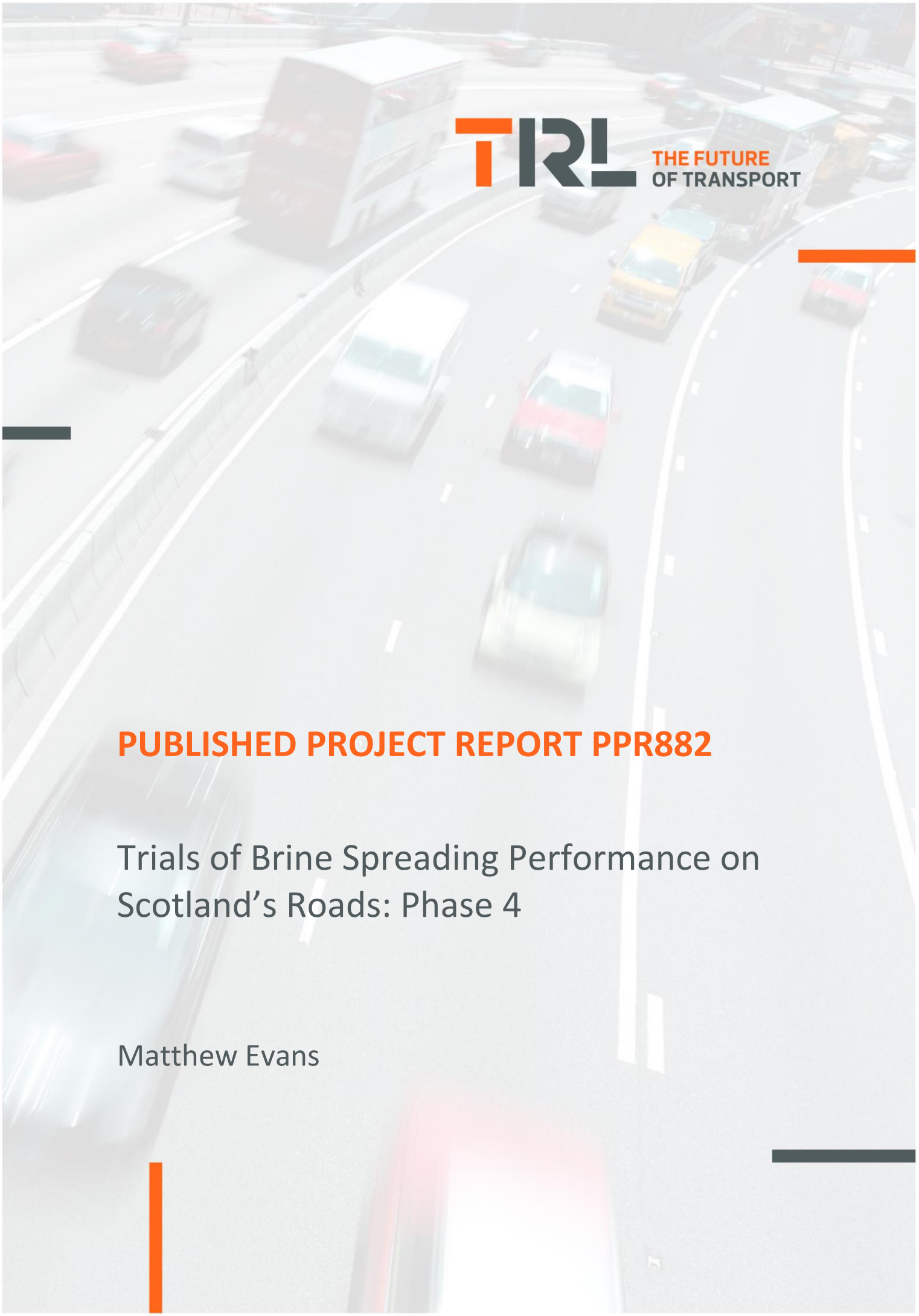

THE FUTURE OF TRANSPORT

PUBLISHED PROJECT REPORT PPR882

Trials of Brine Spreading Performance on Scotland's Roads: Phase 4

Matthew Evans

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Executive Summary

A further phase of Transport Scotland brine spreading trials was carried out during the 2017/18 winter season; with the key aims to assess the effectiveness of brine spreading before and during snow events and in temperatures below -5°C.

The trial was carried out on the A835, part of Precautionary Treatment Route 20-8 within the North West Trunk Road Unit. This site provided high likelihood of snowfall and low temperature conditions.

Brine spreading was carried out using a Schmidt Stratos Combi Flex Spreader with the capability to deliver brine only or pre-wetted treatments. Brine only treatments were applied by spreading from a spinning disc and the brine ratio for the pre-wetted salt could also be varied from the standard 70:30 dry salt:brine to provide a greater brine share for pre-wetted treatments.

Prior to the trial commencing, a treatment matrix was agreed with BEAR Scotland and Transport Scotland for both precautionary treatments and for snow and ice. Monitoring of road and weather conditions was carried out at three locations along the route, with all locations including road weather station data, temperature and residual salt data from embedded road sensors and CCTV images. One location (Aultguish) also included non-invasive road condition sensors to detect the presence of ice or snow on the road and provide 'Grip' readings. The trial site was a Category B patrol route with patrols monitoring conditions, providing salt treatments and ploughing as required with a 3 hour cycle time. The patrol vehicle was equipped with non–invasive road condition and temperature sensors.

The trial period encompassed a number of cold spells and significant snow events with double treatments on most nights during December and January. It is considered the trial route has provided the full range of conditions likely to be experienced on the Transport Scotland network, from frost to snow events and for a range of temperatures. Around half of all the brine treatments during the trial were carried out with some form of precipitation during or after spreading.

These trial results have demonstrated that brine provides an effective treatment for precautionary frost treatments. Wet roads were treated effectively down to -7°C and dry/damp roads to -10.8°C.

The effectiveness was demonstrated for a wider range of conditions than the previous trial phases but limiting factors have also been identified. The effectiveness of brine was limited in conditions where clearance of snow back to black pavement after each plough pass was not achieved i.e. brine was not being spread on a bare pavement and not able to penetrate to the road surface. For brine spreading during snowfall, quick treatment cycle times and ploughing to the road surface are vital to prevent compacted snow.

The trial route had low levels of traffic which can provide challenges for winter maintenance. For example the road surface remained very wet for significant periods after rainfall, with little traffic to disperse water. The trial site was observed to remain too wet for effective brine treatments for a small number of events where rainfall occurred shortly before freezing. However this was also seen to be an issue for spreading pre-wetted salt in comparable conditions.

Based on the conditions under which the brine spreading has been trialled, treatment guidance has been further developed for precautionary treatments and snow clearance.

1 Background

Brine trials have been carried out over the previous three winter seasons on the Transport Scotland network, monitoring the effectiveness of routine brine treatments and comparing them to equivalent pre-wetted salt treatments. These trials have been carried out for precautionary treatments for damp or wet roads with a road surface temperature of less than or equal to -5°C, demonstrating that brine provided an effective service in these conditions and brine spreading was a suitable treatment on the majority of days when spreading occurred on the trial sites. Based on the conditions under which the brine spreading has been trialled, recommended spread rates were provided for precautionary treatments before frost and light snow or rain.

It was considered there was scope for the use of brine for a wider range of conditions, for example before and during more significant snow events, if the effectiveness can be demonstrated operationally on the network. Further trials were proposed over the 2017/18 winter season, to include brine spreading to be carried out before and during snow events and in temperatures below -5°C.

2 Introduction

TRL were commissioned by Transport Scotland to support the development and coordination of a further phase of live trials for the 2017/18 winter season; the overall aim of the trial was to assess the suitability of full liquid treatments for delivering the next generation of Transport Scotland contracts and build on the experience of the previous winter trials.

The trial included assessing the effectiveness of brine for snow treatments and extreme cold temperatures. It was carried out on the A835, part of Precautionary Treatment Route 20-8 within the North West Trunk Road Unit. This site provided high likelihood of snowfall and low temperature conditions.

Key objectives were to:

- Assess the effectiveness of brine treatments for road surface temperatures below -5°C
- Assess the effectiveness of brine treatments applied before and during snowfall
- Identify the limits of effectiveness for brine spreading in comparison to current pre-wetted and dry salt treatments
- Where limits are identified, assess other options that can be applied e.g. higher brine ratio for pre-wetted salt or addition of optimum blends

3 Trial site

Trials were carried out as part of routine winter treatments on Precautionary Treatment Route 20-8 within the North West Trunk Road Unit. This route runs between Inverness and Ullapool and recorded the lowest Road Surface Temperature (RST) on the Scottish trunk roads during the 2016/17 winter season (see red route in Figure 1).

The A835 was chosen to provide the likelihood of the full range of conditions that are routinely experienced on the Transport Scotland network. The route includes single and dual carriageway sections and reaches an altitude of 284m. The route routinely also experiences significant snow accumulations that can lead to drifting and jack-knifing of articulated vehicles on steep inclines.

The route has a treatment length of 79km at an average width of 6.5m.

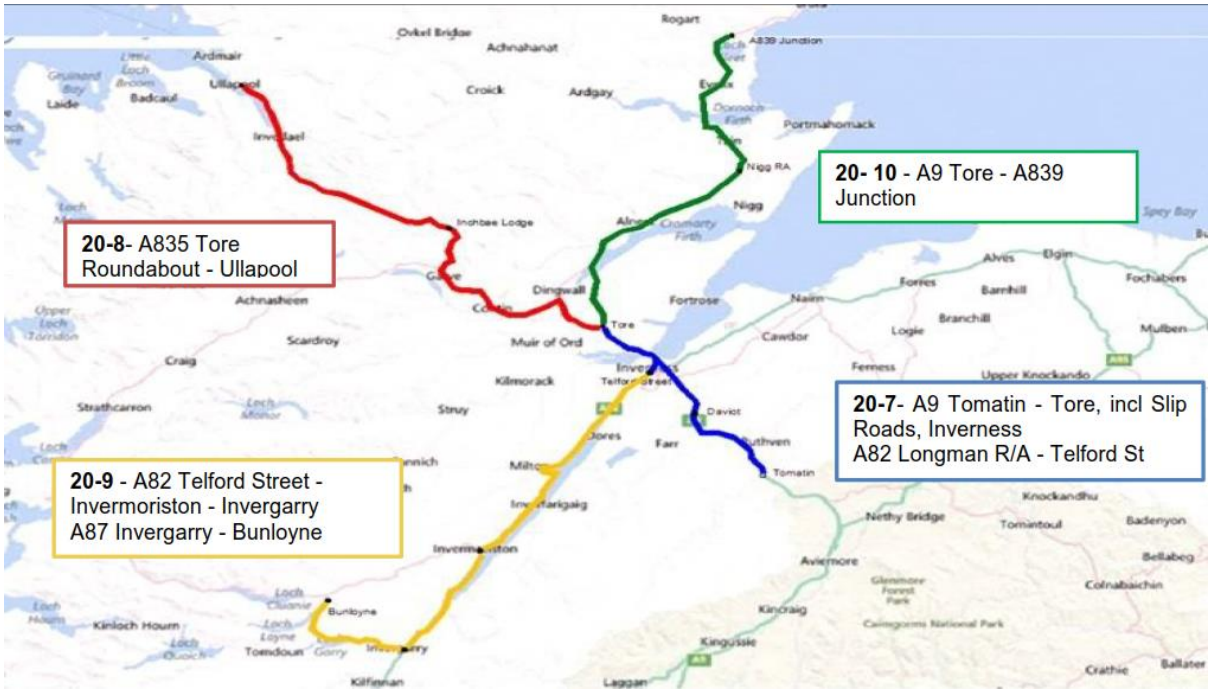


Figure 1. Route 20-8 and other precautionary routes operating from Bridgepoint Depot (Inverness) – taken from North West Unit Winter Service Plan 2017/18

4 Spreader and de-icing chemical

Brine spreading was carried out using a Schmidt Stratos Combi Flex Spreader, the vehicle shown in Figure 2.

Figure 2. Schmidt Stratos Combi Flex Spreader

The vehicle provided the capability to deliver brine only or pre-wetted treatments. The brine ratio for the pre-wetted salt could also be varied from the standard 70:30 dry salt:brine to provide a greater brine share for pre-wetted treatments.

Before the trials all spreaders were calibrated; this including monitoring the discharge rate and carrying out a visual check of the brine and pre-wetted salt distribution.

A test spreading run was made over the trial route, at a spread rate of 30ml/m² and with the correct spread width settings, to confirm there was sufficient spreader brine tank capacity to treat the full length of the route.

Brine only treatments were applied by spreading from a spinning disc as shown in Figure 3. The brine is distributed as large droplets from the spinner. The distribution was observed to cover the full road width and could be directed as required.

Figure 3. Brine distribution from spinner disc

The vehicle was fitted with a 3 metre SNK snowplough, with Kuper GK7 rubber-ceramic edges as shown in Figure 4.

Figure 4. Plough set-up

Brine was produced and stored at the Inverness depot for pumping into the combi spreader when required.

Spread rates were dependent on a brine concentration of 20 to 23%.

The time required for loading the spreader was checked, to ensure turnaround and response time targets could be achieved.

5 Trial methodology

Commencing on the 13th December, the A835 was treated with brine until 31st March 2018.

Prior to the trial commencing, a treatment matrix was agreed with BEAR Scotland and Transport Scotland for both precautionary treatments and for snow and ice.

Brine treatments were carried out in accordance with the standard decision matrix shown in Figure 5.

Spread rates for precautionary treatments and snow clearance are shown in Figure 6 and Figure 7 respectively.

Records of treatment timings and spread rates were obtained from the Operating Company daily action plans.

<table>
<tr><th colspan="4">Decision Matrix</th></tr>
<tr><th></th><th colspan="3">Predicted Road Conditions</th></tr>
<tr><th>Road Surface Temperature</th><th>Wet</th><th>Wet Patches</th><th>Dry</th></tr>
<tr><td>May fall below 1ºC</td><td rowspan="2">Salt before frost</td><td>Salt before frost (see Note A)</td><td>No action likely, monitor weather (see Note A)</td></tr>
<tr><td rowspan="5">Expected to fall below 1ºC</td><td colspan="2">Salt before frost (see Note B)</td></tr>
<tr><td colspan="3">Salt after rain stops</td></tr>
<tr><td colspan="3">Salt before frost and after rain stops (see Note C)</td></tr>
<tr><td colspan="2">Salt before frost</td><td>Monitor weather conditions</td></tr>
<tr><td>Expected snow</td><td colspan="3">Salt before snow</td></tr>
<tr><td rowspan="3">Freezing rain</td><td colspan="3">Salt before rain (see Note C)</td></tr>
<tr><td colspan="3">Salt during rain (see Note C)</td></tr>
<tr><td colspan="3">Salt after rain (see Note C)</td></tr>
</table>

The decision to undertake precautionary treatments may be adjusted to take account of residual salt or surface moisture.

Note A: Particular attention should be given the possibility of water running across carriageways. Such locations will be monitored and treated as required.

Note B: When a weather warning contains reference to expected hoarfrost close monitoring will be required, with particular attention given to timings of precautionary treatments as salt deposited on dry roads may be dispersed before it can become effective.

Note C: Under these circumstances rain will freeze on contact with running surfaces and full pre-treatment should be provided even on dry roads, with continuous monitoring throughout the danger period.

Figure 5. Decision matrix - taken from North West Unit Winter Service Plan 2017/18

Spreading rates for precautionary treatments (ml/m²)		
Road surface condition	**Frost Susceptible/surface water run-off area**	**Road Surface Wet**
A. RST higher than plus 1°C	0	0
B. RST lower than or equal to plus 1°C but higher than minus 2°C	10	20
C. RST lower than or equal to minus 2°C but higher than minus 5°C	10 to 20	20
D. RST lower than or equal to minus 5°C	10 to 20	20
E. RST lower than or equal to plus 1°C but higher than minus 2°C following rain (see note 1)	20	30
F. RST lower than or equal to minus 2°C but higher than minus 5°C following rain (see note 1)	30	30
G. RST lower than or equal to minus 5°C following rain (see note 1)	30	30

H. Hoar Frost	20	20
I. Freezing Fog	10	20
J. Freezing Rain	30	30
K. Snow Accumulations up to 30mm	30	30
L. Snow Accumulations over 30mm	30	30
M. Hard Packed Snow/Ice	See clearance matrix	See clearance matrix

Note 1 Treatments will be carried out after water has dispersed and road surface classed as damp.

Figure 6. Spreading rates for precautionary treatments

Minimum brine spread rates for Snow or Ice Clearance			
Road surface condition	**Spreading (ml/m²)**	**Ploughing**	**Blowing**
Ice formed	30	No	No
Snow covering of less than 30mm	30	Yes	No

Snow covering exceeds 30mm	30	Yes	No
Snow accumulations due to prolonged snowfall	30	Yes (continuous)	Where applicable
Hard packed snow/ice less than 20mm thick	Salt 40g/m² (successive)	No	No
Hard packed snow/ice	Salt/abrasive (successive)	No	No

Figure 7. Clearance matrix

6 Monitoring of road conditions

6.1 Fixed monitoring sites

The Braemore, Aultguish and Brahan fixed weather stations were used to monitor road surface conditions on the A835, with locations shown in Figure 8. Monitoring equipment included:

- Non-invasive DSC111 and DST111 sensors to remotely monitor road condition and surface temperature (Aultguish only)
- Road weather station including wind speed, embedded DRS 511 sensor, CCTV

The road condition from the fixed sensors was continuously and automatically monitored every 10 minutes and the data collated and analysed.

All weather station and patrol data was fed back to the Operating Company control centre and access to weather station data was available through the Vaisala RoadDSS system.

Figure 8. Weather station locations – taken from North West Unit Winter Service Plan 2017/18

6.2 Patrols

The trial site was a Category B patrol route. Category B Patrols are designed to monitor conditions, provide salt treatments and plough as required with a 3 hour cycle: once during the 00.00 – 03.00, 03.00 – 06.00 and 06.00 – 09.00 periods specified.

The patrol vehicle was equipped with the mobile Vaisala DSP 310 condition patrol equipment and temperature sensors. Observations from patrol drivers were recorded on a daily record sheet with copies stored electronically.

7 Results

7.1 Overview of weather conditions

The trial period encompassed a number of cold spells and significant snow events with double treatments on most nights during December and January.

Summary tables of minimum air temperatures and road surface temperatures, (RST) for each weather station are provided in Appendix A.

The coldest conditions were experienced at the Aultguish weather station, with a minimum air temperature of -12.4°C and minimum surface temperature of - 10.9°C.

7.2 Review of brine treatments

Details of the treatments carried out and selected weather station data are presented in Appendix B.

Table 1 shows a summary of the number of frost and precipitation events for which brine spreading was carried out during the trial period. Frost events were nights where freezing surface temperatures occurred, but with no rain or snow during or after treatment. Precipitation event were when de-icer was applied during or in advance of rain/snow and freezing temperatures.

Figure 9 shows the breakdown in brine treatments between frost and precipitation events for different temperature ranges (as measured at the Aultguish weather station).

Around half of all the brine treatments during the trial were carried out with some form of precipitation during or after spreading.

Table 1. Overview of brine treatments

Total treatment days during trial period (brine and pre-wetted)	Brine treatments				% of events where brine spreading used
	No. of Frost events	No. of Precipitation events	No. of frost events where 'Grip'<0.6	No. of precipitation events where 'Grip'<0.6	
91	32	37	0	5	74

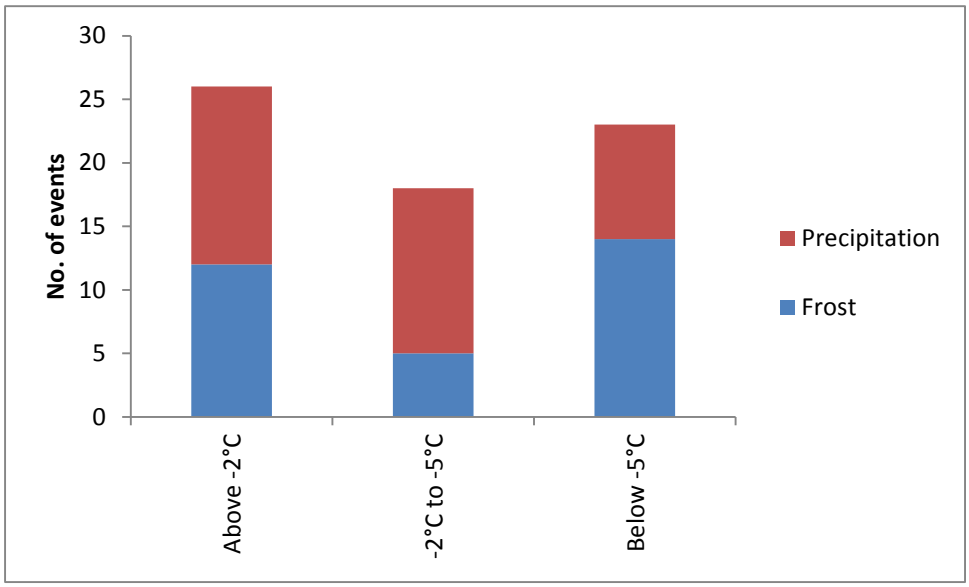


Figure 9. Breakdown of number of frost and precipitation events for different temperature bands (brine spreading only)

7.3 Precautionary treatments before frost

Figure 10 to Figure 12 show the conditions encountered at each of the weather stations during frost events.

The minimum surface temperature for each event is plotted against the maximum total water thickness measured from the non-invasive surface state sensors (Aultguish) and the embedded road sensors (Aultguish, Brahan and Braemore).

The Aultguish weather station enabled a direct comparison between the water thickness measurements recorded by the non-invasive and embedded sensors at the same time as shown in Figure 10.

For each Figure, the data points are colour coded according to the worst case surface state measured from the road sensors.

Key:

	Wet/damp/dry
	Snow/Slushy
	Ice

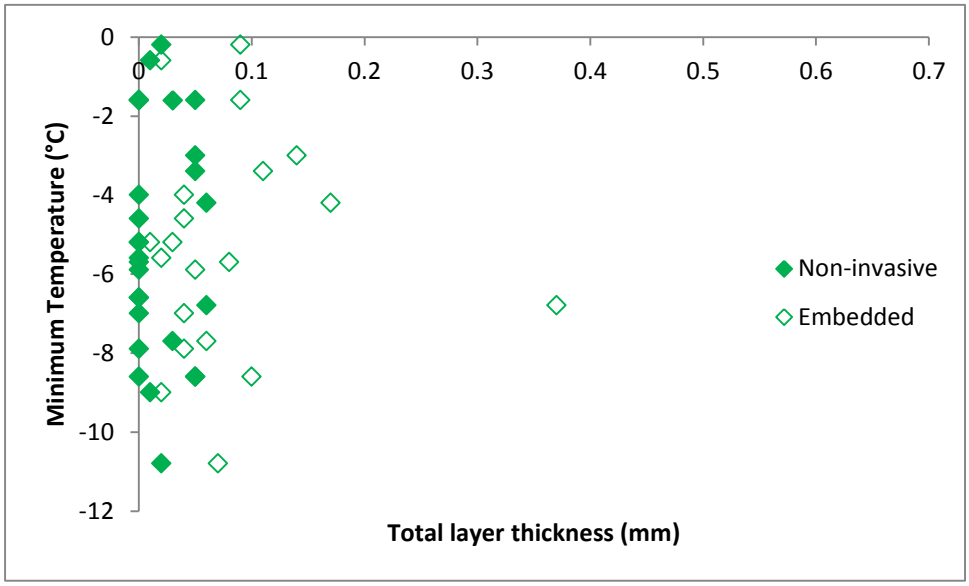


Figure 10. Conditions during frost events at Aultguish weather station

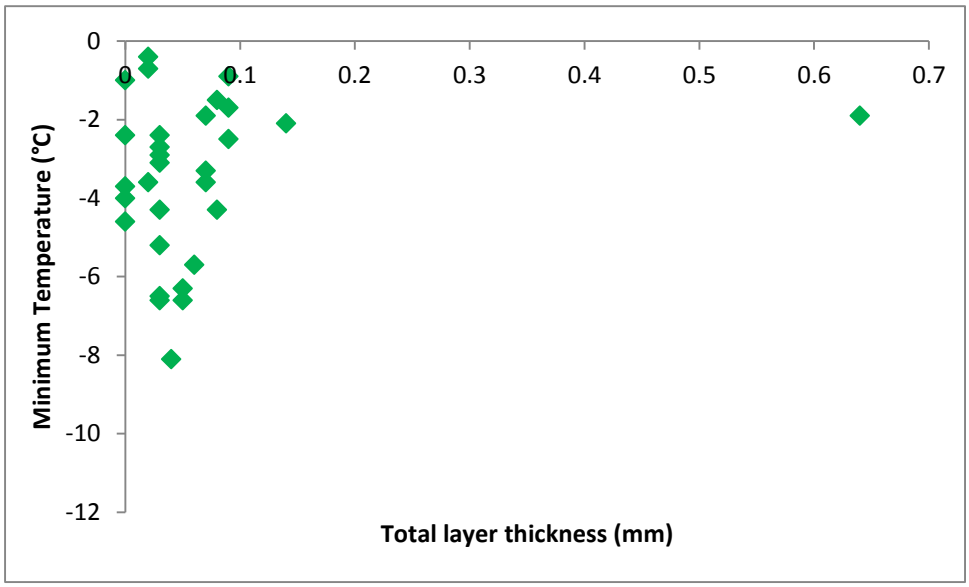


Figure 11. Conditions during frost events at Brahan weather station

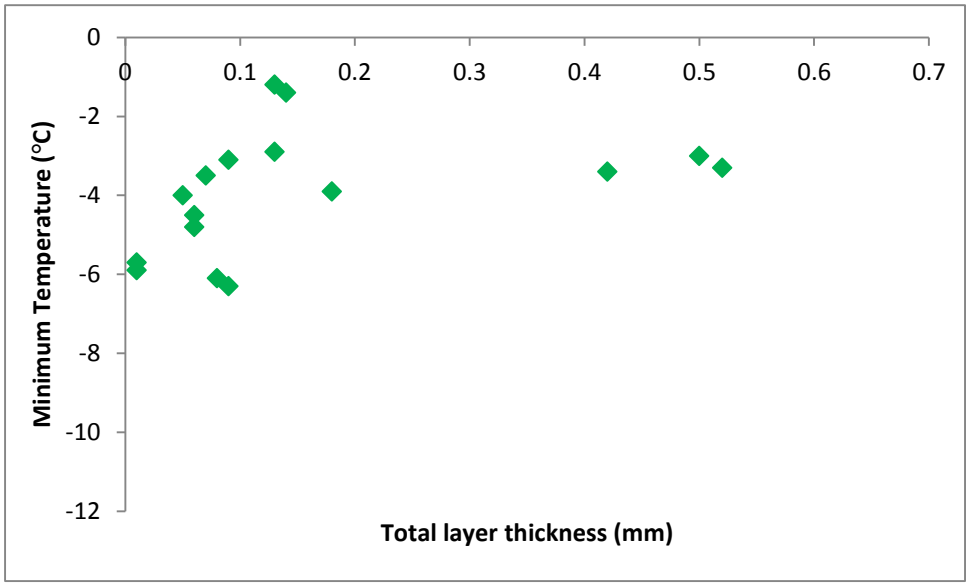


Figure 12. Conditions during frost events at Braemore weather station

Brine has provided an effective treatment for the conditions prevailing during the frost events, with no ice detected at the monitoring sites. All 'Grip' measurements from the non-invasive sensor at the Aultguish site remained above 0.6 during these events.

The figures clearly demonstrate that colder surface temperatures were typically associated with drier roads (lower water film thickness). The minimum surface temperature was -10.8°C, recorded for a frost event with maximum water thickness of 0.02mm.

There was a difference between the maximum thickness measurements reported by the embedded and non-invasive sensors at the Aultguish monitoring site, with the embedded sensors measuring greater thicknesses as shown in Figure 10. The embedded sensors

monitor a smaller area of the road compared to the non–invasive sensor, and consequently can show greater variability in the reported thickness over time.

Based on data from the Aultguish weather station, where there is greater confidence in the accuracy of the thickness measurements from the non-invasive sensor, the wettest road surface measured was 0.06mm, measured for two events with minimum road surface temperatures of -6.8°C and -4.2°C. The road surface was classed as wet for both these events resulting from the road surface temperature falling below the dew point temperature overnight.

7.4 Treatments applied before and during precipitation

To provide evidence for the resilience of brine treatments carried out before and during precipitation events, the weather station and road condition data were analysed for the events where precipitation had occurred during and after spreading for sub-zero road surface temperatures.

The minimum temperatures, maximum water layer thicknesses and total amounts of precipitation measured at the weather stations during precipitation events are summarised in Figure 13, Figure 14 and Figure 15.

The data points were colour coded according to the worst case surface state measured from the road sensors.

Key:

	Wet/damp/dry
	Snow/Slushy
	Ice

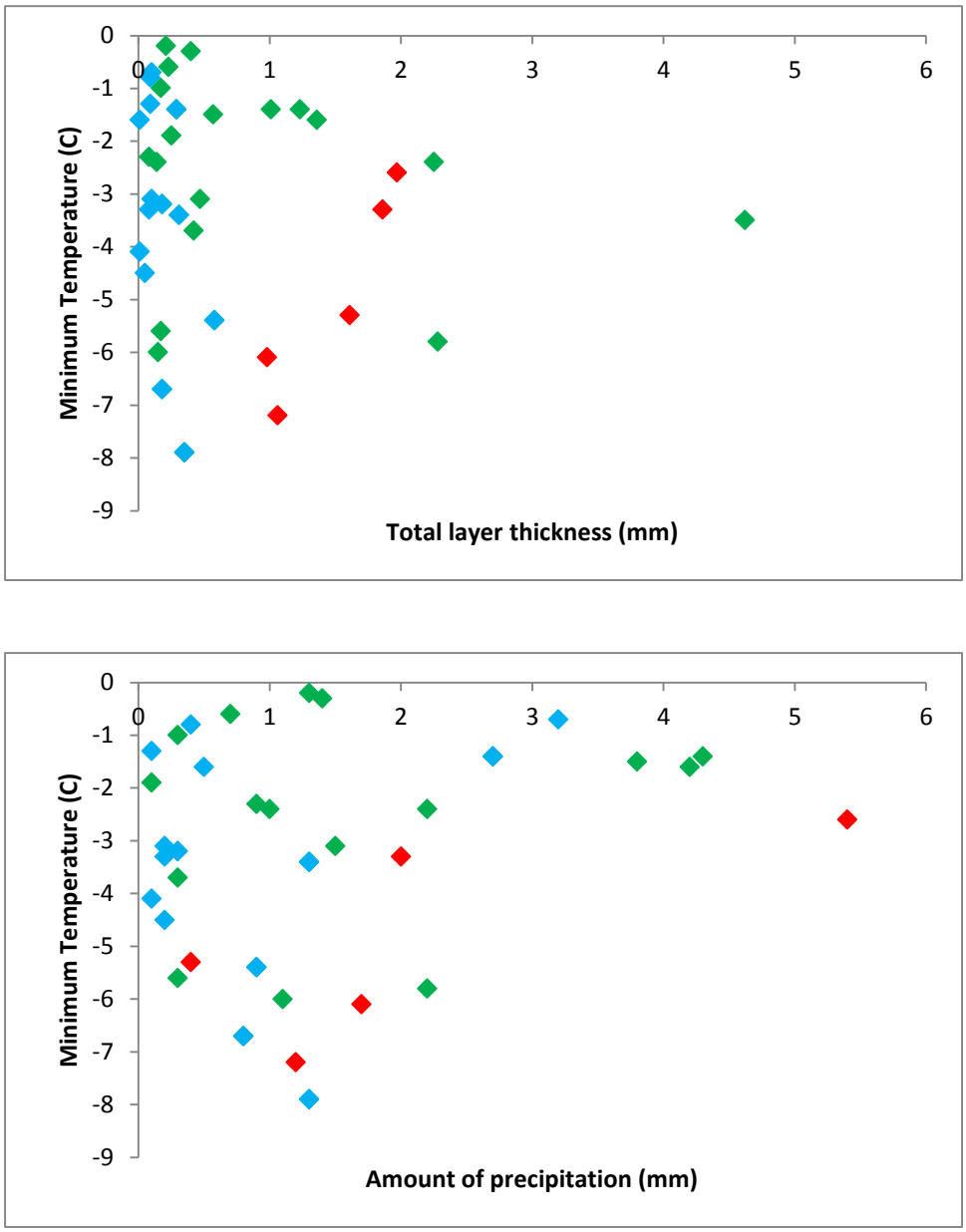


Figure 13. Conditions during precipitation events at Aultguish weather station

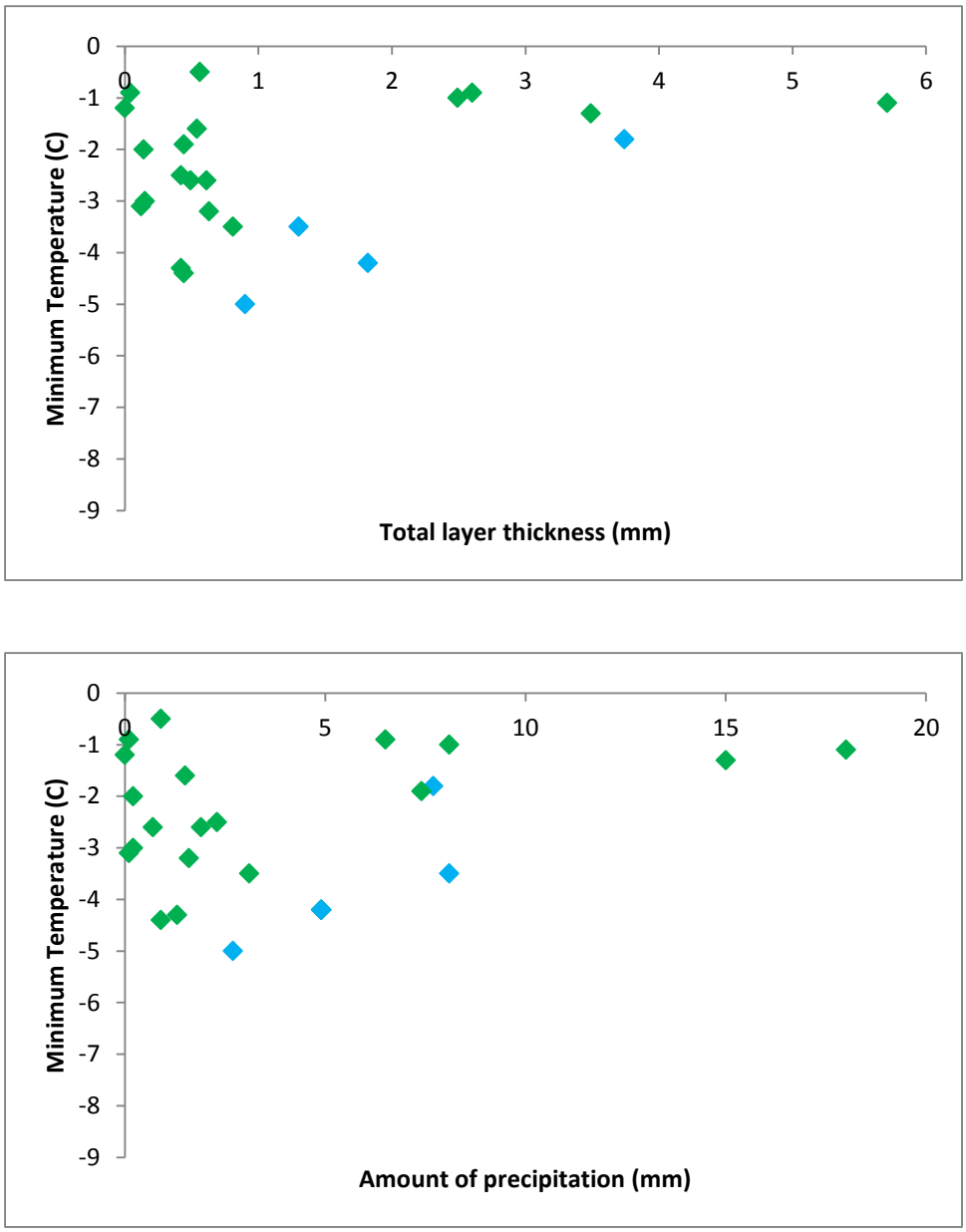


Figure 14. Conditions during precipitation events at Brahan weather station

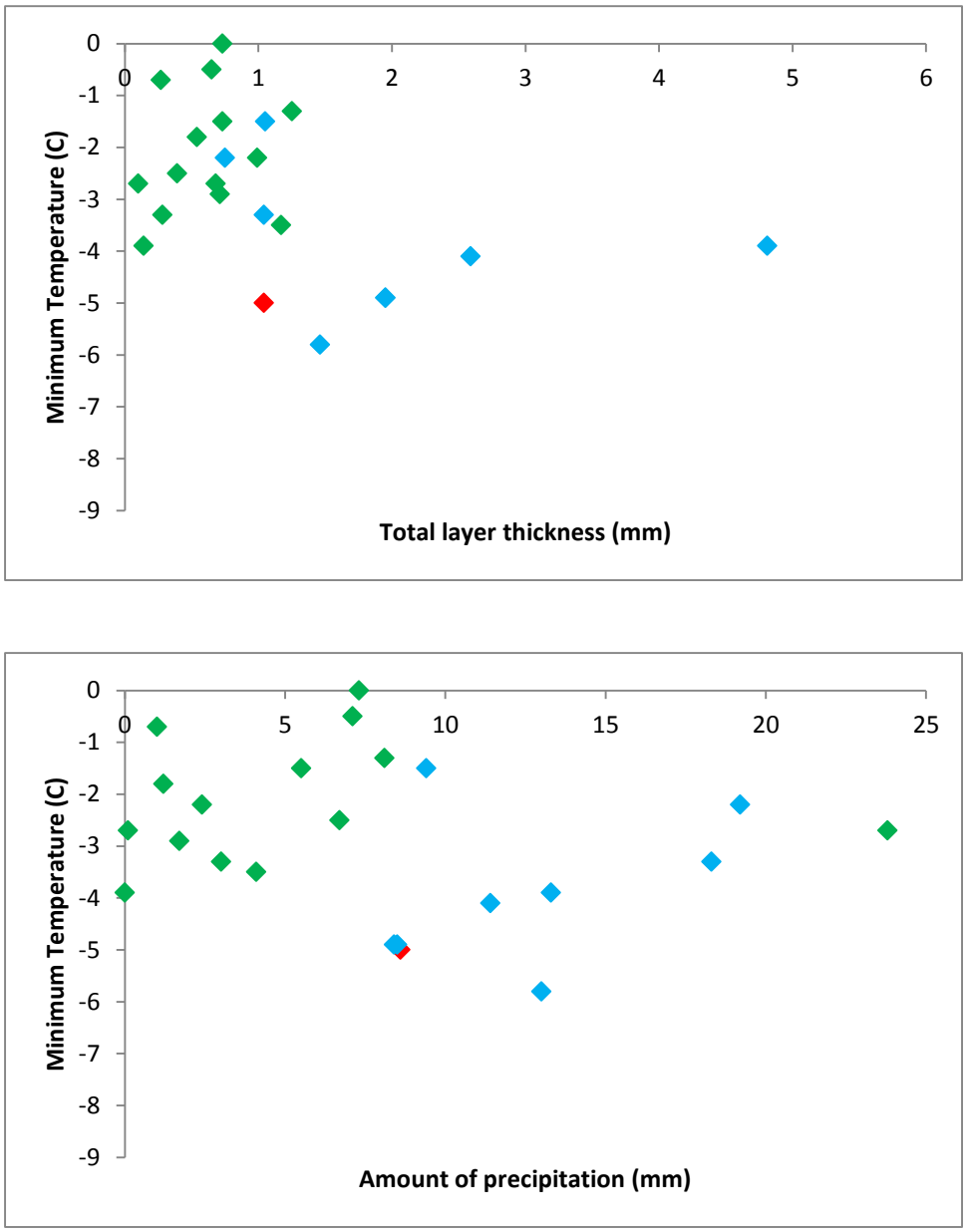


Figure 15. Conditions during precipitation events at Braemore weather station

Treatments were carried out with both brine and pre-wetted salt during the trial. For both types of treatments, events occurred where 'Grip' fell below 0.6 for certain periods.

For the brine treatments:

- Figure 16 shows the minimum 'Grip' levels measured at the Aultguish weather station for the range of water thickness and surface temperatures experienced in each event.
- Figure 17 shows the 'Grip' measurements for the range of precipitation amounts and surface temperatures.

For the pre-wetted treatments:

- Figure 18 shows the minimum 'Grip' measurements for events where pre-wetted salt was spread, for the range of water thickness and surface temperatures.
- Figure 19 shows the 'Grip' measurements for events where pre-wetted salt was spread, for the range of precipitation amounts and surface temperatures.

The data points were colour coded dependent on the minimum level of 'Grip' as follows:

Key:

	'Grip'> 0.6.	Dry or wet surface
	0.6 > 'Grip' > 0.5	Slush or ice forming
	Grip' < 0.5	Snow or ice, slippery conditions
	Indicative boundary between effective treatments and slippery conditions	

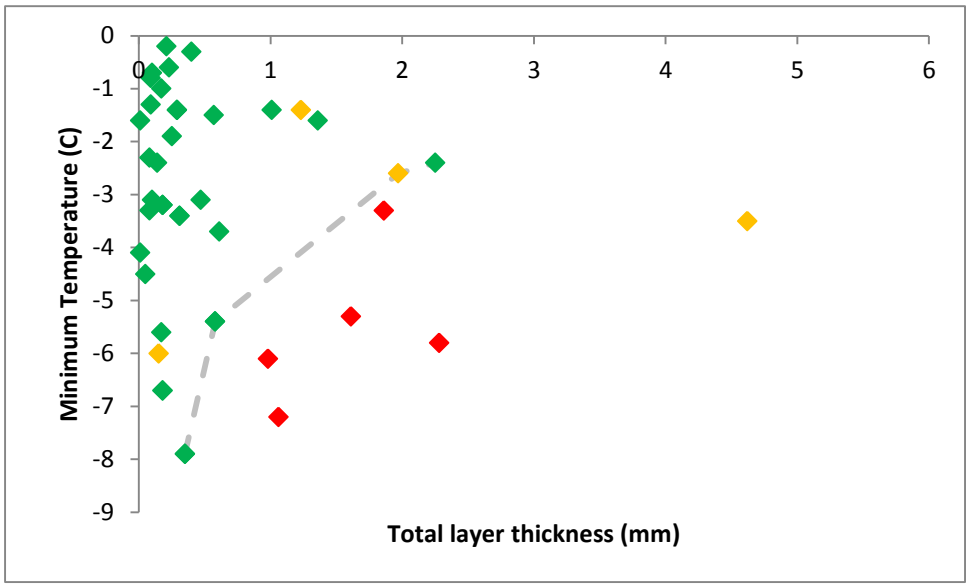


Figure 16. Summary of minimum 'Grip' levels at Aultguish weather station during precipitation events – brine spreading

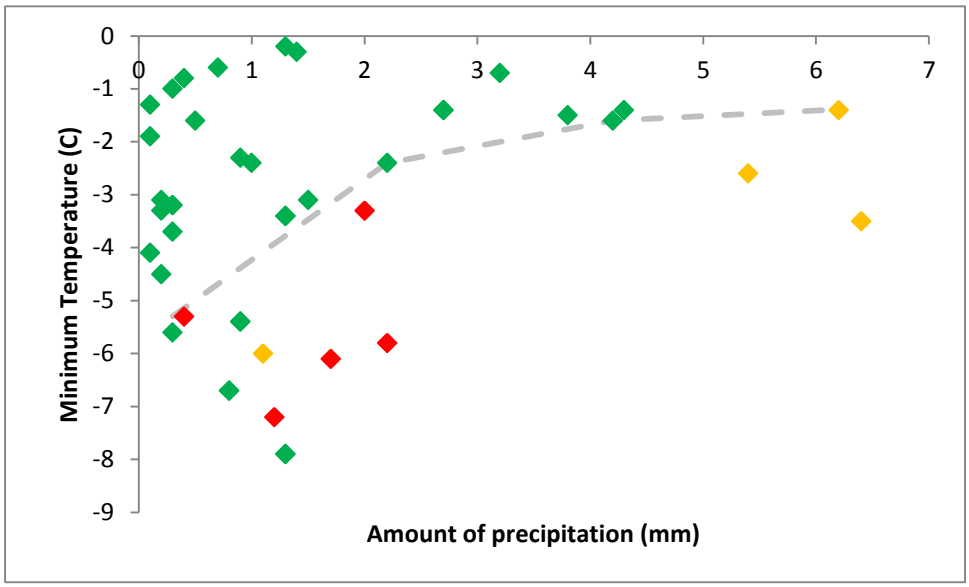


Figure 17. Summary of minimum 'Grip' levels at Aultguish weather station during precipitation events - brine spreading

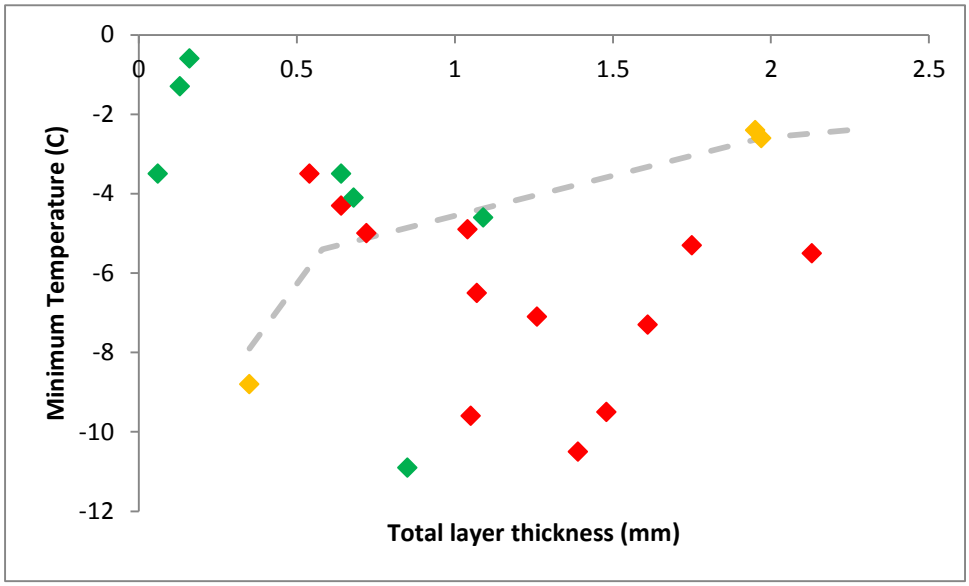


Figure 18. Summary of minimum 'Grip' levels at Aultguish weather station during precipitation events – pre-wetted salt

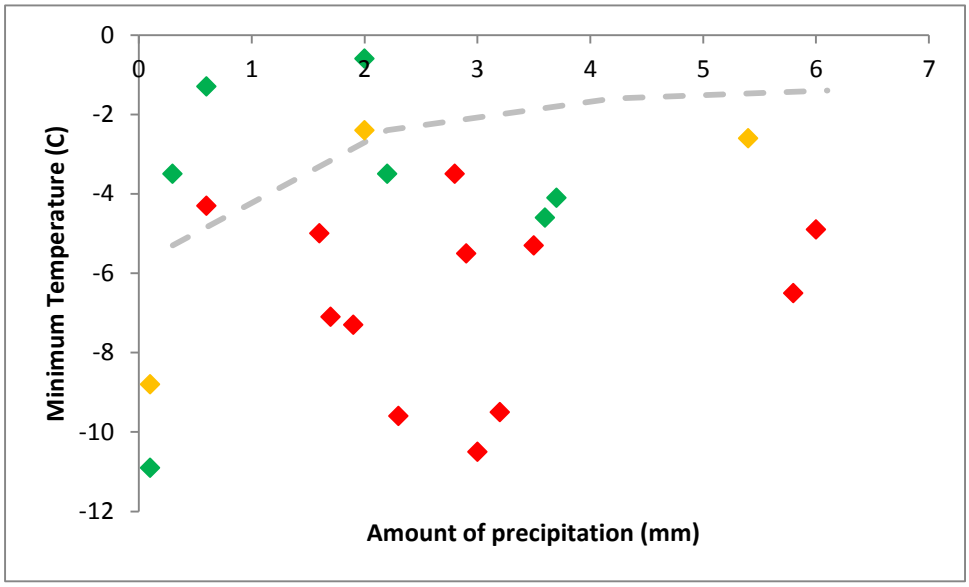


Figure 19. Summary of minimum 'Grip' levels at Aultguish weather station during precipitation events – pre-wetted salt

Figure 16 and Figure 17 demonstrate a clear divide between the conditions where brine provided an effective treatment ('Grip'>0.6) and where slippery conditions occurred, indicated by the dashed line included on each figure. Effective treatments were for the conditions above the line and slippery conditions below the line. Larger layer thickness and/or lower temperatures result in snow or ice detected on the road surface and low 'Grip' values.

The figures show that during the trials there were a number of snow and rainfall events resulting in 'Grip' values below 0.6 and/or ice or snow detected, which are discussed in more detail in the following sections.

7.4.1 Treatments during snowfall ('Grip' less than 0.6)

Table 2 summarises the key parameters assessed for snow events where 'Grip' fell below 0.6, including the total amount of precipitation (from rain or snow), water film thickness on the road surface and minimum road surface temperatures. The description of these events is included in Appendix C.

Table 2 Summary of snow events and treatments

Date	Maximum layer thickness (mm)	Total precipitation (mm)	Minimum temperature (°C)	Minimum 'Grip'	Description of event	Treatment
13/12/2017	2.25	2.2	-7.2	0.26	Spreading was carried out on slushy road shortly after light snowfall. Slushy/snowy road state reported during intermittent snowfall overnight, with 'Grip' occasionally dropping below 0.6 during snow.	Ploughing and treating 20ml/m² Additional dry and pre-wetted treatments
14/12/2017	4.62	6.4	-3.5	0.51	Slushy road state reported up to midnight, with wet road surface maintained after with additional dry and pre-wetted treatments.	Ploughing and treating 20ml/m² Additional dry and pre-wetted treatments.
15/01/2018	1.86	2	-3.3	0.13	Brine spreader patrolling route during continuous snowfall. Patrol reported ice under snow and ice detected on embedded sensor.	Brine Treatment at 30ml/m² Ploughing and treating
10/02/2018	0.15	1.1	-6	0.59	Brine spreader patrolling route during snowfall. Small amount (<0.02mm) ice/snow detected by non-invasive sensor. Minimum 'Grip' of 0.59.	Ploughing and treating 20ml/m² Additional dry and pre-wetted treatments
14/02/2018	5.4	1.97	-2.6	0.55	Initial brine treatment at 20ml/m² followed by periods of light snowfall.	Brine treatment at 20ml/m² Additional dry and pre-

						wetted treatments
06/03/2018	1.23	6.2	-1.4	0.51	Brine spreader patrolling route during snowfall. Continuous light snowfall overnight.	Ploughing and treating 20ml/m²

Snow events on the 15th and 16th January enabled a comparison between the effectiveness of brine with a treatment carried out the following night in similar conditions, but using only pre-wetted salt.

Surface temperatures fell below freezing at approximately 17.00 on the 15th January and remained below freezing overnight and throughout the next day and night. Figure 20 show the road surface temperature, intensity of precipitation, road surface state and level of 'Grip' measured during each event. Figure 22 show CCTV images of the road conditions throughout each event. For each event there were comparable amounts of precipitation, with 2mm total during the event on the 15th January and 2.9mm on the 16th January.

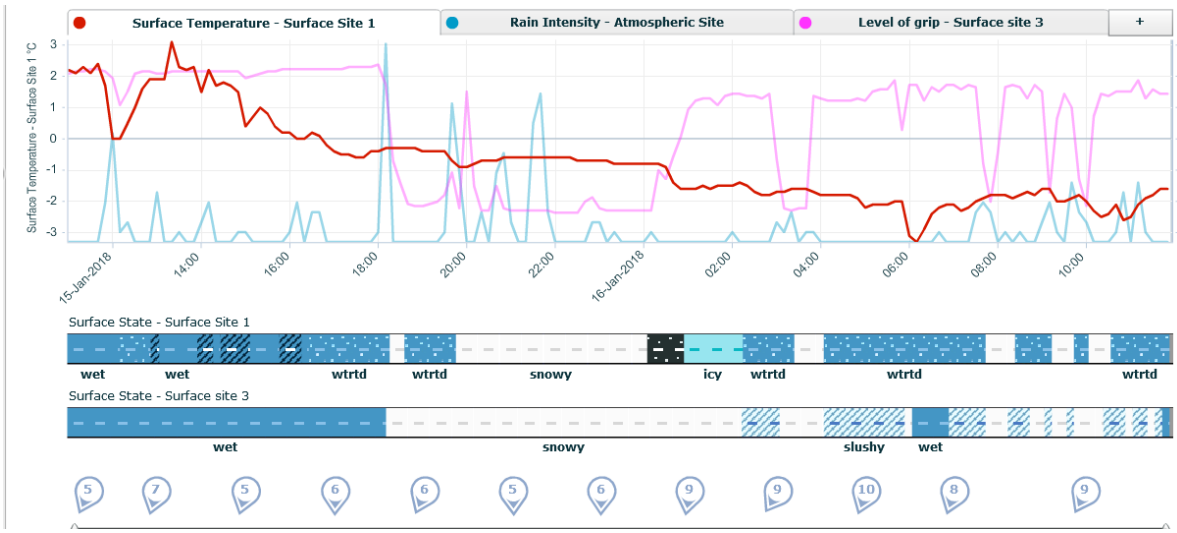
Vaisala have defined a Winter Mobility Index, the percentage of time the road conditions do not significantly impede mobility during a storm event ('Grip' value of 0.6 or higher) when precipitation is on the surface with below freezing surface temperatures. The Mobility Index was calculated for the events on the 15th and 16th January between time 18:00 and 06:00, with 'Grip' levels maintained above 0.6 for 37% of the time for the brine treatment and 44% of the time for the pre-wetted treatments, representing a small improvement for pre-wetted salt.

For both events the road surface was covered in snow during the evening, which was the period when the most intense snowfall occurred, with gradual recovery back to black through the early morning. The CCTV images showed quicker regain time to bare pavement for the pre-wetted salt, with black road conditions clearly visible at 06.00, compared to the brine treatment where significant snow is still present. (It should be noted that from around 07:30 on the morning of the 16th there was further snowfall)

During the brine treatments on the 15th, the drivers reported that the spreader's tyres were not able to break through to the road surface as they would typically experience. The drivers also reported ice under the snow. As shown in Figure 20, the embedded sensor reported ice for a short time during both brine and pre-wetted treatments.

Figure 21 shows the amount of chemical measured from the embedded road sensor during each event. Higher levels of salt were generally measured during the pre-wetted treatments, although the amount of chemical on the road surface fell to a similar minimum amount at around 22:00 for both events. This was during the period where there were no treatments being carried out, before more intensive spreader activity resumed from around midnight. The lower sensor readings will be partly due to the lower amounts of salt spread by brine, and may also be an indication that the brine is not penetrating to the road surface as would the solid salt particles.

15th January - Brine



16th January – Pre-wetted

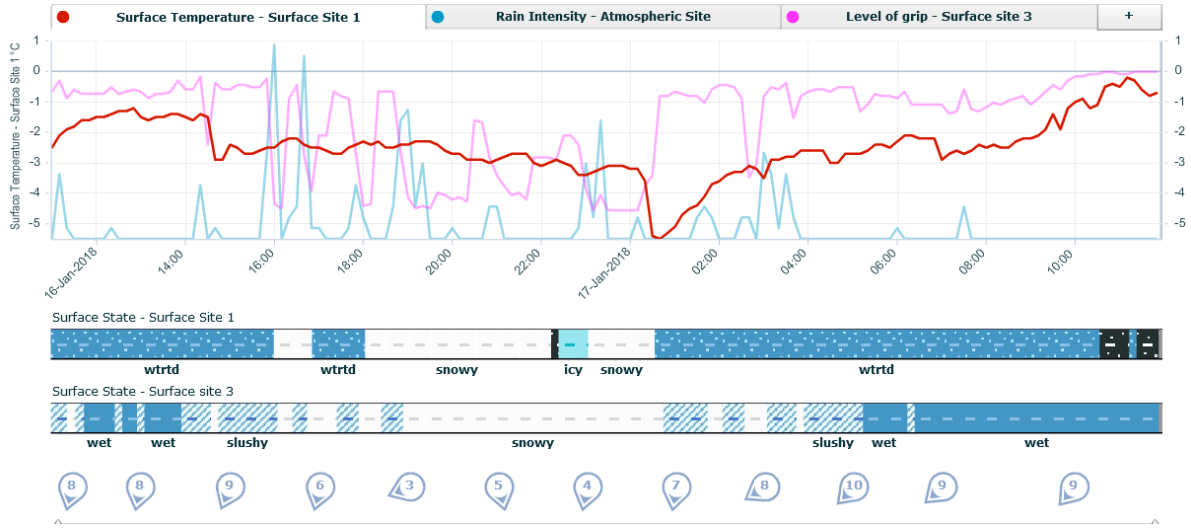


Figure 20. Weather station data from Aultguish site for 15th and 16th January – showing RST, Precipitation intensity, road surface state and 'Grip'. (Surface Site 1 is embedded sensor, Site 3 is non-invasive)

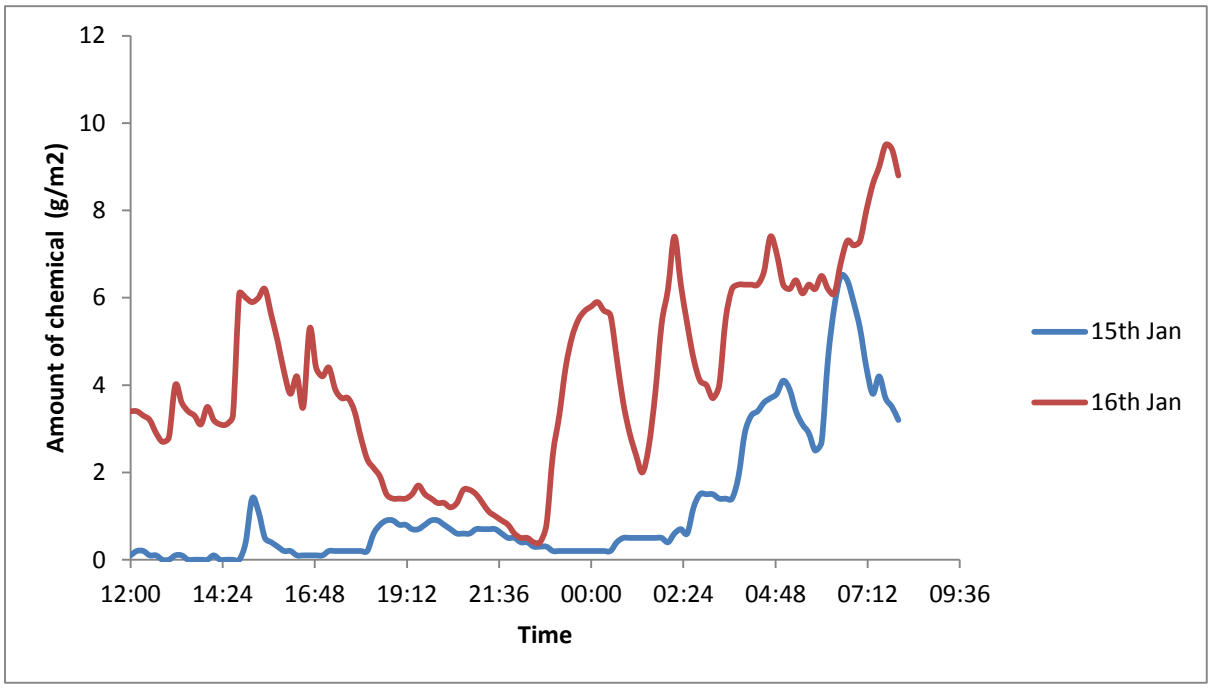


Figure 21. Amount of chemical reported from embedded sensor at Aultguish site

15.00 **15th January - Brine** **16th January – Pre-wet**

18.00

21.00

00:00

03:00

06:00

07:20

09:00

Figure 22. Comparison of road conditions at Aultguish during 15th and 16th January.

7.4.2 Treatments on very wet road surfaces

There were a series of events during the trial period where precipitation occurred during and after treatment resulting in very wet (but not snow covered) road surfaces followed by freezing conditions.

Table 3 summarises the key parameters for such events where 'Grip' fell below 0.6, measured at the Aultguish weather station, or ice was reported on the route from patrols. Included in the table are 5 brine treatments and 2 pre-wetted treatments (carried out shortly before the trial commenced). Included in Appendix D, Figure 24 to Figure 29 shows the rain intensity and measured water thickness at the Aultguish site for each event.

For treatments after rainfall, the current guidance in the winter service plan is that roads can be classed as damp 20 minutes after rain has stopped. This guidance was based on previous research carried out on the Highways England network.

A wet road is typically classed as between 0.05 to 0.1mm of water on a lightly trafficked route such as the A835. As can be seen from the road conditions, these were events where the road surface would be classed as very wet, with up to nearly 2mm of water in some events. Table 4 shows the time, and road surface temperature, at which the road surface was classed as wet (0.1mm thickness) and damp (0.05mm thickness) as it dried/drained after rainfall stopped.

The trial site was observed to remain wet for significantly longer periods than 20 minutes after rain stopped during these events. In some cases, for example the 2nd January, the road remained wet (water thickness greater than 0.05mm) for 6 hours (this was for freezing conditions and surface temperature around 2°C below the dew point temperature).

For all these events, there were no further treatments during the evening period after spreading.

Table 3 Summary of freezing wet road events

Date	Maximum layer thickness (mm)	Total precipitation (mm)	Minimum temperature (°C)	Minimum 'Grip'	Description of event	Treatment
30/12/2017	0.42	0.3	-3.6	0.6	Spreading carried out on very wet road during light snowfall. Icy road detected by non-invasive sensor at 23:30, 8 hours after spreading, with one ice reading at embedded sensor 9 hours after spreading. Amounts of ice detected were small (<0.02mm) and minimum 'Grip' was 0.6. Reactive call out because of ice, with wet road surface reported after treatment (pre-wetted salt).	Brine 20ml/m²
31/12/2017	0.18	0.8	-2.8	0.75	Spreading carried out on very wet road during light rain. Patrol reported icy conditions at 00:10.	Brine 20ml/m²
01/01/2018	0.98	1.7	-1.1	0.19	Spreading carried out on very wet road during light rain/snow - ice and low 'Grip' detected by non-invasive sensor 8 hours after spreading with minimum 'Grip' of 0.19.	Brine 20ml/m²
02/01/2018	1.61	0.6	-1	0.28	Spreading carried out on very wet road during light rain/snow -	

					ice and low ‘Grip’ detected by non-invasive sensor 4 hours after spreading with minimum ‘Grip’ of 0.28.	
05/01/2018	0.47	1.5	-3.1	0.68	Spreading carried out on wet road followed by rain/snowfall. Observation and photographs/video of a slippery and sparkling road surface from patrol driver at 02:45 at Garve (between Brahan and Aultguish weather station)	Brine 20ml/m²
27/11/2018	0.33	0.7	-0.8	0.43	Spreading carried out on wet road (0.09mm water thickness) followed by rain. Ice detected by non-invasive sensor at 22:50, 7.5 hours after treatment.	Pre-wetted salt 20g/m²
28/11/2018	1.94	1.5	-0.4	0.28	Spreading carried out on wet road (0.09mm water thickness) followed by rain. Ice detected by non-invasive sensor at 21.20, 6 hours after treatment.	Pre-wetted salt 20g/m²

Table 4. Time and road surface temperature at which roads classed as wet and damp after rainfall (spreading at approx. 15:30)

	Wet road (0.1mm)		Damp road (0.05mm)	
Date	**Time**	**Surface temperature (°C)**	**Time**	**Surface temperature (°C)**
27/11	17:20	1.1	18:40	0.5
28/11	20:20	-0.2	21:30	-0.6
30/12	18:10	-1	19:20	-1.2
31/12	18:00	0.5	19:10	0.3
01/01	22:40	-0.7	23:20	-1.6
02/01	21:10	-2.2	Road remained wet	

7.5 Operator feedback

Feedback from the spreader drivers was that treatments with brine were effective for the frost conditions but struggled or were shorter lasting in the more severe snow and wet conditions encountered on the route. The comments were that brine did not penetrate snow as would normally be relied on from solids salt particles, although there was some comment that brine can soften snow if ploughing behind the spreader.

Some particular events that were noted by the drivers are included in Table 2 and described in Appendix C. For example:

- During the snow event on the 15th January, the drivers reported that wheel tracks of the spreaders were not cutting through to the road surface as they would typically experience, and there were reports of ice under the snow. The embedded sensors also reported ice for a time during this event.
- A patrol driver observed a 'sparkling' road surface and slippery conditions after treatment in the early morning of the 6th January (photos and video taken that demonstrated the effect observed). This was during the initial trial period, using brine with concentration measured at 24% on the morning of the 5th January (See Section 7.6.2 for discussion of brine concentrations). A possible explanation for the observations might be salt precipitating from the concentrated brine at low temperatures.
- Ice was reported from patrols during the spreading events from 30th December to 2nd January. These were a series of similar events where precipitation occurred during the period of the afternoon treatments, with ice detected during the evening period. The reports correlated with ice detected from the sensors at the Aultguish weather station, and the Braemore weather station for the 31st December (see Section 7.4).

7.6 Spreader operation

7.6.1 Pre-wetted brine ratio

The spreader used for the trial provided the capability to deliver pre-wetted treatments with different ratios of brine to salt.

Some trial runs were undertaken to assess the performance of pre-wetted salt with an increased brine ratio of 70:30 brine:salt. In particular the aim was to assess if this offered an effective treatment for snow or wet conditions where brine was observed to struggle, while still providing savings in salt use.

When attempting the pre-wetted treatments, issues with the hydraulic system prevented spreading both brine and salt. The problem was rectified by the replacement of a hydraulic pump, but conditions during the remainder of the trial period were not severe enough to enable an assessment of the effectiveness.

There was some feedback from the operators from the observations possible that the spreading of the increased brine share pre-wetted salt improved treatment effectiveness, but this will need to be trialled more extensively in future testing.

7.6.2 Brine concentration

As part of BEAR standard operating procedures, daily checks are carried out of the concentration of brine samples taken from the saturators. The concentration is measured with a refractometer and records retained electronically.

Analysis of these records identified that brine concentration varied between 23 and 25% during the initial trial period. As shown in Table 5, increasing the concentration of a solution of sodium chloride will result in a decrease in the freezing temperature until a concentration of 23.3% is reached (the Eutectic Point). As the brine concentration increases above 23.3%, the freezing point will start to increase sharply.

Table 5. Sodium chloride brine freezing point by concentration

% of NaCl by weight	Freezing point (°C)
20	-16.46
23	-20.69
23.3	-21.13
24	-17.00
25	-10.40
26	-2.30

It should be stated that the 'freezing' at concentrations above the eutectic point is a process of excess salt crystallising from the solution to form solid sodium dehydrate (hydrohalite), not ice. If the brine concentration exceeds 23%, there is an increased risk of salt re-crystallising within the pumps, pipes and nozzles of the spreader. In certain conditions, for example a nearly saturated salt solution on a road surface with falling temperature, it might be a possible that salt can crystallise on the road surface (as hydrohalite), as surface temperatures fall below the freezing point of the concentrated brine solution. Some of the observations from the trial might also be a result of this process, for example the 'sparkling' and slippery road conditions observed by the patrol driver on the morning of 6th January.

Once the issue with high brine concentration had been identified, a maximum brine concentration limit of 23% was put in place and closely monitored for treatments from the 26th January onwards. This concentration is the point where brine has the lowest freezing temperature and reduces the risk of salt recrystallization in the spreaders or on the road surface.

7.6.3 Brine delivery mechanism

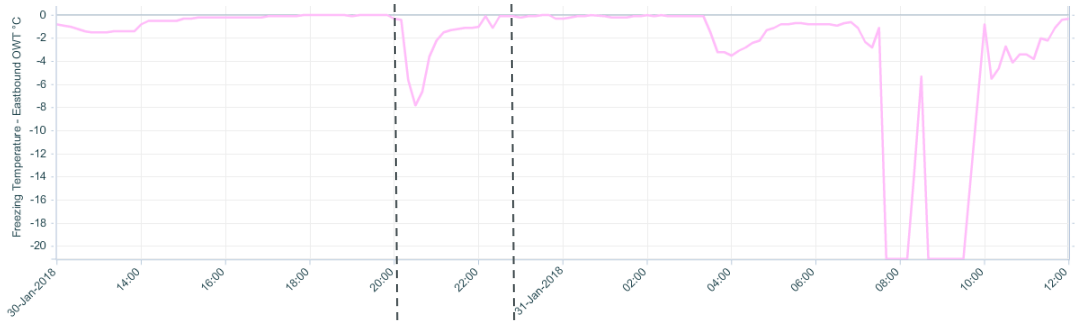
As described in Section 4, the brine was spread from a spinning disc. The distribution was observed to cover the full road width, but there was some feedback from the drivers that the brine spray was affected by cross winds.

Figure 23 shows the Freezing Point response from embedded sensors at each weather station during a treatment carried out on the 30th January. The sensor response is dependent on the amount of water on the road surface, and for this event the road surface at each site was at a similar level of wetness (a wet road surface at all sites, water film thickness at time of spreading 0.24mm (Brahan), 0.28mm (Braemore) and 0.11mm (Aultguish).

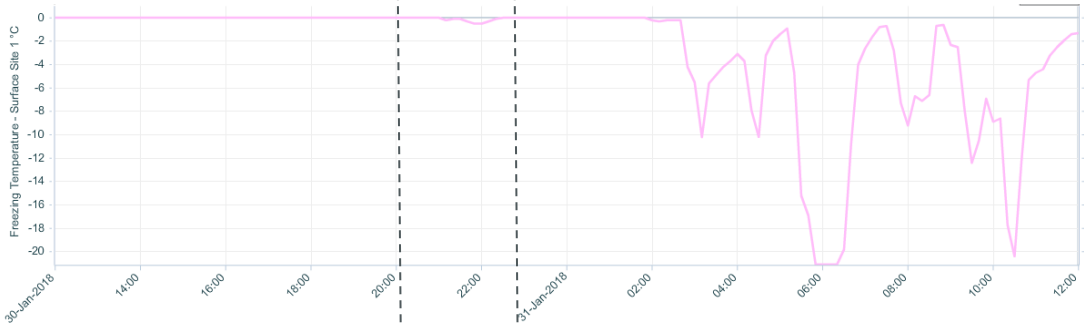
Spreading was carried out at time 20:00 with a spread rate of 20ml/m², with the sensor responses highlighted between the dashed line on the figure. Wind speeds were significantly higher at the Aultguish site, with maximum speeds of nearly 30mph measured around the time of spreading compared to 10mph at Brahan, and the south westerly wind direction blowing across the road at the Aultguish location.

As shown in Figure 23, there was very little sensor response at the Aultguish sensor in comparison to the other sites where a significant decrease in the freezing points was measured. This is most likely a consequence of the brine spread at the Aultguish site being carried away from the target area by the strong crosswind.

Brahan – Average wind speed 9.8mph, Max wind speed 9.8mph



Aultguish – Average wind speed 20.6mph, Max wind speed 29.3mph



Braemore – Wind speed N/A

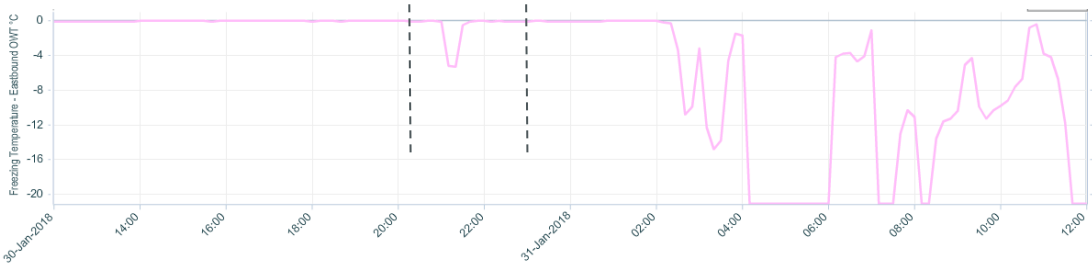


Figure 23. Freezing point response from embedded road sensors, 30th January.

8 Discussion

Trial conditions

The 2017/18 winter season and A835 trial route has provided a much severer test environment than the previous trial phases.

Very low temperatures have been experienced, down to below -10°C, with the lowest temperatures experienced during the drier frost conditions. The toughest conditions have been presented through a combination of precipitation and freezing temperatures, with surface temperatures during snowfall as low as -7.9°C (recorded at Aultguish)

It is considered the trial route has provided the full range of conditions likely to be experienced on the Transport Scotland network, from frost to snow events and for a range of temperatures.

The trial route has low levels of traffic which can provide challenges for winter maintenance. For example the road surface remained very wet for significant periods after rainfall, with little traffic to disperse water. Trafficking can also help to break up and disperse snow and ice as long as the snow has not become compacted on the road surface. These conditions provide a challenge whatever type of treatment is applied.

Treatment effectiveness

The severity of frost and precipitation events and suitability of brine treatments will depend on a range of different factors. Some of these key factors will include the minimum road surface temperatures, the maximum water layer thicknesses (or equivalent water layer for snow) and the type, amount and timing of precipitation.

These trial results have demonstrated that brine provides an effective treatment for precautionary frost treatments. Wet roads were treated effectively down to -7°C and dry/damp roads to -10.8°C.

The previous trial phases had provided some evidence for the effectiveness of brine treatments for precipitation events; conditions tested included amounts of precipitation up to 1mm water from rain or snow, and for surface temperatures down to -2°C.

From the Phase 4 trial results, the effectiveness was demonstrated for a wider range of conditions than the previous trial phases but limiting factors have also been identified.

An indication of the conditions for which ‘Grip’ levels were maintained above 0.6 at all times during treatments are summarised for precautionary frost treatments (see Table 6) and treatments before and during precipitation (see Table 7).

Table 6. Minimum temperatures where 'Grip' maintained above 0.6 for frost treatments

Road Surface State	Minimum temperature (°C)
Damp/dry road (Water thickness less than 0.02mm)	-10.8
Damp/dry road (Water thickness less than 0.05mm)	-8.6
Wet road (Water thickness less than 0.06 mm)	-6.8

Table 7 Minimum temperatures where 'Grip' maintained above 0.6 for precipitation events

Amount of precipitation		Minimum temperature (°C)
Rain(mm)	Snow(mm)	
0.3	3	-5.3
1	10	-4.5
2	20	-3.3
3	30	-2.5
4	40	-1.8
5	50	-1.5

During severe events it is not always reasonably practicable to maintain clear road conditions at all times. The aim of the treatments will then be to recover the road conditions as quickly as possible and prevent the build-up of compacted snow and ice on the carriageway that cannot be ploughed away.

Recent research in Germany reported at the 2018 International Winter Road Congress (Hanke, 2018; Hess and Hausmann, 2018) highlighted the importance of short cycle times between ploughing passes to prevent compacted snow forming on the road. The research was based on treatments with pre–wetted salt, and demonstrated the amounts of salt required and frequency of ploughing and salt application to maintain loose, non-compacted snow on road surfaces. The amount of salt required is significantly less than the amount that would be needed to melt the snow, as long as the required frequency of snow clearance and de-icer application can be maintained. For continuous snowfall, Hess and Hausmann

presented the amount of salt required for each cm of fresh snowfall to keep the snow in a ploughable condition. Based on these amounts, an indication can be given of the thickness of snow for which effective treatments can be provided by brine and pre-wetted salt spreading.

Column 2 in Table 8 presents the thickness of snow for which 'Grip' was maintained above 0.6 in the Phase 4 trial (this was based on the assumption that 1mm of water is equivalent to 10mm of snow). As a comparison, included in the table is the thickness of fresh snow that is predicted to be kept in ploughable condition for a 20 and 30ml/m² brine treatment or a 20g/m² pre-wetted treatment, calculated by applying the results from the work as presented by Hess and Hausmann.

Some assumptions are made here of salt loss after spreading (30% loss for brine and 40% loss for pre-wetted salt). It is considered that spreading on a wet or slushy road in low traffic will negate the advantage of brine spreading to a certain extent. The combination of low traffic and quick dissolution of the salt on the wet surface will prevent the significant loss from dispersal of solid salt particles which has typically been measured in salt loss trials, hence the more similar losses that have been assumed for the brine and pre-wetted salt.

Table 8. Predicted maximum thickness of snow that can be maintained in ploughable condition

Air temperature (°C)	Thickness of fresh snow (cm)			
	Phase 4 Trial results	20ml/m² Brine*	30ml/m² Brine*	20g/m² Pre-wet*
-1	2.8	1.7	2.6	5
-2	2.3	0.9	1.3	2.5
-3	1.7	0.6	0.9	1.7
-5	1.2	0.35	0.5	1
-7	0.4	0.25	0.4	0.7
-10	-	0.2	0.3	0.5

* Thickness calculated based on the research by Hess and Hausmann (2018)

The limits for snow thickness measured in the trial were comparable to thicknesses presented by Hess and Hausmann.

Snow build up on the roads, and periods of 'Grip' less than 0.6, have been measured following both brine and pre-wetted treatments during this trial period. From the observations during the trial, spreading of brine on a snow covered surface is not then able to penetrate to the road surface and clear snow as effectively as from spreading of solid salt.

The capability of brine treatments to provide a recovery in road conditions is therefore very dependent on clearance of snow back to bare pavement after each plough pass i.e. spreading of brine on a bare pavement.

During the treatments of the trial site, snow sometimes built up during the evening periods, before more frequent ploughing passes from spreader vehicles during the early morning periods. For brine treatments it is considered essential, even more so than for pre-wetted or dry spreading, to maintain frequency of spreading and ploughing passes at all times after the initial treatment. This will help to prevent the build-up of compacted snow, when subsequent ploughing or vehicle action cannot then break through to the road surface.

The trial site is a less trafficked route than the Highways England network and also other major routes on the Transport Scotland network, and the road construction along much of the route is also more akin to the local road network rather than motorways or dual carriageways. This combination of low traffic and road construction resulted in the trial site remaining wetter for significant periods after rainfall. As was shown from surface temperatures in Table 4, waiting for the road conditions to be damp before treating is not always a feasible option and treatments must be carried out on very wet roads before freezing occurs.

Roads can be too wet for an effective treatment from a single pass, and this has been demonstrated to be an issue for both pre-wetted and brine spreading. In such circumstances repeat treatments may then be required to prevent icy conditions occurring as temperatures continue to fall.

Treatment recommendations

Based on the conditions under which the brine spreading has been trialled, guidelines are provided in Table 9 for treatments during frost and Table 10 for precipitation events.

Table 9. Recommended brine spread rates for frost events

Road Surface Temperature (RST) when frost/ice is predicted	Recommended Spread Rates – Brine Spreading (ml/m²)	
	Dry/Damp Road	Wet Road
RST lower than or equal to plus 1°C but higher than minus 2°C	10	20
RST lower than or equal to minus 2°C but higher than minus 7°C	20	20
RST lower than or equal to minus 7°C	20	N/A

Key notes:

- Spread rates are for road wetness less than 0.1mm thickness (i.e. a road on which traffic produces fine spray)
- Roads can remain wet after rain for significant periods (2-3 hours) before effective brine treatments are possible

Table 10. Recommended brine spread rates for precipitation events

Road condition	Recommended Spread Rates – Brine Spreading (ml/m²) For initial and follow up treatments, in combination with ploughing back to road surface	
	Light snow Max 10mm	Moderate/heavy snow More than 10mm to maximum 25mm
RST lower than or equal to plus 1°C but higher than minus 2°C	20	20
RST lower than or equal to minus 2°C but higher than minus 6°C	20	N/A

RST lower than minus 6°C	N/A	N/A
Light rain showers forecast <1mm[1]	30	-

Key notes:

- Definitions for snowfall intensity are aligned with the definitions provided in the NWSRG Practical Guide for Winter Service. Light snow is taken to be snow equivalent to 1mm of water (or less). Moderate or heavy snow is equivalent to more than 1mm water.
- Generally, there is about 1mm of water in 10mm of normal snow, 5mm of wet snow and 15mm of dry powdery snow.
- The aim of the treatments is to keep snow in a ploughable condition at all times – i.e. a condition where ploughing is back to the road surface
- Where compacted snow or ice has formed, and ploughing back to the road surface is not possible, treatments should be carried out with pre-wetted or dry salt

Spreader operation

As discussed in Section 7.6.3 the feedback from drivers was that the brine droplets can be dispersed by strong wind, with road sensor readings indicating low salt reaching the sensor where wind speeds of 30 mph occurred at spreading.

It is known that wind can have a significant effect whether spreading solid salt or liquids. For example, Persson et al (2014) investigated the effect on the spread pattern of a cross wind of 4.5 m/s (10mph) and demonstrated that, for solid salt, the wide effect is predominantly due to the movement of finer particles less than 1mm in size. For liquids, the effects will likely depend on the amount of fine spray generated when being distributed. This fine spray may be dispersed away from the target area by both cross winds and also the turbulence generated by the spreading vehicle.

Fonnesbach (2018) demonstrated the effect of vehicle turbulence on brine distribution. Where the liquid was spread by jet nozzles hitting the ground and atomizing the brine in the turbulent zone behind the spreader, it was measured that up to 40% of the brine can be moved from the area behind the spreader. Increasing the distance behind the spreader at which the liquid hit the asphalt, such that the brine was spread outside of the turbulent zone behind the vehicle, significantly increased the amount of brine reaching the target area.

Hanke (2018) reported that initial tests spreading brine from spinning discs mechanisms have shown that good distribution can be achieved for spread widths up to 8m and spreading speeds up to 40km/h, with a dosage not too low (20g/m² or more). This would suggest the A835 spreading route was at the upper limit of spreading capability for the disc distribution method.

Overall, the trial results would suggest that wind is an issue that must be considered for the suitability of brine for a route, and that brine spreading from a disc may be more effected than spreading pre-wetted salt, however further work will be needed to assess what are the limits for wind speeds where significant issues will occur and what the impacts of different spreading mechanisms (e.g. spray bar or spinner) will be.

9 Conclusions and recommendations

Key conclusions

- Brine effectiveness cannot be specified by a simple lower temperature limit but must also take account of the road wetness and amount of precipitation.
- Brine provided an effective treatment for precautionary frost treatments on wet roads down to -7°C and dry/damp roads to -10.8°C.
- During frost events (with no precipitation during or after spreading) no ice was detected at the monitoring sites and 'Grip' levels remained above 0.6.
- The effectiveness of brine spreading during and before rain and snow was demonstrated for a wider range of conditions than the previous trial phases, but limits were also identified for brine effectiveness.
- The effectiveness of brine was limited in conditions where clearance of snow back to black pavement after each plough pass was not achieved i.e. brine was not being spread on a bare pavement and not able to penetrate to the road surface.
- For brine spreading during snowfall, quick treatment cycle times and ploughing to the road surface are vital to prevent compacted snow.
- For some events, the trial site was observed very wet (too wet for effective brine treatments) for significantly longer periods than 20 minutes after rain stopped, which is the current guidance to operators.
- Observations indicated that brine spreading from a disc may be more affected by wind than spreading pre-wetted salt. Further work will be needed to assess what are suitable wind speed limits and to fully understand the advantages of different spreading mechanisms (e.g. spray bar or spinner).

Recommendations

- Where limits have been identified for brine effectiveness, further trials should identify potential mitigation measures. Key actions will include:
    - Effective ploughing to black and short treatment cycle times
    - Further trialling of increased brine share for pre-wetted salt
    - Consideration of driver shift arrangements in snowfall such that cycle times are maintained during handover periods to prevent snow build up
    - Treatment strategies for very wet roads – e.g. double treatments

- Further trials should use a spray bar and nozzles for the liquid distribution mechanism. This will enable:
    - Investigation of effectiveness of liquid spreading in higher wind speeds
    - Increased scope for trialling at lower spread rates, greater speeds and spread widths
    - More effective spreading of a wider range of liquid de-icers (e.g. ABP additives)

- Improved reporting mechanism for operator feedback

10 Acknowledgements

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The assistance of the following was much appreciated: Kevin Campbell of BEAR Scotland; Iain McDonald and Martin Thomson of Transport Scotland.

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Appendix A Minimum air temperatures and RSTs at weather stations

Table 11 – Minimum air temperatures for weather stations by month

Weather Station	Minimum air temperature (°C) by month			
	Dec	Jan	Feb	Mar
Brahan	-6.8	-8.2	-7.1	-5.9
Aultguish	-10.6	-12.4	-10.9	-7.0
Braemore	-5.4	-7.1	-6.8	-7.3

Table 12 – Minimum surface temperature (RST) for weather stations by month

Weather Station	Minimum RST (°C) by month			
	Dec	Jan	Feb	Mar
Brahan	-6.9	-8.3	-6.9	-7.9
Aultguish	-9.3	-10.9	-10.5	-9.6
Braemore	-5.9	-9.3	-6.3	-7.8

Appendix B Summary of treatments and sensor data

Table 13. Summary of conditions – frost events

Date	Time and type of Treatment (T1=10ml/m², T2=20ml/m², TF=Brine spreader patrol)	Minimum surface temperature (°C)	Maximum layer thickness (mm)	Ice/snow reports (Patrol)	Minimum 'Grip'	Additional treatment at monitoring locations (dry or pre-wetted)
21/12/2017	18.00 T2 and 02.00 T1	-1.6	0.03	No	0.79	No
29/12/2017	15.00 T2 and 03.00 T2	-4.2	0.06	No	0.77	No
03/01/2018	15.00 T2 and 03.00 T2	-3	0.05	No	0.78	No
06/01/2018	15.00 T2 and 03.00 T2	-9	0.01	No	0.8	Yes
07/01/2018	16.00 T2 and 04.00 T2	-10.8	0.02	No	0.8	Yes
08/01/2018	15.00 T2 and 03.00 T2	-6.8	0.06	No	0.78	No
09/01/2018	15.00 T2 and 03.00 T2	-3.4	0.05	No	0.78	Yes
10/01/2018	15.00 T2 and 03.00 T2	-7.7	0.03	Yes	0.79	Yes
11/01/2018	15.00 T2 and 03.00 T2	-8.6	0.05	Yes	0.78	Yes
12/01/2018	15.00 T2 and 03.00 T1	-1.6	0.05	No	0.78	No
26/01/2018	15.00 T2	-0.2	0.02	No	0.78	No
21/02/2018	16.00 T2 and 03.00 T1	-4.6	0	No	0.81	No
22/02/2018	16.00 T2 and 03.00 T1	-4	0	No	0.81	No
23/02/2018	15.00 T2 and 03.00 T1	-5.9	0	No	0.81	No
24/02/2018	16.00 T2 and 03.00 T1	-8.6	0	No	0.81	No
25/02/2018	15.00 T2 and 03.00 T1	-7	0	No	0.81	No
26/02/2018	15.00 T2 and 03.00 T2, TF	-7.9	0	No	0.81	No

09/03/2018	19.00 T2 and 03.00 T2	-5.2	0	No	0.81	No
10/03/2018	17:00 T2	>0				
13/03/2018	23:00 T1	>0				
16/03/2018	22.00 T2	-1.6	0	No	0.81	No
18/03/2018	16.00 T2 and 03.00 T2	-5.7	0	No	0.82	Yes
19/03/2018	16.00 T2 and 03.00 T1	-5.6	0	No	0.82	Yes
20/03/2018	19.00 T1	>0				
23/03/2018	21.00 T2	-0.6	0.01	No	0.82	No
24/03/2018	00:00 T2	>0				
27/03/2018	03:00 T1	>0				
28/03/2018	21.00 T2	-5.2	0	No	0.82	No
30/03/2018	02:00 T1	>0				
31/03/2018	20.00 T2 and 04.00 T1	-6.6	0	No	0.82	No

Table 14. Summary of conditions– precipitation events

Date	Time and type of Treatment (T1=10ml/m², T2=20ml/m², TF=Brine spreader patrol)	Minimum surface temp (°C)	Maximum layer thickness (mm)	Precipitation amount (mm)	Type of event	Ice/snow reports (Non-invasive Sensor)	Ice/snow reports (Embedded Sensor)	Ice/snow reports (Patrol)	Min 'Grip'
13/12/2017	15.00 T2 and 03.00 T2	-7.2	1.06	1.2	Snow	Snow	Snow	Snow	0.26
14/12/2017	15.00 T2 and 03.00 T2	-3.5	4.62	6.4	Snow	Slushy	No	Snow	0.51
15/12/2017	15.00 T2 and 03.00 T2	-5.8	2.28	2.2	Snow	Snow	Snow	Snow	0.38
16/12/2017	15.00 T2 and 03.00 T2	-5.4	0.58	0.9	Snow	No	No	No	0.75
17/12/2017	15.00 T2 and 03.00 T2	-3.3	0.08	0.2	Rain	No	No	No	0.78
25/12/2017	18.00 T2 and 03.00 T1	-3.2	0.18	0.3	Snow	No	No	No	0.75
26/12/2017	Pre-wet	-3.5	0.54	2.8	Snow	Snow	No	Snow	0.48
27/12/2017	Pre-wet	-4.9	1.04	6	Snow	Snow	Snow	Snow	0.36
28/12/2017	Pre-wet	-8.8	0.35	0.1	Snow	Ice	Ice	Yes	0.51
30/12/2017	15.00 T2 and 03.00 T2	-3.7	0.61	0.3	Snow	Ice	Ice	Yes	0.6
31/12/2017	15.00 T2 and 03.00 T2, TF	-6.7	0.18	0.8	Rain	No	No	Yes	0.75
01/01/2018	16.00 T2 and 04.00 T2	-6.1	0.98	1.7	Rain	Ice	No	Yes	0.19
02/01/2018	15.00 T2 and 03.00 T2	-5.3	1.61	0.4	Snow	Ice	No	Yes	0.28
05/01/2018	16.00 T2 and 04.00 T2	-3.1	0.47	1.5	Snow	No	No	Yes	0.68
13/01/2018	17.00 and 03.00 T1	-0.8	0.09	0.4	Rain	No	NO	No	0.78
15/01/2018	15.00 T3 and 03.00 T3, TF	-3.3	1.86	2	Snow	Snow	Snow	Snow	0.13
16/01/2018	Prewet	-5.5	2.13	2.9	Snow	Snow	Ice	Snow	0.14
17/01/2018	Prewet	-7.3	1.61	1.9	Snow	Snow	Snow	Ice	0.12
18/01/2018	Prewet	-5	0.72	1.6	Snow	Snow	No	Snow	0.4
19/01/2018	Prewet	-9.5	1.48	3.2	Snow	Snow	Snow	Snow	0.13
20/01/2018	Prewet	-10.9	0.85	0.1	Snow	Slushy	No	No	0.65
21/01/2018	Prewet	-2.4	1.95	2	Snow	Snow	Snow	No	0.56
28/01/2018	T2 03:00	-0.3	0.4	1.4	Rain	No	No	No	0.71
29/01/2018	15.00 T2 02.00 T1	-0.6	0.23	0.7	Rain	No	No	No	0.76

30/01/2018	20.00 T2 and 02:00 T3	-1.5	0.57	3.8	Snow	Snow	No	No	0.63
31/01/2018	15.00 and 03.00 T2, TF	-1.6	1.36	4.2	Snow	Slushy	No	Snow	0.65
01/02/2018	Prewet	-1.3	0.13	0.6					0.76
02/02/2018	Prewet	-0.6	0.16	2					0.75
03/02/2018	Prewet	-3.5	0.06	0.3					0.77
04/02/2018	Prewet								
05/02/2018	Prewet	-4.6	1.09	3.6					0.61
06/02/2018	Prewet	-10.5	1.39	3					0.13
07/02/2018	15:00 T2 and 03.00 T1	-0.2	0.21	1.3	Rain	No	No	No	0.73
08/02/2018	20.00 T3 and 03.00 T2, TF	-3.4	0.31	1.3	Snow	No	No	Snow	0.75
09/02/2018	14.00 T2 and 02.00 T2	-2.4	0.14	1	Snow	No	No		0.75
10/02/2018	17.00 T2 and 03.00 T2	-6	0.15	1.1	Snow	Snow	No		0.59
11/02/2018	Prewet	-5.3	1.75	3.5					0.13
12/02/2018	Prewet	-4.1	0.68	3.7					0.65
13/02/2018	Prewet	-4.3	0.64	0.6					0.26
14/02/2018	16.00 T2 and 03.00 T2	-2.6	1.97	5.4	Snow				0.55
15/02/2018	Prewet	-3.5	0.64	2.2					0.66
16/02/2018	16.00 T2 and 03.00 T2, TF	-1	0.17	0.3	Rain	No	No	No	0.76
17/02/2018	17.00 T2 and 03.00 T2	-1.9	0.25	0.1	Rain	No	No	No	0.77
20/02/2018	16.00 T2 and 03.00 T2	-5.6	0.17	0.3	Rain	No	No	No	0.75
26/02/2018	15.00 T2 and 03.00 T2, TF	-7.9	0.35	1.3	Snow	No	No	Snow	0.73
27/02/2018	Prewet	-7.1	1.26	1.7					0.41
28/02/2018	Prewet	-9.6	1.05	2.3					0.12
01/03/2018	Prewet	-6.5	1.07	5.8					0.12
02/03/2018	15.00 T2 and 03.00 T2	-2.3	0.08	0.9	Snow	No	No	No	0.77
03/03/2018	15.00 T2 and 03.00 T2	-1.6	0.01	0.5	Snow	No	No	No	0.81
04/03/2018	16.00 T2 and 03.00 T1, TF	-0.7	0.1	3.2	Snow	No	No	No	0.77
05/03/2018	15.00 T2 and 03.00 T2, TF	-1.4	1.01	4.3	Snow	Slushy	No	Snow	0.64
06/03/2018	15.00 T2 and 03.00 T2, TF	-1.4	1.23	6.2	Snow	Icy	No	Snow	0.51

07/03/2018	18.00 T2 and 03.00 T2	-3.1	0.1	0.2	Rain	No	No	No	0.77
08/03/2018	18.00 T2 and 04.00 T2	-4.5	0.05	0.2	Rain	No	No	No	0.78
17/03/2018	16.00 T1 and 01.00 T2	-4.1	0.01	0.1	Snow	No	No	No	0.81
25/03/2018	21.00 T2 and 04:00 T1	-1.3	0.09	0.1	Rain	No	No	No	0.77
29/03/2018	00:00 T2	-1.4	0.29	2.7	Snow	No	No	No	0.74

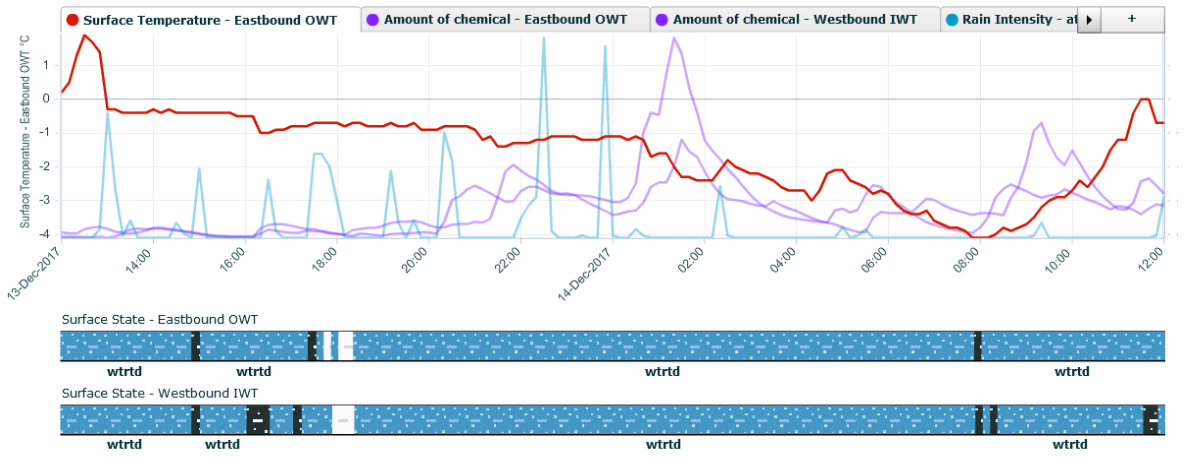
Appendix C Treatments during precipitation – snowy road conditions

C.1 13th December

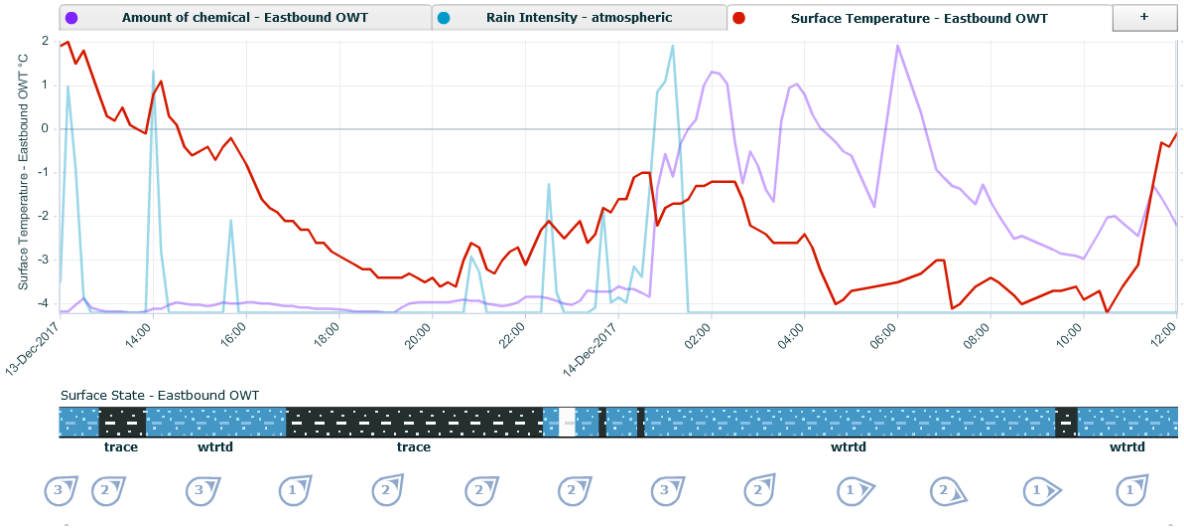
At Aultguish light snowfall from 14:40 to 15:30, with continuing, intermittent periods of snowfall overnight.

Aultguish

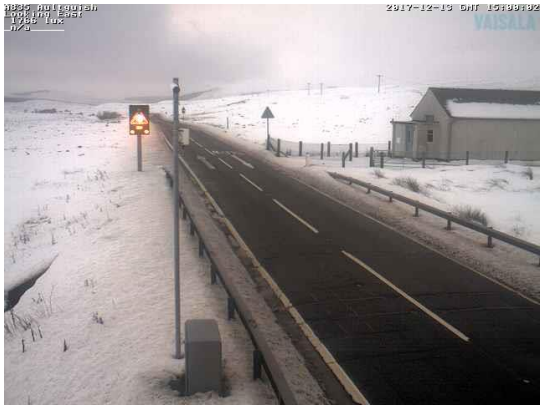
Braemore



Brahan



15.00



15:50

16:40

22:00

00:50

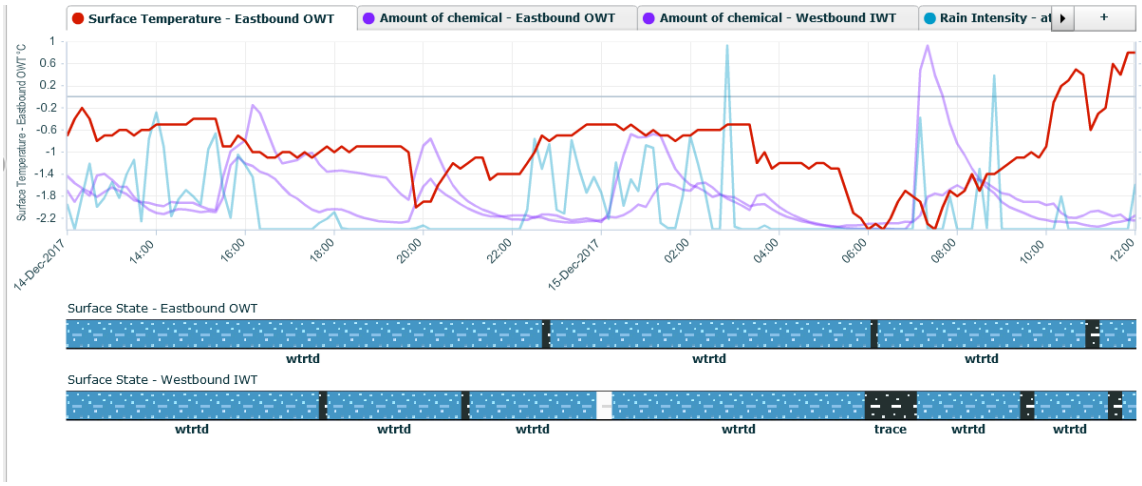
02:00

C.2 14th December

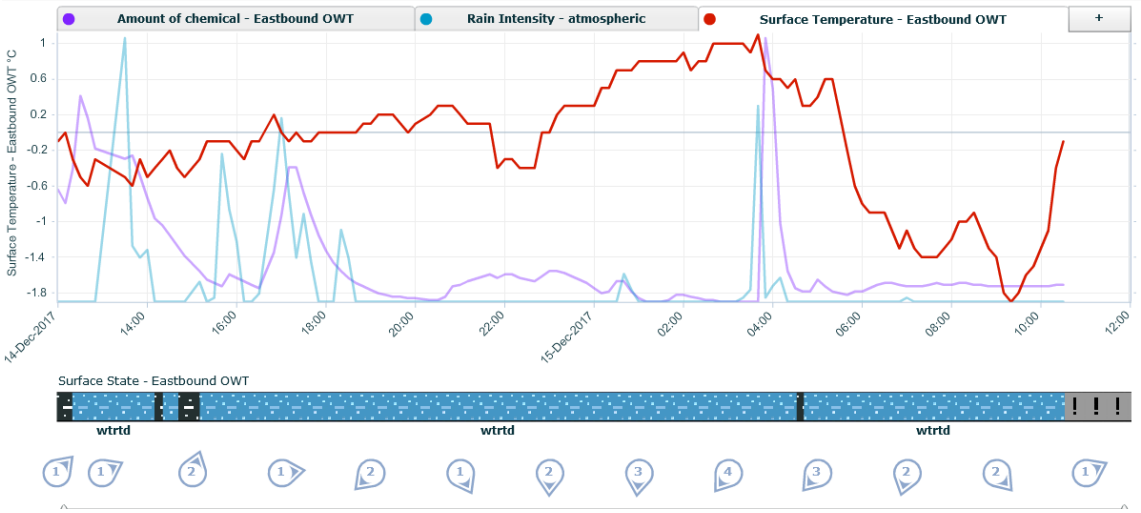
Light snowfall throughout the afternoon settling on road surface, with further period of snowfall between 23.00 and 04:00.

Aultguish

Braemore

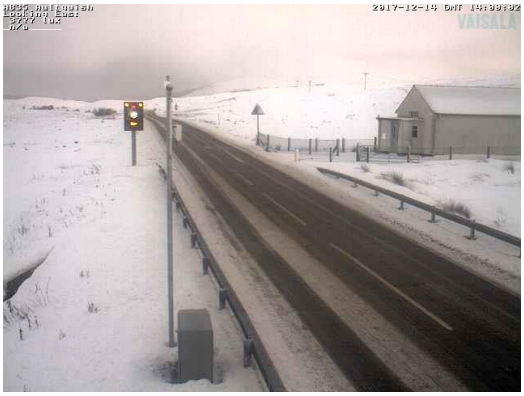


Brahan



13:30

14:00



16:00

23:00

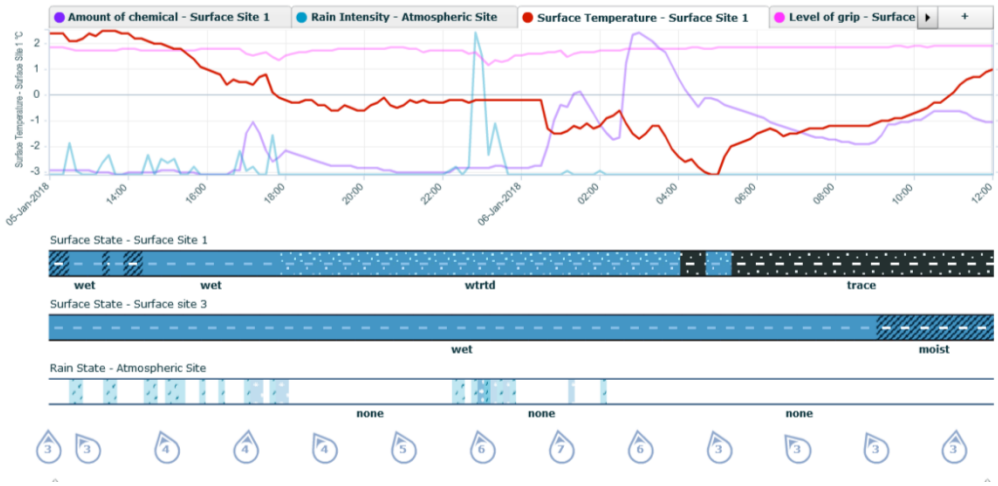
23:50

02:00

C.3 5th January

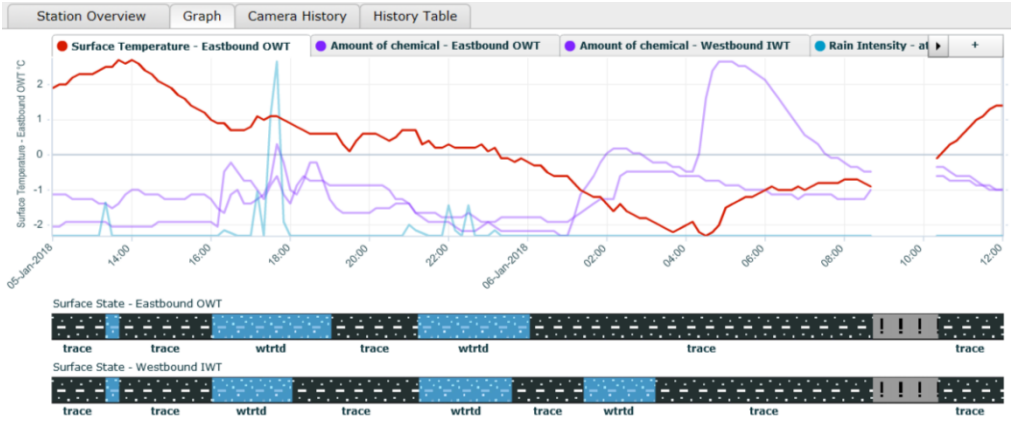
Rainfall and wet road surface during afternoon and overnight. Spreading carried out on wet road surface. Observation of ice from patrol driver at 02:45 at Garve.

Aultguish



Brahan

Braemore



Images from Brahan - nearest to site of ice report in Garve at 01:45

23:10

00:00

01:50

C.4 15th and 16th January

See Section 7.4.1

C.5 6th March

20ml/m² at 15.00 and 03.00 and spreader remaining on route.

Continuous light snow during treatment and overnight.

Slushy/icy conditions reported between 17.40 and 01.30

Amount of precipitation following treatment until slushy state = 1.4mm in 2 hours

Appendix D Treatments during precipitation – wet (black) road conditions

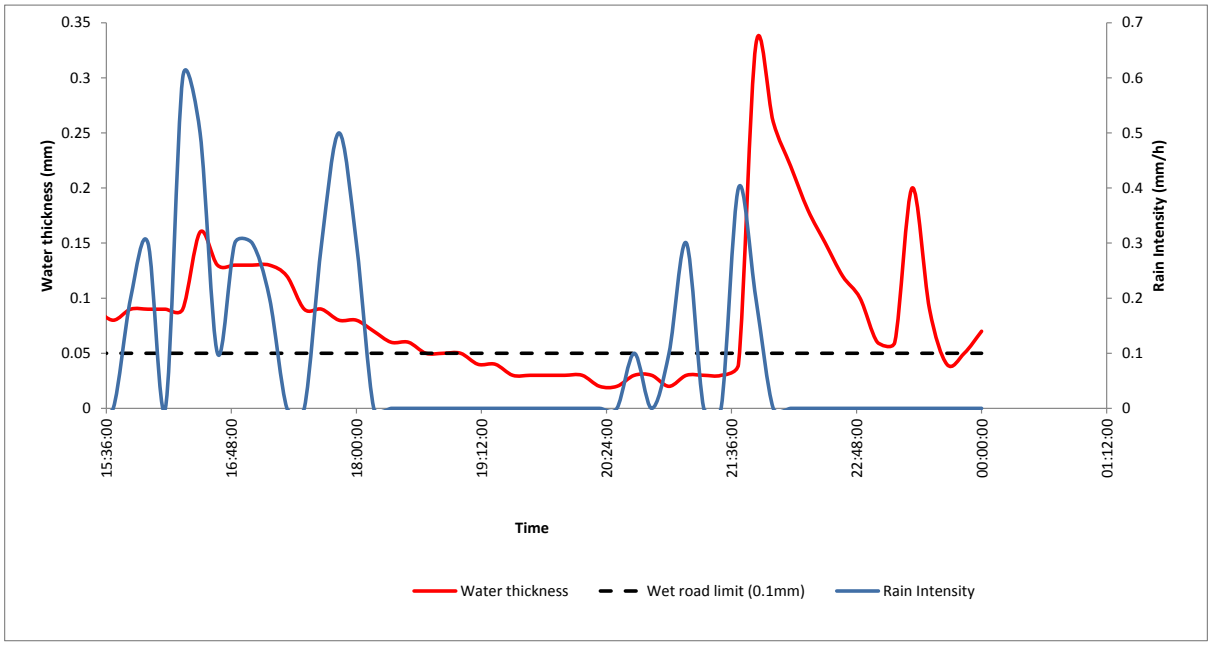


Figure 24. Water thickness at Aultguish site – 27th November (pre-wetted treatment at time 16:10)

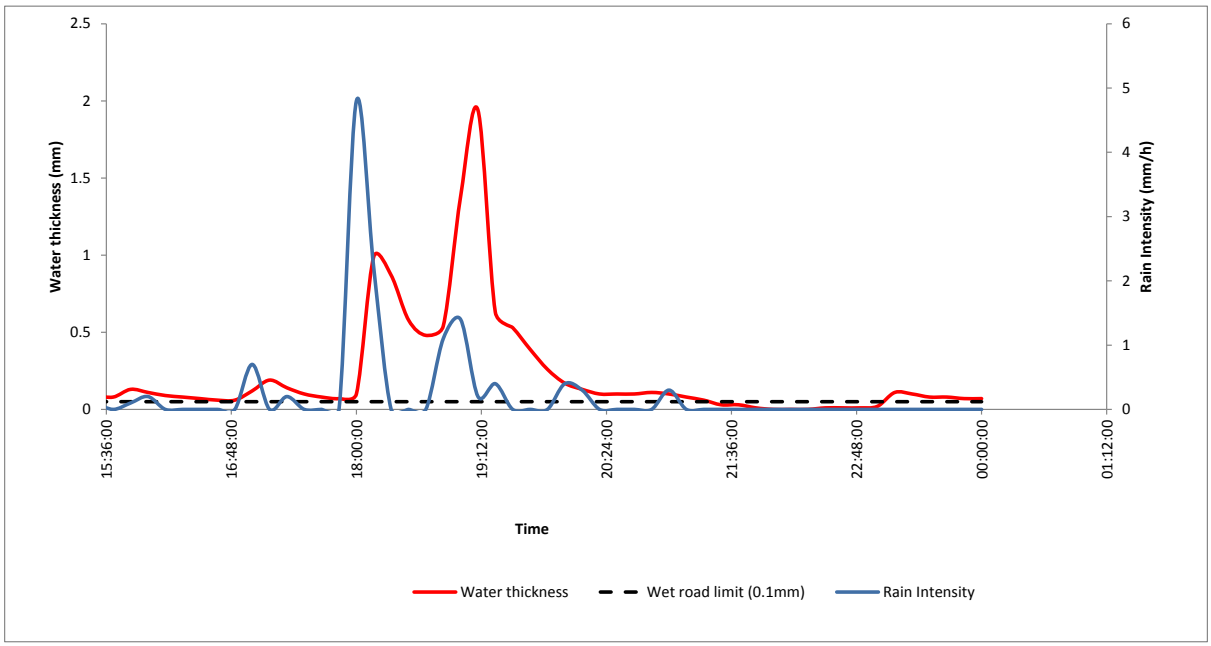


Figure 25. Water thickness at Aultguish site – 28th November (pre-wetted treatment at time 16:00)

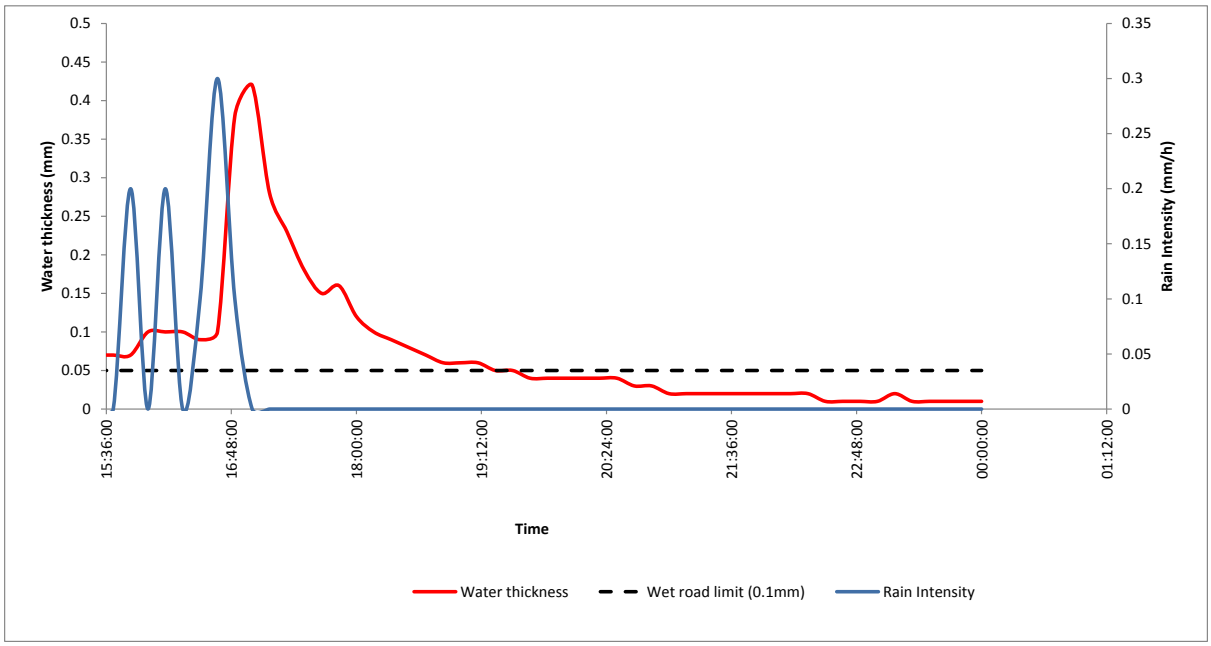


Figure 26. Water thickness at Aultguish site – 30th December (brine treatment at time 16:00)

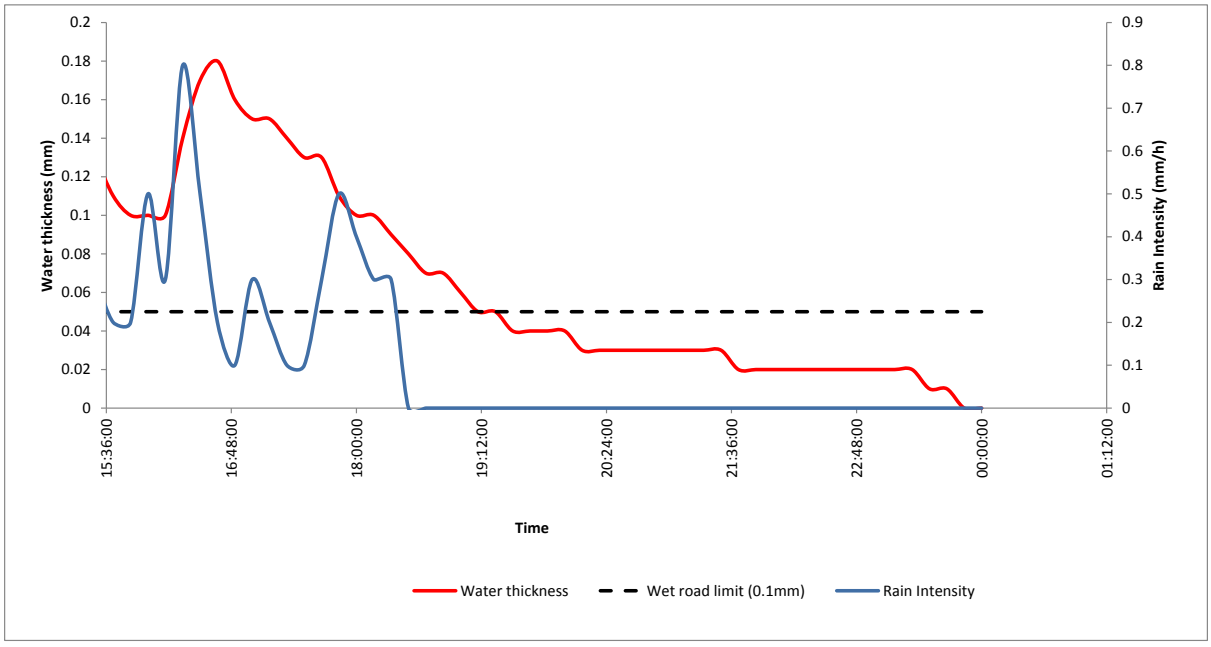


Figure 27. Water thickness at Aultguish site – 31st December (brine treatment at time 16:00)

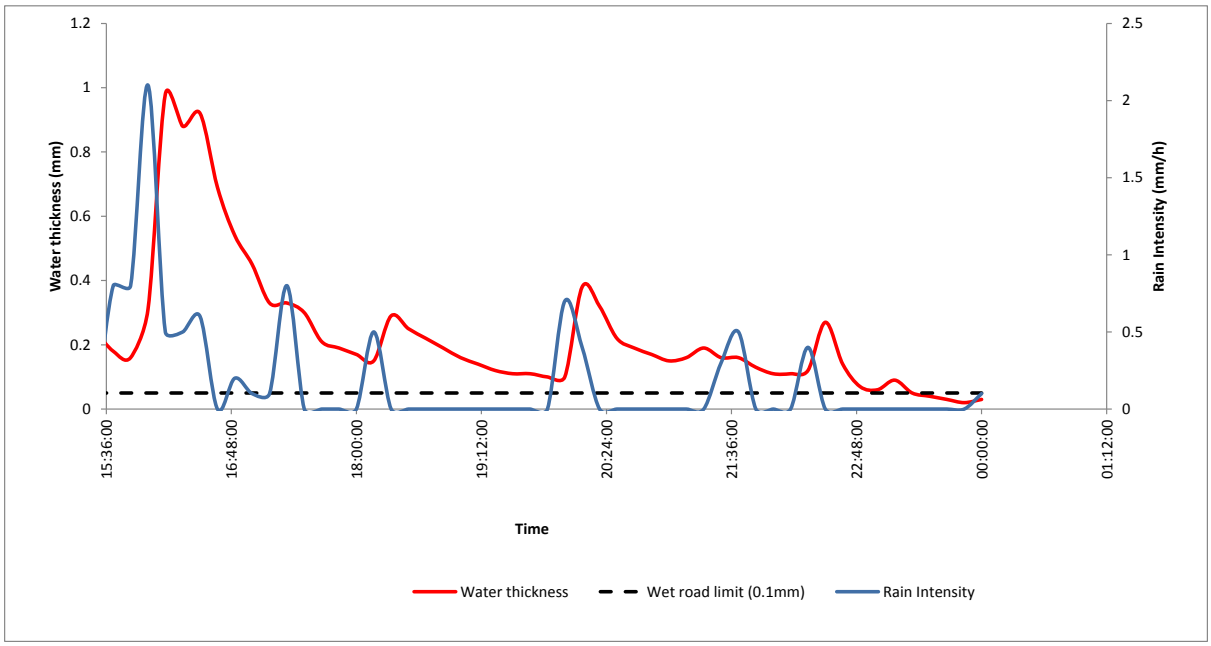


Figure 28. Water thickness at Aultguish site – 1st January (brine treatment at time 16:00)

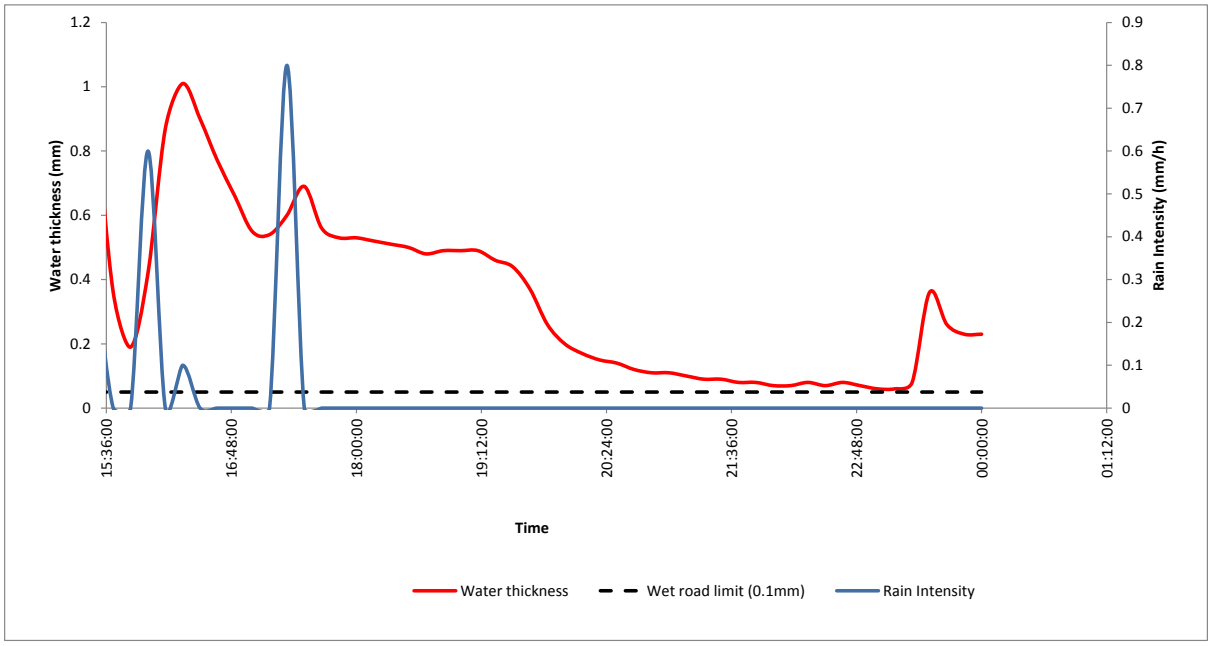


Figure 29. Water thickness at Aultguish site – 2nd January (brine treatment at time 15:00)

Trials of Brine Spreading Performance on Scotland's Roads: Phase 4

A further phase of Transport Scotland brine spreading trials was carried out during the 2017/18 winter season; the key aims to assess the effectiveness of brine spreading before and during snow events and in temperatures below -5°C.

The trial period encompassed a number of cold spells and significant snow events with double treatments on most nights during December and January. It is considered the trial route has provided the full range of conditions likely to be experienced on the Transport Scotland network, from frost to snow events and for a range of temperatures. Around half of all the brine treatments during the trial were carried out with some form of precipitation during or after spreading.

These trial results have demonstrated that brine provides an effective treatment for precautionary frost treatments. Wet roads were treated effectively down to -7°C and dry/damp roads to -10.8°C.

Other titles from this subject area

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PPR841	Trials of Brine Spreading Performance on Scotland's Roads: Phase 3

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