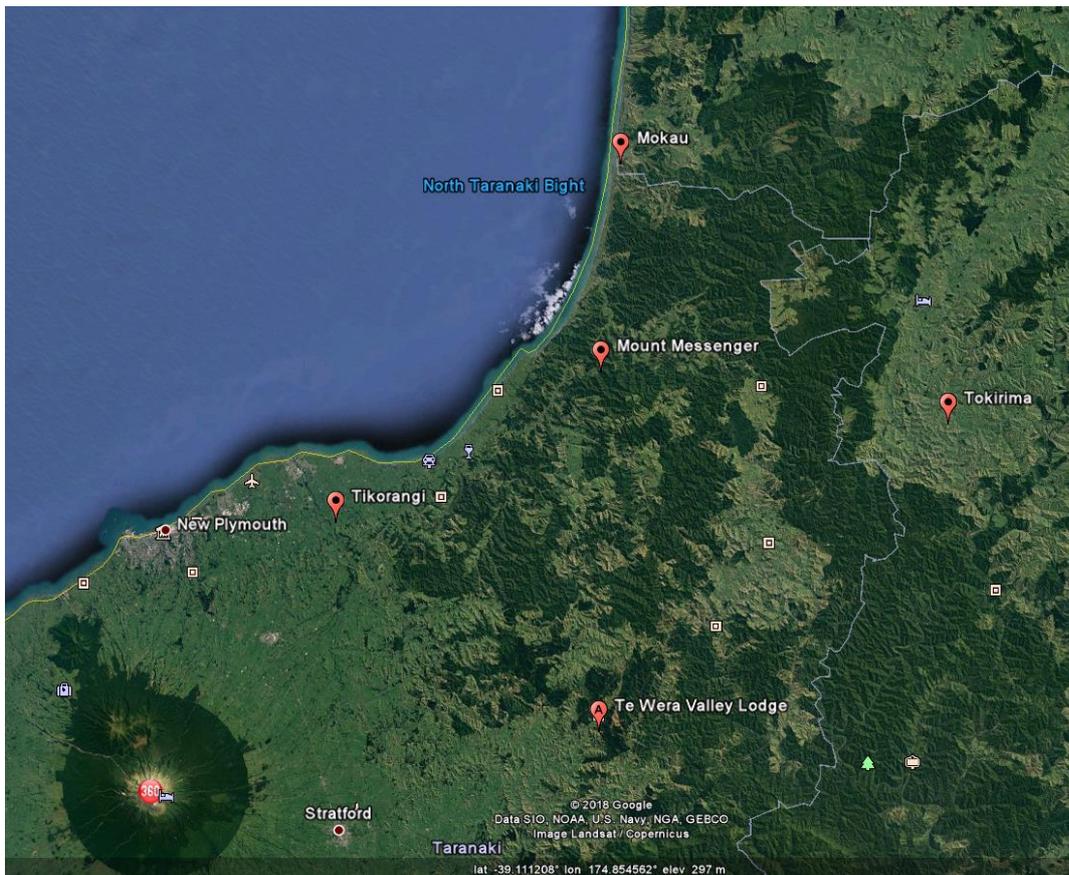


Figure 1: Locations of weather stations

- Freezing of Groundwater Seepage or prior rain:** If water drains over the road from a spring or other water source like a creek resulting from prior rain, during the day the water remains liquid, but during the night (with cold, clear, still conditions) can freeze on the road surface. Furthermore, wet roads often freeze up very rapidly when the air above is dry. The reason for this is cooling from evaporation. We all experience the chill of evaporative cooling when we exit from a shower or bath--this cooling is greatest when the air around us is dry. Thus, on a cold, dry night evaporation from a wet road can cause the surface to cool much more rapidly

than dry road surfaces nearby, resulting in localized icing. These conditions are able to be avoided by suitable design of the road drainage system.

- 5 **Light rain falling on a frozen roadway surface:** Although the icing threat from frost is lessened by its slow accumulation and relatively minimal thickness, this is not true when light rain falls on a frozen roadway when it is possible for a coat of ice to be deposited in minutes. However, this scenario is typical of more elevated or polar continental climates in winter and relatively uncommon in this area of New Zealand. For the ground to freeze the wind must be light, the skies must be clear and the air very dry. So, most frosts won't be associated with rain. If the air is not dry, fog will tend to form first, preventing the surface below from freezing. However, if there has been an overnight period of light winds, clear skies and cold dry air and a band of rain arrives just before sunrise then ice is possible. This is particularly true on bridges which can often be a degree or two colder than the surrounding ground due to lack of heating from the ground below the surface. This may also be true in shady spots, but the terrain maps with the proposed road shown to me by the Mt Messenger Alliance indicate that all parts of the road will get a few hours of sun during the afternoon, even in Winter.
- 6 **Black Ice:** This is a thin sheet of ice, relatively dark in appearance, but actually clear (so it looks like the road beneath), that may form from either of the processes described in paragraphs 3 and 4 above. Black Ice is much less common in this part of New Zealand compared to the North Island central high country or inland Southland and Otago.

Conditions for fog to form

- 7 There are several ways to form fog, but in this region of New Zealand Radiation Fog is by far the most common. Radiation fog is formed by the cooling of land after sunset by infrared thermal radiation in calm conditions with a clear sky. The cooling ground then cools adjacent air by conduction, causing the air temperature to fall and reach the dew point, forming fog. In perfect calm, the fog layer can be less than a meter thick, but turbulence can promote a thicker layer. Radiation fogs occur at night, and usually don't last long after sunrise, but can persist all day in the winter months especially in areas bounded by high ground. Radiation fog is most common in autumn and early winter.
- 8 The term "fog" is typically distinguished from the more generic term "cloud" in that fog is low-lying, and the moisture in the fog is often generated locally (such as from a nearby body of water, like a lake or the ocean, or from nearby moist ground or marshes). Fog is defined as reducing visibility to less than 1 km.

- 9 Based on a similar weighted interpolation (as was done for frost) between fog records at the nearest stations at Mokau, Te Whera Forest, Tokirima and Tikorangi, I estimate that there are about 30 fog days a year in the area of the proposed new road. There is a strong gradient in number of fog days as you move inland from the coast with only 2 days per year at Mokau and Tikorangi rising to 20 days per year at Te Whera Forest (in my opinion the most similar to Mt Messenger) and over 100 days per year at Tokirima.

Fog in tunnels

- 10 Although fog may occasionally form over the road I do not expect it to be a problem in the tunnel as temperatures there will remain well above those outside when fog is an issue.

Comparison with other locations in Taranaki

- 11 We do not have measurements of fog or ice for the Mount Messenger area itself so estimates of these conditions have been made by interpolating from the 4 surrounding nearest stations that do measure these elements. In my opinion there is no large-scale meteorological (e.g. mean wind speed or average dew point) reason to prefer the existing highway route over the proposed new route. However, the existing route does climb approximately 100 m higher with many tight corners that don't see the sun during the winter. This will lead to colder road temperatures, thus increasing the potential for frost and icing. On the other hand, the existing road is higher in its valley than the proposed road is in its valley in the sections before the two roads rejoin to the north of Mt Messenger. In the case of shallow fogs this would mean the proposed new route would occasionally be in fog when the old route wasn't, thus increasing the potential for fog to affect the new route. However, this potential for fog would be no higher, and probably is less, than that for the continuation of the road north of the tie-in where the road follows the stream to the west of the state highway and then the Tongoporutu river very closely, within a height of a few metres.
- 12 Weather records in the Taranaki region indicate that the frequency of fog goes up considerably as you move inland, as does the frequency of frost, but to a much lesser extent.
- 13 In summary, both icing and fog may sometimes be an issue in the Mt Messenger region, but considerably less frequently than further inland. The main differences between the existing and proposed routes are: the potential for a higher frequency of frost and icing on the existing route due to its tight, shaded corners and higher elevation; a higher frequency of fog affecting the northern part of the proposed new route since it is closer to the valley floor just before the roads rejoin. However, the frequency of fog in this region would be no higher than that, north

of the junction between the existing and new roads, alongside the stream and subsequently the Tongoporutu river.

Yours sincerely

A handwritten signature in black ink, appearing to read "M. J. Revell". The signature is written in a cursive style with a large initial 'M' and a distinct 'J'.

Dr Michael John Revell