



PUBLISHED PROJECT REPORT PPR622

Treatment Matrix Review

M Evans, J Martin, R Jordan and C Reeves

Prepared for: Highways Agency, Network Services

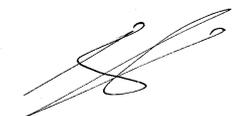
Project Ref:

Quality approved:

Matthew Evans
(Project Manager)



Barry Cleave
(Technical Referee)



[Type text]

[Type text]

[Type text]

Disclaimer

This report has been produced by the Transport Research Laboratory under a contract with Highways Agency. Any views expressed in this report are not necessarily those of Highways Agency.

The information contained herein is the property of TRL Limited and does not necessarily reflect the views or policies of the customer for whom this report was prepared. Whilst every effort has been made to ensure that the matter presented in this report is relevant, accurate and up-to-date, TRL Limited cannot accept any liability for any error or omission, or reliance on part or all of the content in another context.

When purchased in hard copy, this publication is printed on paper that is FSC (Forest Stewardship Council) and TCF (Totally Chlorine Free) registered.

Contents amendment record

This report has been amended and issued as follows:

Version	Date	Description	Editor	Technical Referee
1.0	08/06/2012	Draft Report	ME	BC
1.1	24/07/2012	Final draft	ME	BC
1.2	12/11/2012	Final report	ME	BC

[Type text]

[Type text]

[Type text]

Contents

Executive Summary	4
1 Introduction	12
2 Background	12
3 Assessment of the understanding and use of the current spread rates	14
3.1 General	14
3.2 Feedback from Service Providers - Questionnaire responses and review meetings	14
3.2.1 Conditions where spread rates are considered too low	14
3.2.2 Conditions where spread rates are considered too high	16
3.2.3 Treatment frequency	17
3.2.4 Assessing wetness of road	18
3.2.5 Assessing residual salt levels	20
3.2.6 Effect of surfacing type	21
3.2.7 Making spot treatments and use of 'blast button'	22
3.2.8 Monitoring of the amounts of salt spread	23
3.3 Use and understanding of the treatment matrix	24
3.3.1 General	24
3.3.2 Areas selected and analysis periods	24
3.3.3 Analysis method	26
3.3.4 Area A	27
3.3.5 Area B	29
3.3.6 Area C	32
3.3.7 Area D	34
3.3.8 Area E	36
3.3.9 Area F	39
3.4 Discussion	42
3.4.1 Use and understanding of the Treatment Matrix	42
3.4.2 Effectiveness of spread rates	45
4 Capability of the winter fleet	46
4.1 General	46
4.2 Background	46
4.3 Investigation of Fleetstar capability	48
4.3.1 Fleetstar report types	48
4.3.2 Calculating the target amount of salt for each turnout	49
4.3.3 Measuring amounts of de-icer discharged for each turnout	49

4.3.4	Assessing accuracy of the data - Comparison of Fleetstar data with manual records	50
4.4	Comparison of measured and target amounts from Fleetstar	51
4.5	Discussion	55
4.6	Recommendations for use of Fleetstar data	56
5	Effectiveness of Spread Rate Matrix for different salt types	57
5.1	General	57
5.2	Type of salt used and feedback from Service Providers	57
5.3	Factors that can effect spreader performance	58
5.4	Comparison of results from trials with indigenous and other salt types	58
5.5	Discussion	65
6	Investigation of winter incidents	67
6.1	Introduction	67
6.2	Data sources for road incidents	67
6.2.1	STATS19	67
6.2.2	Other data sources	68
6.3	Overview of winter collisions	68
6.3.1	Overall trend	68
6.3.2	Comparison between dry and pre-wetted periods	69
6.4	Comparison of collisions on routes with dry and pre-wetted precautionary treatments	70
6.4.1	Analysis method	70
6.4.2	Matching WRF1 and STATS19 data	70
6.4.3	Summary of data available in WRF1 database	71
6.4.4	Comparison of collisions	71
6.4.5	Hauer 'before and after' collision analysis	72
6.5	Discussion	73
7	Recommendations	75
7.1	Greater emphasis on the use of pre-wetted salt	75
7.2	Further work to inform repeat treatments in sustained freezing	75
7.3	Further guidance for problematic conditions	76
7.4	Improved use of weather information (HAWIS)	77
7.5	WRF1 reporting	77
7.6	Spreader calibration and monitoring	78
7.6.1	Monitoring of spreader performance	78
7.6.2	Calibration	78
8	Conclusions	80

9	Acknowledgements	83
10	References	83

Executive Summary

Background

New spread rates for precautionary salt treatments on the Highways Agency's network were introduced in January 2010.

The initial feedback from Service Providers, after using the rates during the remainder of the 2009/10 winter, was that the treatments at the reduced rates were found to be effective and there were no concerns that winter related incidents had increased as a result of their introduction. Consequently, the reduced rates were rolled out as the standard rates for the 2010/11 winter.

The rates have now been in use for two winter seasons over a range of conditions. Because effective winter service is essential for all stakeholders, it was considered appropriate to review the rates and their use to determine whether they are as effective as initially thought and that an increase in winter related incidents has not occurred on the Agency's network that could be linked to these spread rates.

In summary, the main objectives of this work were to:

- Determine how Service Providers understand and use the current spread rates
- Determine the range of winter conditions for which the spread rates have been used
- Determine any difficulties and practical issues when using the spread rates
- Determine whether spreading vehicles have been calibrated properly and deliver the spread rates accurately
- Determine whether the spread rates are appropriate for the different types of salt used by the Agency, including indigenous, imported and strategic salt
- Determine if there is a statistically significant change in incident rates with dry salting with the old winter fleet and pre-wetting salting with the new winter fleet and if this can be linked with the salt spread rates.

A questionnaire was issued to Service Providers to obtain feedback on the rates and identify road conditions (weather and traffic) where the rates may have been considered to be too low or too high. The questionnaire also sought information on how service providers took into account specific road and weather conditions in decision making, for example road wetness and residual salt levels. There was representation by the project team for this work at meetings arranged by the Agency and Service Providers as part of their normal review process. This was used to obtain the views of Service Providers on the effectiveness of the treatment matrix and how it is used.

In order to determine how Service Providers understand and are implementing the current spread rate matrix, the WRF1 Winter Reporting System (the internet based system that records proposed and confirmed actions during the winter period) was reviewed by TRL and Halcrow. This enabled information to be gathered to determine what precautionary spread rates have been used for a sample of six Service Providers, selected to cover all regions of the country. Analysis was carried out over periods selected to enable an assessment to be made across the range of weather conditions encountered when carrying out precautionary treatments on the Agency's network for the 2011/12 winter. Further information on the policy and implementation for each Area was obtained from the questionnaire responses.

Details of the amount of salt discharged during spreader turnouts were obtained for the new winter fleet, to assess the performance of spreaders in delivering the new spread rates and confirm spreaders are properly calibrated for the treatments. An assessment was also made of the appropriateness of the spread rates when using different, non-indigenous salt types and the potential effect on the salt distribution when using different salt types was considered.

Finally, an investigation was carried out of the number of incidents on the Agency's network when winter service treatments had been carried out. Stats19 accident data was analysed in conjunction with information from the WRF1 system to identify trends and characteristics of winter incidents for periods before pre-wetted salting was introduced (i.e. when there was dry salting with the old fleet of Foden spreaders) and with pre-wetted salting with the current spread rates which were introduced in January 2010.

Use and understanding of the Treatment Matrix

The evidence from the review of WRF1 and feedback from Service Providers indicates that Service Providers generally understand the requirements and guidance notes in the treatment matrix guide.

The review of WRF1 has shown that the majority of pre-wetted treatments in the analysis period were consistent with the treatment matrix guide (for the forecast minimum RST and weather conditions reported on WRF1).

The full range of spread rates was used in each Area in the analysis period with the exception of the double treatment, $2 \times 15 \text{g/m}^2$, specified for the lowest temperature band on wet roads. The maximum rate used for any single treatment in the analysis period was 20g/m^2 . In the lowest temperature band, the majority of precautionary treatments were made with 18g/m^2 of pre-wetted or dry salt, even during periods where snow showers were experienced. There has been no specific feedback from Service Providers on the practicality or effectiveness of the treatment specified for these particular conditions. Because of the lack of evidence, no firm conclusions can be drawn at present on the effectiveness of the $2 \times 15 \text{g/m}^2$ treatment specified for wet roads in this coldest temperature band.

Within each temperature band, it was not possible to assess how accurately spread rates took account of road surface wetness, due to the lack of information on road wetness within WRF1. From the results, it was clear that there was an equal split between the use of spread rates specified for dry and wet conditions. The even split between the dry and wet road surface wetness spread rates might indicate that Service Providers are conservative in assessing the road wetness as dry/damp conditions should be more prevalent than wet conditions on the network. The questionnaire issued to Service Providers sought information on how road wetness was assessed and the problems encountered when assessing the road wetness. Assessment is primarily based on information from the weather forecasts and local knowledge of surface water runoff risks. Some Service Providers indicated that road sensors are not sufficiently accurate to determine if the road is wet or dry and six of the Service Providers indicated that reliable weather information was not available (sufficient to determine road surface wetness), however further comments were not given on the particular aspects that were not reliable. Better weather information and improved use of HAWIS could improve decision making with regard to surface wetness, resulting in lower spread rates and greater efficiencies in salt use.

Within an Area, local factors will come into play regarding the treatment decisions made for particular routes. The temperature and weather conditions reported in WRF1 are not broken down by route, hence is to be expected that there will be some variation in the spread rates used from those specified based on conditions as reported in WRF1.

Where treatments are not in agreement with the treatment matrix, further analysis has shown this is often where the temperature reported on WRF1 is near to the boundary with another temperature band in the guide. For example, where WRF1 reports a minimum temperature just below -2°C , some routes have been treated with the spread rate specified for the temperature band above -2°C . When the temperature is just above -5°C , spread rates on some routes were as specified for the temperature range between -5°C and -10°C .

When spread rates used by Service Providers did not match the matrix guidance, this could be a result of Service Providers taking account of residual salt levels. Feedback from the questionnaire has indicated that spread rates may be reduced to take account of residual salt after treatments on successive days. Following successive treatments, Service Providers reported in the questionnaire that they may reduce rates to those for a higher temperature band or delay treatments outside peak hours. In some cases, Service Providers stated that treatments are not made at all, based on the amount of residual salt estimated. Turnouts have been identified in the analysis periods where lower rates have been used after successive days spreading, or where no action has been taken in frost conditions.

The frequency of treatment is an important factor with regard to the residual levels of salt on the road. The treatment matrix guide does not recommend a time for repeat treatment frequency, and feedback from Service Providers has indicated that further guidance is needed on this. As discussed in the report, a common treatment regime on the Agency's network is to spread in the early evening and early morning when temperatures remain below freezing from evening through the following morning's rush hour. A maximum time of 12 hours appears to be used by Service Providers before repeat treatment is required during sustained freezing.

To inform the guidance on repeat treatments, further work is required to better understand appropriate rates and timing for repeat treatments in periods of sustained freezing, in order to optimise the use of salt while providing adequate treatment in these conditions. For example, how can the spread rate and frequency of treatment take account of the following factors?:

- Different temperature-time profiles after carrying out treatments
- Changes in surface wetness during sustained freezing
- Residual salt levels

It is recommended that further investigation be made of the use of HAWIS to improve decision making, in particular with regard to the above factors.

Where pre-wetted salting technology is available the treatment matrix guide recommends that pre-wetted salt is always the preferred option for precautionary treatments, including for treatments before light snow. Dry salt is recommended only when ice has formed, or snow is lying. Therefore, based on the matrix guide, the use of dry salt is only recommended at $20\text{g}/\text{m}^2$, either as a single or successive treatment ($2 \times 10\text{g}/\text{m}^2$).

The review has shown that dry salting is frequently used for precautionary treatments in all the temperature bands specified in the guide, when pre-wetted salting was available and would be the recommended option from the treatment matrix. Both pre-wetted and dry salting were frequently used across an Area for the same turnout, with the pre-wetted and dry salt spread at the precautionary rates in the matrix guide. On a number of occasions, dry salt was also spread at rates not specified in the guidance e.g. 9g/m². Sometimes the facilities for producing brine are not available, e.g. if a saturator is out of order, and dry salting will be carried out as a result. When this is the case, this is generally recorded on the reports submitted to WRF1.

The inappropriate use of dry salt results in more salt being spread than is necessary. It is considered by TRL that, due to the increased loss of dry salt, particularly on dry or damp roads, and the better distribution of pre-wetted salt that the use of pre-wetted salting as defined in the treatment matrix and guide should always be the preferred choice when brine is available. In the colder temperatures, near to -10°C, pre-wetted salting will also increase the rate of dissolution of the salt, this in particular for dry or damp roads.

It should be noted that the spread rates were developed for treatments on roads after trafficking had dispersed water. For treatments on very wet roads and when precipitation has occurred after spreading, repeat treatments are required and spreading dry salt in these circumstances will not prevent the need for these repeat treatments. This is also likely to be the case for a very heavy hoar frost, where a lot of moisture is precipitated out of the atmosphere. There has been no feedback from Service Providers on when or why dry salting is preferred contrary to the guidance recommendations and this area would warrant further investigation.

Effectiveness of spread rates

Feedback on the treatment matrix guide was obtained from Service Providers to identify any conditions (weather and traffic) when the recommended rates have been considered to be too low or too high. Further feedback was obtained on how specific road and weather conditions are taken into account in the decision making process.

From the questionnaire responses and other feedback, the conditions identified by some Service Providers, where the rates were considered too low or there was a need for further guidance included:

- Freezing soon after rainfall
- Heavy hoar frosts
- Treatment of porous thin surfacings
- Low traffic conditions, especially on Sunday mornings.

Recommendations were made for additional guidance in using the treatment matrix for these conditions.

Performance of spreaders in delivering the new spread rates

The Agency tracks and monitors the winter fleet using Cybit's Fleetstar GPS vehicle tracking system. This system records each vehicle's position and a wide range of other information on the vehicle's operations. Information reported on spreading includes the times when vehicles are spreading, the rate and pattern of the spreading, the amounts of salt and brine spread, spread width, lane position and if vehicles are ploughing.

To assess the spreader performance and calibration (in terms of amount of salt discharged against spread rate settings), details of the amount of de-icer discharged during spreader turnouts were obtained by TRL and Halcrow from the Fleetstar system. Records were also obtained, for a sample of Service Providers, of measurements recorded manually by the Service Provider of the amount of salt discharged during spreading turnouts to further assess spreader performance and for comparison with the data reported by Fleetstar.

An initial investigation was carried out of the Fleetstar system, with advice and assistance from Halcrow engineers involved with installation and validation of the system, to confirm what information can be obtained and to what accuracy, regarding the amounts of salt and brine discharged in a spreading run. Following this investigation and consultation with the suppliers of the system, a method was identified by which the measured amount of salt and brine discharged could be compared with the 'target' amount i.e. the amount that should be discharged if spreading at the correct spread rate. The target amount of salt and brine to be discharged, i.e. spread rate x length spread x spread width, can be obtained from Fleetstar for each turnout of every spreader in the winter fleet. The actual amount of salt and brine discharged, as automatically recorded from the spreaders onboard weighing system as the spreader leaves and returns to the depot for each turnout, can also be obtained from Fleetstar.

If robust conclusions are to be drawn from the data reported from Fleetstar it is important to have confidence in the accuracy of results obtained from the onboard weighing system and counter readings. The onboard weights are measured with the spreader in motion and it is expected that this motion will cause some variation in the weights recorded due to the effect on the weight applied at any given moment to the load cells that measure the onboard weight. The accuracy of the analysis method is also based on the assumption that the weights recorded by the spreader onboard weighing system are correct i.e. calibrated.

Comparing measurements and records obtained manually by Service Providers and reported by Fleetstar allowed an indication of the reliability of the Fleetstar analysis method to be obtained. Variability was observed in the ratio between the onboard weights and counter readings recorded manually by the Service Provider and recorded on Fleetstar, which indicated an uncertainty in the comparison between the measured amount of salt discharged and the target amount of at least $\pm 20\%$.

For a sample of 3 Areas, a comparison was made between the amount of de-icer discharged as measured from the onboard weighing system and the target amount. The ratio between the measured and target amounts of de-icer discharged were calculated for each precautionary, pre-wetted spreading run carried out in the analysis periods. Results were omitted where there were issues with the data recorded and it was clear that this was a result of the data logging and reporting rather than the spreader performance.

Based on the data reported on Fleetstar, the average amount of salt discharged over all turnouts in each Area showed variation from the target amount of between 8 and 25%. Analysis of the distribution in the amounts discharged over all turnouts for each Area showed there was also a significant spread in the results obtained.

The variation of the mean from the target amount, measured for the selected Areas, was greater than would be expected if assuming the correct amount of de-icer is spread with a measurement uncertainty of $\pm 20\%$. This may indicate that there is variation in the

spreader performance or that there is greater uncertainty in each measurement than assumed.

In summary, the investigation of the information reported from Fleetstar has indicated there may be variation in the spreader performance however it cannot be assessed if the variation is within acceptable limits using the data available at present.

Using the data as reported is also a time consuming process and is not a practical method to implement. A method for measuring spreader performance to a greater accuracy is required before any firm conclusions can be made.

It should be stressed that using the data logging system to make an accurate assessment of the amounts of de-icer discharged, as investigated in this study, was not part of the specification for the data logging system. Recommendations were therefore made for how Fleetstar could be further developed for this purpose, for consideration under the current review of the data logging system being carried out as part of the Highways Agency winter review.

Effect of different salt types

Feedback was obtained from Service Providers on the types of salt currently in use and the effect of changing salt type on the spreader performance.

Prior to this report, TRL has carried out salting trials on Romaquip and Schmidt spreaders from the new winter fleet with a number of different types of salt for the dry salt component. The results from these trials have been collated in this report and the possible effect on the salt distribution profile relative to that obtained with indigenous salt has been assessed.

Service Providers are clearly using salt types other than the indigenous 6mm rock salt. Evidence when particular salt types have been used on the network is not available and there is insufficient evidence to make firm conclusions on whether spreading the alternative de-icer types is fully effective. Service Providers have indicated that no changes to spreader settings are needed when spreading different salt types, with some Areas carrying out calibration checks.

The comparison of the results from trials carried out with the different salt types shows that the amount of salt discharged and the salt distribution profile can vary significantly with the salt type and the grading. Although there are insufficient results to draw firm conclusions, it was possible to comment on the trends in the salt distribution profiles based on factors such as the salt grading.

The results have highlighted the importance of spreaders being calibrated for the particular type of salt being spread, to provide confidence that the required amounts of salt are actually being spread within the lanes.

To provide confidence that the spread rates in the treatment matrix guide are appropriate for the different salt types, it is recommended that

1. Service Providers calibrate each spreader for the salt type being spread.
2. Periodic visual checks are made of the salt distribution when using non indigenous salt types to confirm sufficient coverage of the full spread width required.

Investigation of Winter Incidents

Data on incidents on the Agency's network were analysed with the aim to identify any trends or characteristics of winter incidents before pre-wetted salting was introduced and with pre-wetted salting with the current spread rates which were introduced in January 2010.

The first part of this task was an overview of the winter incidents on the strategic road network covering the period from the use of dry salting with the old winter fleet through to the use of the current reduced rates with pre-wetted salt. This overview compared the total number of incidents per quarter before and after the introduction of the new pre-wetted spread rates, in comparison to the general trend of decreasing incidents over this period.

In the second part of the task WRF1 was used to collate information on the precautionary treatments used on each day on each road in each Area. Information from the WRF1 database was then combined with the Stats19 collision data to enable analysis of trends and characteristics of collisions on routes with different precautionary treatments. i.e. comparison between dry and pre-wetted precautionary treatments.

STATS19 data was used as this provides a comprehensive and reliable source of information across the whole of the country. However, it must be noted that the data only includes collisions involving injury that become known to the police and is therefore an incomplete record of all road incidents and casualties.

The initial analysis of the STAS19 collision data for before and after the change in salting regime has shown that there has been a greater reduction in total number of collisions in the winter periods compared to the corresponding summer periods. The reason for this difference may be due to many factors, including changes to the type of treatment used.

While this overview can provide some indication that there has been no significant increase in numbers of collisions, it is of limited use for assessing the effectiveness of the new precautionary spread rates, as both the winter analysis periods include all treatments made i.e. both precautionary and treatments for snow and ice. The winter period analysed after the introduction of the new rates also included a significant proportion of treatments with dry salting both as precautionary treatments and treatments for snow and ice. The use of the summer data as the control, to account for overall trends in collision rates, is also not ideal as conditions may be very different in the summer to winter.

To provide sufficient numbers of collisions for comparison, it has been necessary to use a broad set of data. Collisions have been compared on days where precautionary treatments have been made, but analysis has not been carried out for particular spread rates, weather conditions or taken account of any local factors e.g. areas prone to ice, which will reduce the number of collisions available for analysis. The time of treatment was not compared with the time of each collision. Data has been used from all Areas, and it has been assumed that spreaders are performing correctly.

The analysis of the collisions which occurred on roads where the treatment was known from WRF1 indicated that, based on the data used, any difference in the collisions rates between the period of dry precautionary salting and pre-wetted salting with the current rates falls within the general trend in collision rates.

Evidence was sought in the questionnaire issued to Service Providers on particular conditions of concern where spread rates were considered too low, and this identified areas of concern that would not be identified from the analysis of collision data.

While it is considered that the data can provide an overall check that there are no obvious issues with the current spread rates, it has not been possible to identify particular conditions or spread rates that are not effective or confirm that there has been no effect on the likelihood of incidents.

1 Introduction

The new (current) spread rates for precautionary salt treatments on the Highways Agency's network were introduced in January 2010. The initial feedback from Service Providers was that the treatments at the reduced rates were found to be effective and there were no concerns that winter related incidents had increased as a result of their introduction. Consequently, the reduced rates were rolled out as the standard rates for the 2010/11 winter.

The rates have now been in use for two winter seasons over a range of conditions. Because effective winter service is essential for all stakeholders, it was considered appropriate to review the rates and their use, to determine whether they are as effective as initially thought and that they are not contributory to an increase in winter related incidents on the Agency's network.

This review is the subject of this project and its main objectives were to:

- Determine how Service Providers understand and use the current spread rates
- Determine the range of winter conditions for which the spread rates have been used
- Determine any difficulties and practical issues when using the spread rates
- Determine whether spreading vehicles have been calibrated properly and deliver the spread rates accurately
- Determine whether the spread rates are appropriate for the different types of salt used by the Agency, including indigenous, imported and strategic salt
- Determine if there is a statistically significant change in incident rates with dry salting with the old winter fleet and pre-wetting salting with the new winter fleet and if this can be linked with the salt spread rates.

2 Background

In January 2008, TRL was commissioned to undertake research to identify appropriate spread rates for precautionary salt treatments for road surface types on the Agency's network. This coincided with the introduction of the Agency's new winter fleet that has the capability for spreading pre-wetted salt as well as dry and treated salt. New spread rates for pre-wetted and dry salting were proposed in the summer of 2009. They took into account information on the performance of the new winter fleet and the effect of trafficking on residual salt levels after spreading and the amount of water on the road surfaces.

It was recommended that the new spread rates be introduced in stages and that the effect on accident rates be monitored before successive reductions. The largest potential reductions in spread rates were for road surface temperatures down to -5°C. A reduction corresponding to 50% of the difference in the proposed and then current rates was suggested in the first instance, followed by two further 25% reductions. The 50% reduction was duly introduced in the treatment matrix guide produced at the start of the 2009/10 winter season.

However, compared to the preceding winters, the winters of 2008/09 and 2009/10 were colder and there was more snowfall. Throughout the country, salt stocks ran low as

highway authorities tried to keep roads free of ice and snow. Although salt suppliers increased their production, they were unable to replenish stocks at a sufficient rate to maintain treatments at the same spread rates as previous years. Salt saving measures were sought and the decision was taken to introduce the new rates proposed by TRL in full in January 2010, i.e. the staged reduction was abandoned and the full reduction was introduced.

A comparison of the precautionary rates for dry salting with the old winter fleet and the new rates is shown in Table 1. The new rates clearly represent a significant reduction in the amount of salt being spread in certain conditions. For example, spreading on a dry or damp road at temperatures between -2°C and -5°C ; with the new rates the amount of pre-wetted salt spread is $9\text{g}/\text{m}^2$, which is approximately $7\text{g}/\text{m}^2$ of salt. This is compared to $20\text{g}/\text{m}^2$ of dry salt for the old rates, therefore a greater than 50% reduction in the amount of salt spread.

Table 1. Comparison of precautionary spread rates for dry salting with the old winter fleet and the new rates

Conditions	Pre 2009/10 dry salting spread rate (g/m^2)	Dry salting spread rate (g/m^2)	Pre-wetted salting	
			Pre-wetted salting spread rate (g/m^2)	Pre-wetted salt content (g/m^2)
Frost or forecast frost RST at or above -2°C (irrespective of dry, damp or wet conditions)	10	8	8	6.2
Frost or forecast frost RST below -2°C and above -5°C and dry or damp road conditions	20	10	9	6.9
Frost or forecast frost RST below -2°C and above -5°C and wet road conditions	20	16	15	11.5
Frost or forecast frost RST at or below -5°C and above -10°C and dry or damp road conditions	20	18	18	13.8
Frost or forecast frost RST at or below -5°C and above -10°C and wet road conditions	20 + 20	2x15	2x15	23.1

3 Assessment of the understanding and use of the current spread rates

3.1 General

The main objectives of this sub-task were to:

- Determine how Service Providers understand and use the current spread rates
- Determine the range of winter conditions for which the spread rates have been used
- Determine any difficulties and practical issues when using the spread rates

3.2 Feedback from Service Providers - Questionnaire responses and review meetings

A questionnaire was issued to Service Providers to obtain feedback on the rates and identify road conditions (weather and traffic) when the rates have been found to be too low or too high. The questionnaire also sought how specific road and weather conditions are taken into account in decision making.

There was also representation by the project team at meetings arranged by the Agency and Service Providers as part of their normal review process, to obtain the views of Service Providers on the effectiveness of the treatment matrix and how it is used.

This section summarises the questionnaire responses and feedback from Service Providers obtained at a Winter Service Community meeting and an Area mid-season review meeting. Questionnaire responses were received from 15 Service Providers; these are shown in detail in Appendix A.

Figure 1 to Figure 11 summarise the questionnaire responses received from each Area. Feedback from comments included in the questionnaire responses and from attendance at the Service Provider meetings is recorded and discussed within the following sections.

3.2.1 Conditions where spread rates are considered too low

Figure 1 summarises the responses to the question: For what road and weather conditions do you consider the currently recommended spread rates are too low?

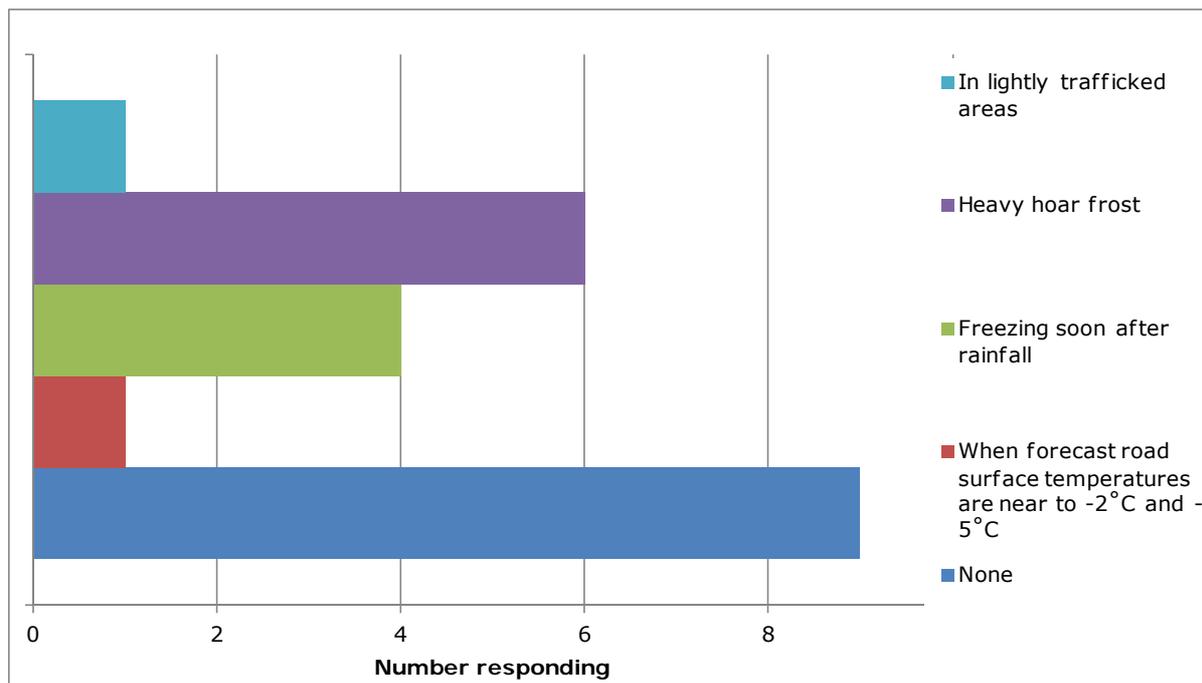


Figure 1 For what road and weather conditions do you consider the currently recommended spread rates are too low?

Feedback arising from the questionnaire and meetings with Service Providers included:

- Approximately half of the Service Providers reported in the questionnaire responses that there were no conditions where spread rates were considered too low. Six Service Providers considered the rates too low for treating heavy hoar frosts and four for preventing freezing soon after rainfall.
- Comments in the questionnaire responses included that the suitability of the rates depended on the treatments carried out prior to the day in question i.e. residual salt levels. Other comments were that a second application should be applied when there is a prolonged/heavy hoar frost.
- Regarding the spread rates required on thin surfacing, there was feedback in the winter community meeting from one Service Provider about the need to treat a particular identified section of thin surfacing at 40g/m² every 2 hours. This particular section of open textured surfacing was wetter than other parts of the network and required increased level and frequency of treatment to maintain the residual salt levels.
- One Service Provider noted that they encountered an increased risk of incidents in low traffic conditions, especially on Sunday mornings. There was a need for guidance on follow-up treatments in these conditions.
- Generally, a lot of salt is put down before snow, with 40g/m² a typical spread rate, rather than 18g/m² as specified in the matrix before light snowfall.
- One Service Provider commented that low rates may reduce some of the factor of safety, for example when there are errors in the forecast.

3.2.2 Conditions where spread rates are considered too high

Figure 2 summarises the responses to the question: For what road and weather conditions do you consider the currently recommended spread rates are too high?

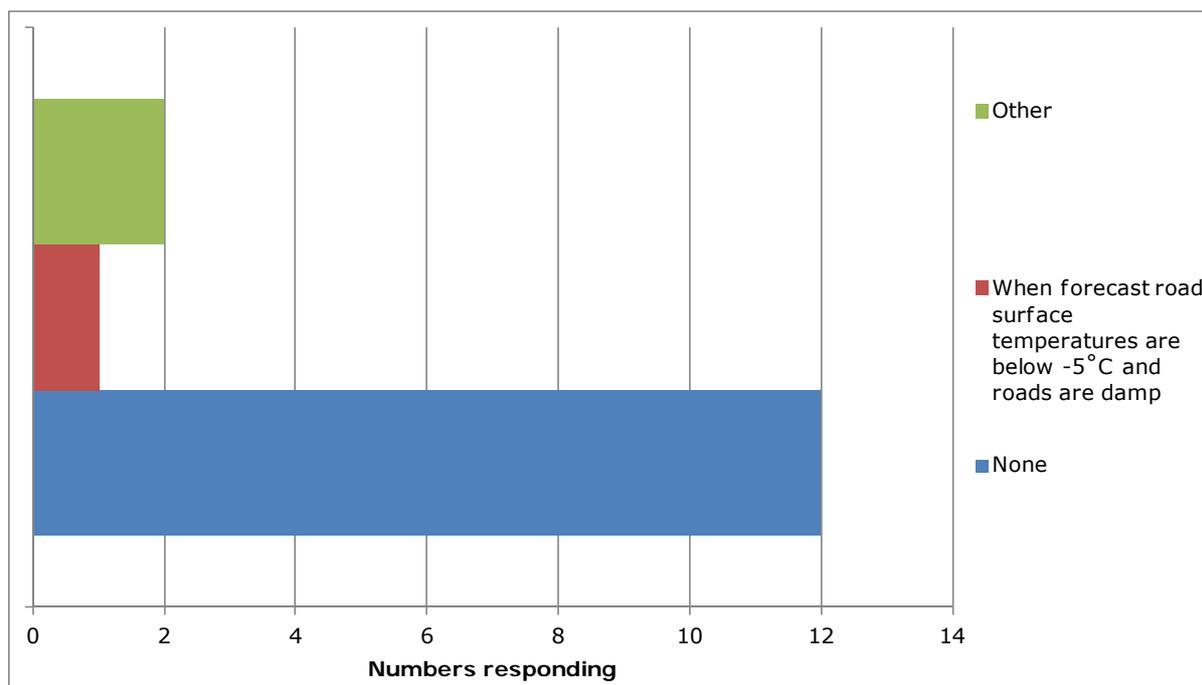


Figure 2 For what road and weather conditions do you consider the currently recommended spread rates are too high?

Feedback included:

- Twelve of the Service Providers did not consider there were any conditions where the spread rates were too high.
- One Service Provider noted that for treatments during heavy snow when it is accumulating, treatments are made at 10g/m² rather than 20g/m², to allow two full circuits of ploughing and treating before returning to the depot
- One Service Provider commented that they can get into a "2 treatments a day rut" i.e. afternoon and early morning. Similarly, another provider normally spread more than required by the Treatment Matrix because two treatments are often made – one in the evening and one in the early morning and commented that further guidance is needed on treatment frequency.
- Rates may be too high during periods without rainfall but where frost is forecast, where the only risks are poor residual salt and very cold conditions
- One Service Provider used a combination of treatments to achieve recommended spread rates e.g. 2x8g/m², with the first treatment early evening and the additional treatment as temperatures drop below -5°C.

3.2.3 Treatment frequency

Figure 3 summarises the responses to the question: Under what road and weather conditions do you make follow-up precautionary treatments (excluding times when precipitation occurs after first treatment)?

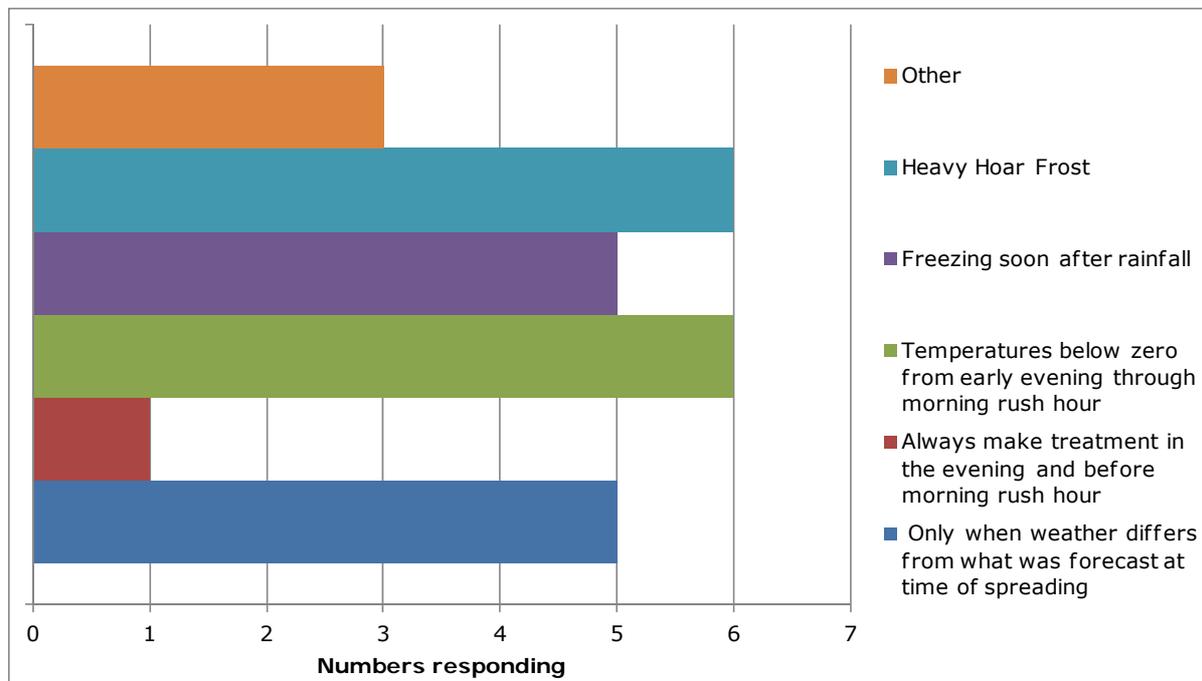


Figure 3 Under what road and weather conditions do you make follow-up precautionary treatments (excluding times when precipitation occurs after first treatment)?

Feedback included:

- Follow-up precautionary treatments are commonly carried out under a range of different scenarios.
- A common treatment regime is to spread in the early evening and early morning. Examples of this, taken from the questionnaire response and meeting discussions, include:
 - When it is assumed that temperatures will not fall to the minimum straight away, therefore two treatments at reduced rate to put down required dosage and cover risk at both ends of the treatment period
 - When there is an early evening frost and then either forecast precipitation or ice forming in the early hours of the following morning.
 - When there is an extended time below 0°C - examples stated were 6, 11 and 12 hours after which a repeat treatment is made
 - When temperatures were below zero from early evening through morning rush hour and the roads were damp or wet
 - Where certain parts of the network have very low traffic flows at dawn on weekends and Bank Holidays.

- Other scenarios for the need for follow up treatments include the following:
 - If there is a forecast change e.g. reduction in RST to the next coldest band, un-forecast rain event
 - Repeat treatments of sections of thin surfacing e.g. 40g/m² every 2 hours when temperatures are below freezing.

3.2.4 Assessing wetness of road

Figure 4 summarises the responses to the question: When making the decision on the spread rate, what information do you use to assess whether the road surface will be damp or wet?

Figure 5 summarises the responses to the question: When making the decision on the spread rate, what problems do you encounter when assessing whether the road surface will be damp or wet?

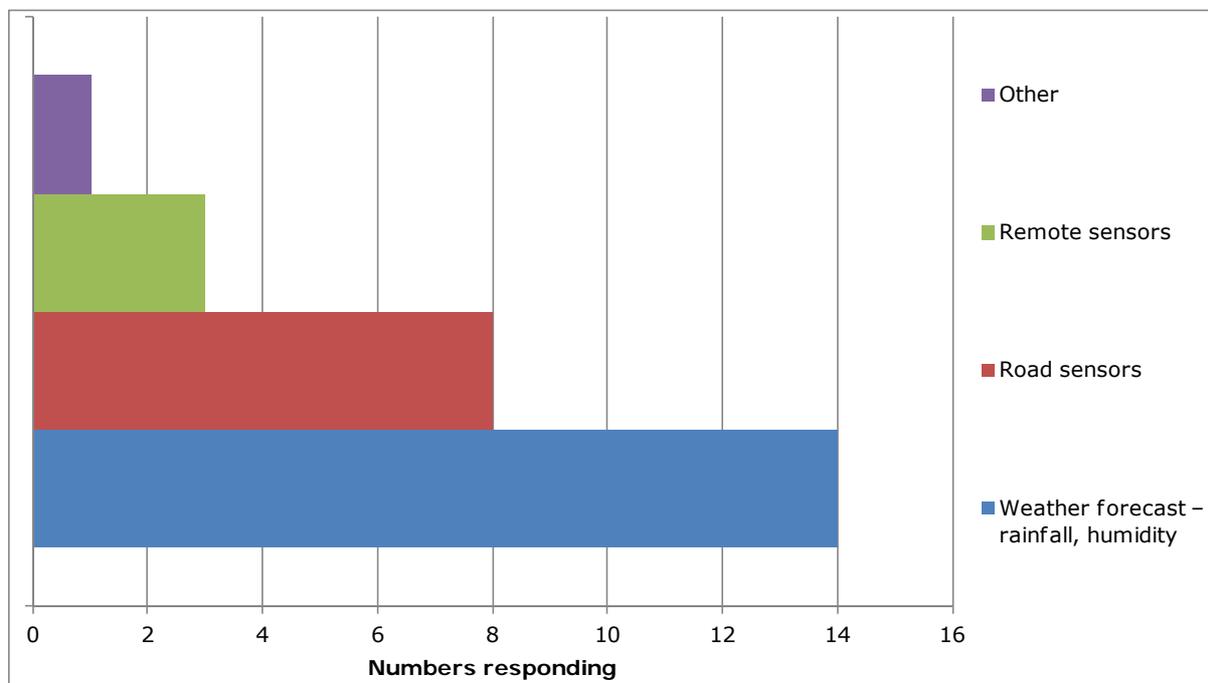


Figure 4 When making the decision on the spread rate, what information do you use to assess whether the road surface will be damp or wet?

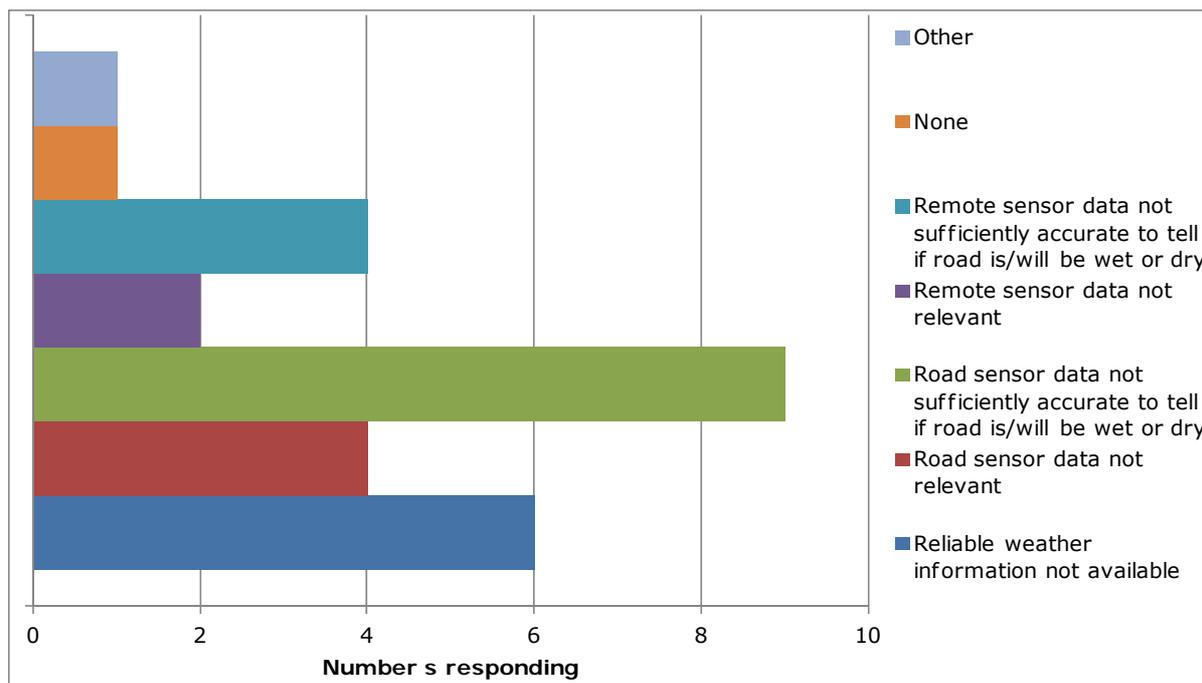


Figure 5 When making the decision on the spread rate, what problems do you encounter when assessing whether the road surface will be damp or wet?

Feedback included:

- Assessment is primarily based on information from the weather forecasts and local knowledge of runoff risks. Eight of the Service Providers stated that road sensors are used to assess road wetness. Only 3 areas make use of remote sensors. CCTV is also sometimes used.
- Comments were made that road sensors can only be representative of a short section of a route.
- Some Service Providers indicated that road sensors are not sufficiently accurate to determine if the road is wet or dry.
- Six of the Service Providers indicated that reliable weather information was not available, however further comments were not given on the particular aspects that were not reliable.

3.2.5 Assessing residual salt levels

Figure 6 summarises the responses to the question: When making the decision on the spread rate, how do you assess residual salt levels?

Figure 7 summarises the responses to the question: How are the spread rates reduced when there is evidence of (sufficient) residual salt?

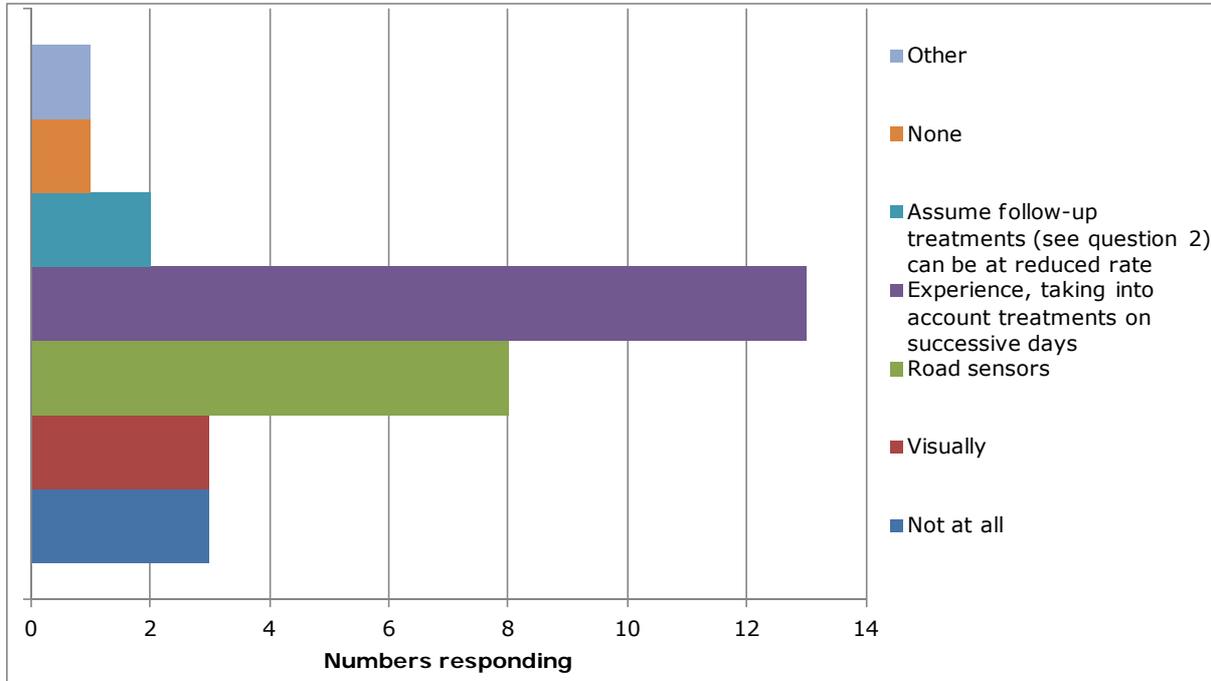


Figure 6 When making the decision on the spread rate, how do you assess residual salt levels?

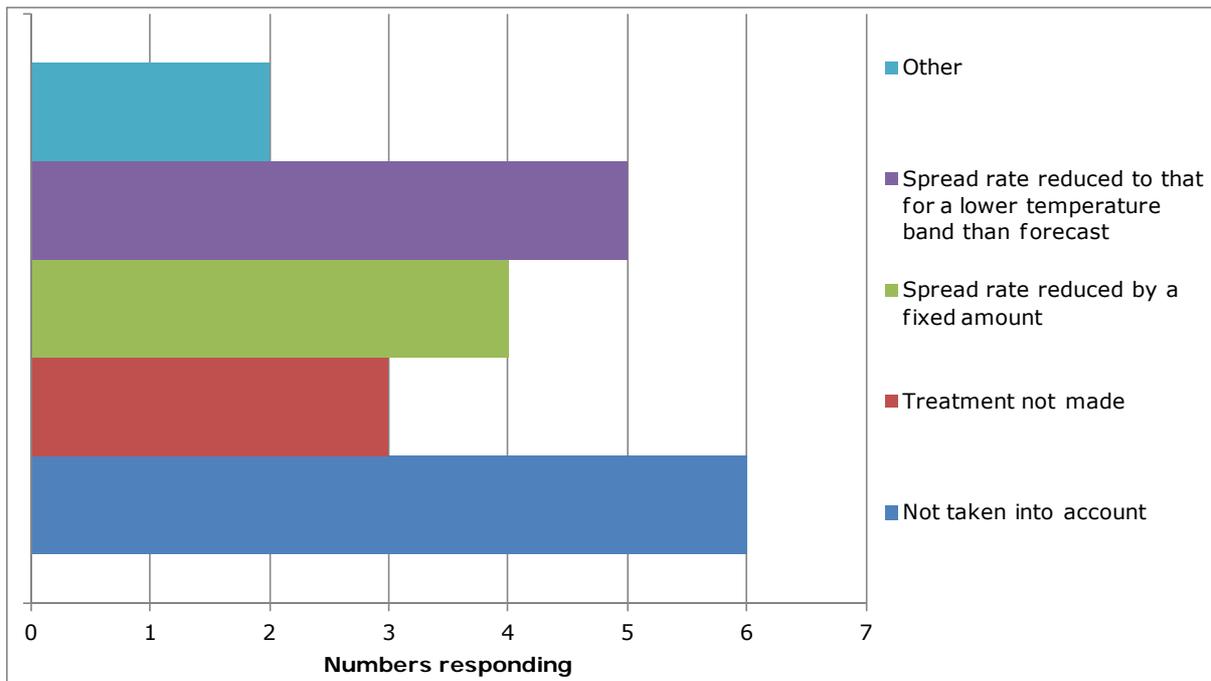


Figure 7 How are the spread rates reduced when there is evidence of (sufficient) residual salt?

Feedback included:

- Assessment of residual salt levels is primarily based on experience, taking into account treatments on successive days. Eight of the Service Providers make use of road sensor data.
- Residual salt levels are usually only considered after treatments have been carried out on successive dry days (low humidity/no precipitation).
- Following successive treatments, service providers may reduce rates to those for a lower temperature band when temperatures are close to the boundary. Another comment made by several Service Providers was that residual salt can be used to delay treatments outside peak hours or reduce the rate of treatment.

Three Areas responded that treatments are sometimes not made if they consider there is sufficient residual salt.

3.2.6 Effect of surfacing type

Figure 8 summarises the responses to the question: Do you increase the spread rates for certain types of thin surfacing?

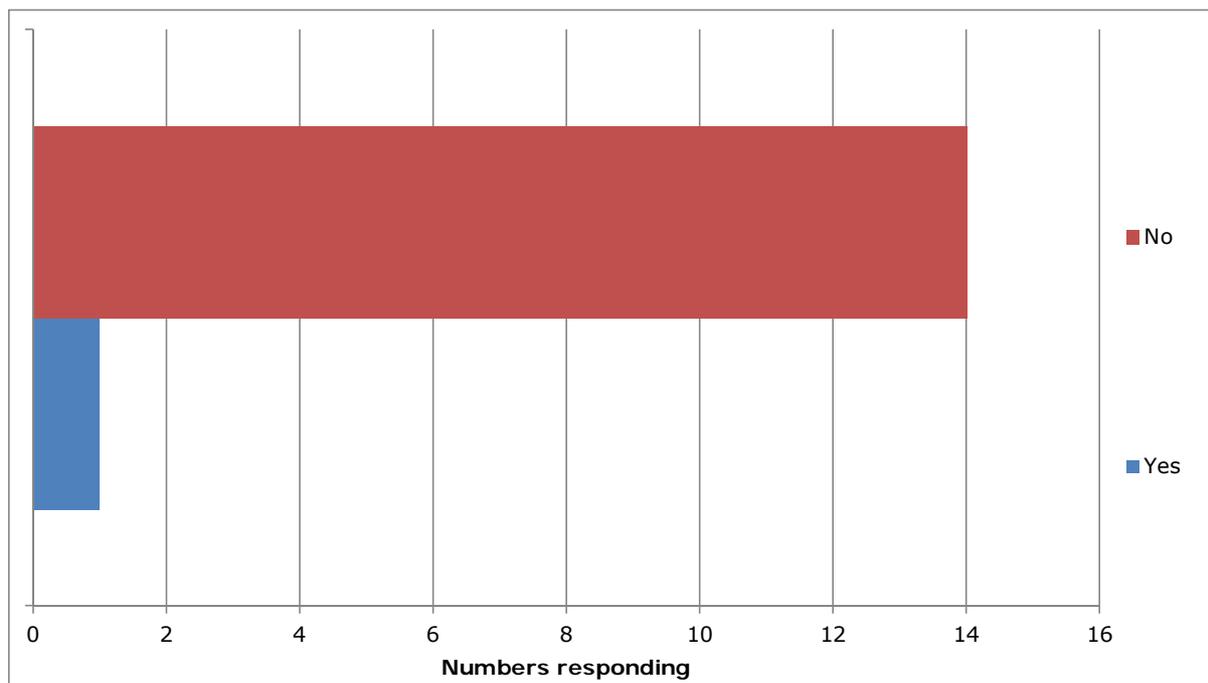


Figure 8 Do you increase the spread rates for certain types of thin surfacing?

Feedback included:

Only one of the Service Providers in the questionnaire response indicated that spread rates are increased for thin surfacing.

Some comments were made that more problems are encountered on newer thin surfacing, and one Area does not rely on residual salt on negatively textured surfacings.

3.2.7 Making spot treatments and use of 'blast button'

Figure 9 summarises the responses to the question: Where is the blast button used?

Figure 10 summarises the responses to the question: Under what conditions is the blast button used at critical locations?

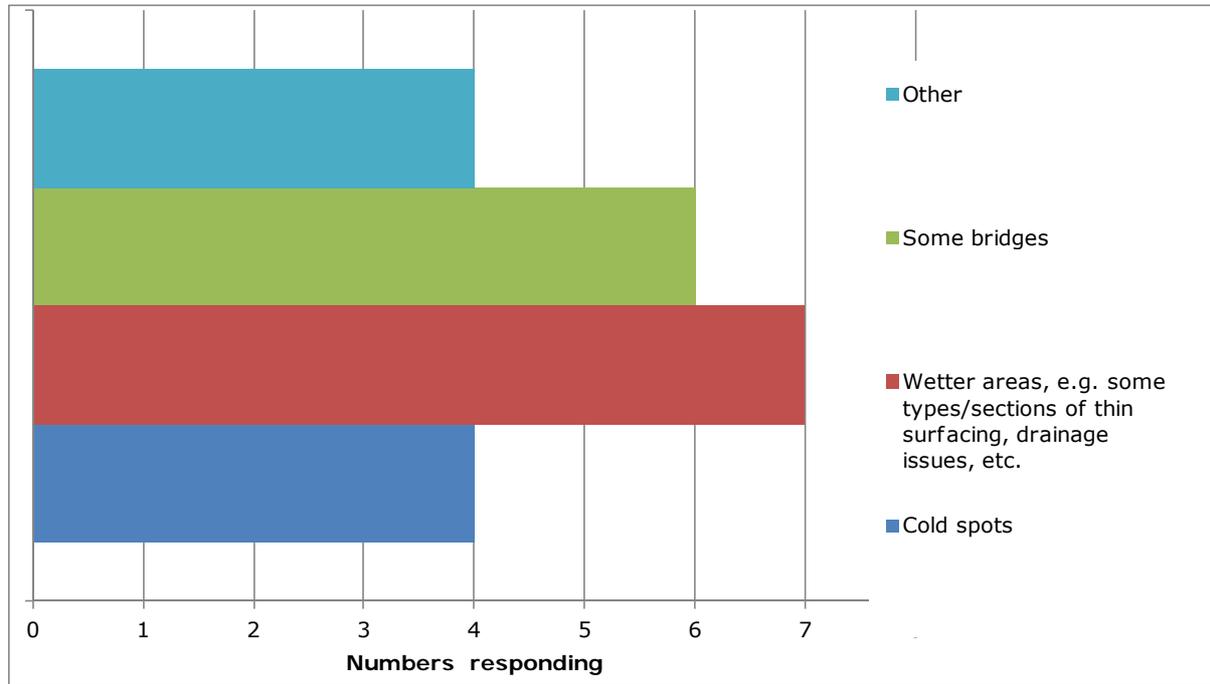


Figure 9 Where is the blast button used?

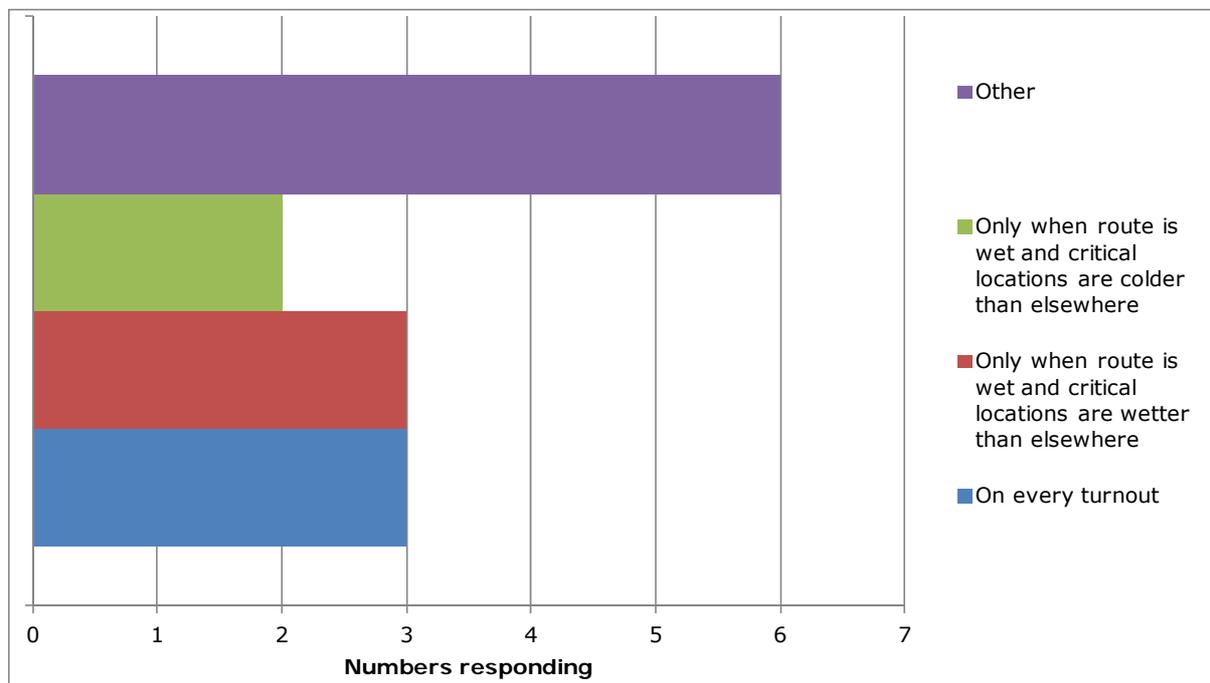


Figure 10 Under what conditions is the blast button used at critical locations?

3.2.8 Monitoring of the amounts of salt spread

Figure 11 summarises the responses to the question: How do you monitor the amount of salt discharged?

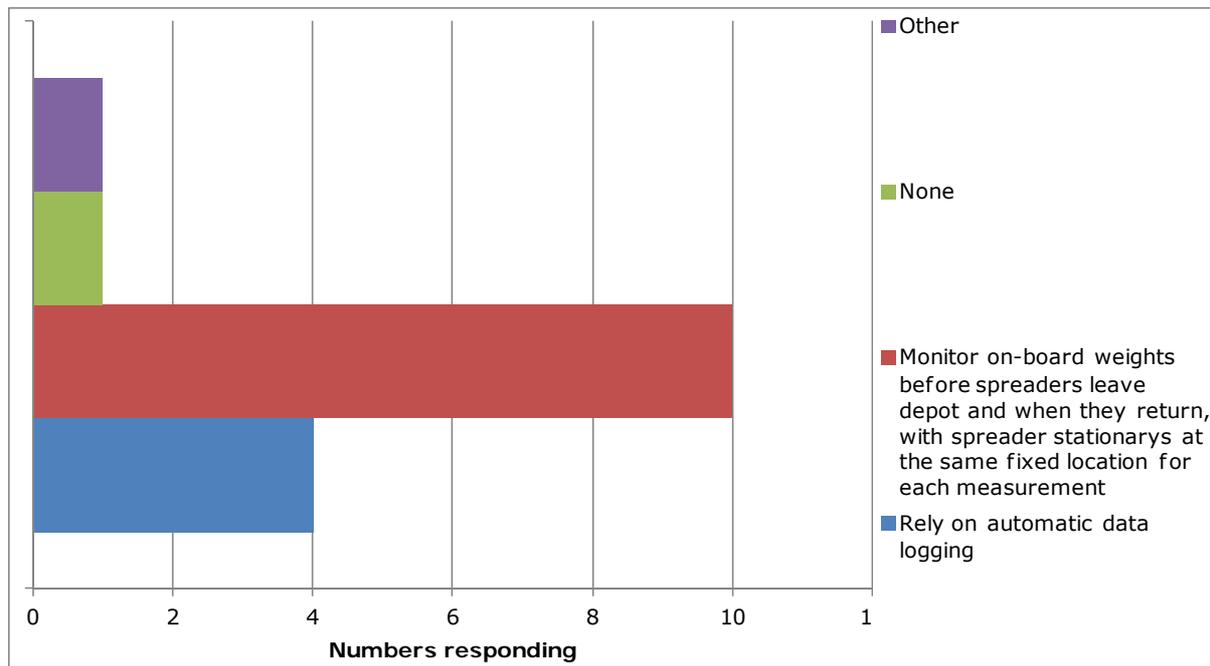


Figure 11 How do you monitor the amount of salt discharged?

Feedback included:

- Some Areas carry out measurements of the amounts of salt spread using the Spreader on-board weighing system or weighbridges at the depots
- One Area had attempted to use the weights provided by the automatic data logging system on the spreaders however had been unsuccessful to date. One of the problems noted was that readings are automatically taken whilst under braking or cornering when weight distribution will vary.

3.3 Use and understanding of the treatment matrix

3.3.1 General

In order to determine how Service Providers understand and are using the current spread rates, information was obtained on the treatments made since the current treatment matrix of spread rates was issued in January 2010.

The WRF1 Winter Reporting System is the internet based system that records proposed and confirmed actions during the winter period. WRF1 was reviewed to determine what spread rates have been used by a sample of Service Providers on selected days.

3.3.2 Areas selected and analysis periods

Table 2 and Table 3 show the range of conditions encountered in December 2011 and February 2012 for each Area as recorded on WRF1. As can be seen from the tables, these periods covered the full range of weather conditions for which spread rates are given for precautionary treatments in the treatment matrix, with the exception of wet roads in the coldest temperature range.

- Six Areas were selected, referred to as A to E, with one Area from each region of the country to capture the full range of weather conditions covered by the treatment matrix.

Table 2. Weather conditions reported within each Area in December 2011

Weather Conditions	Area 1	Area 2	Area 3	Area 4	Area 5	Area 6	Area 7	Area 8	Area 9	Area 10	Area 11	Area 12	Area 13	Area 14
Frost (RST \geq -2c)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓
Frost on dry roads (-2 < RST > -5c)	✓	✓		✓	✓	✓	✓	✓	✓	✓		✓	✓	✓
Frost on wet roads (-2 < RST > -5c)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓
Frost on dry roads (-5 \leq RST > -10c)	×	×	✓	×	×	×	✓	✓	✓	✓		✓	✓	×
Frost on wet roads (-5 \leq RST > -10c)	×	×	×	×	×	×	×	×	×	×		×	×	×
Light snow forecast	×	×	×	×	×	×	×	×	×	×		×	✓	✓

Table 3. Weather conditions reported within each Area in February 2012

Weather Conditions	Area 1	Area 2	Area 3	Area 4	Area 5	Area 6	Area 7	Area 8	Area 9	Area 10	Area 11	Area 12	Area 13	Area 14
Frost (RST \geq -2c)	✓	✓	✓	✓	✓	✓	✓	✓	✓	×		✓	✓	✓
Frost on dry roads (-2 < RST > -5c)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓
Frost on wet roads (-2 < RST > -5c)	✓	✓	✓	✓	✓	✓		✓	✓			✓	✓	✓
Frost on dry roads (-5 \leq RST > -10c)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	×
Frost on wet roads (-5 \leq RST > -10c)	×	×	×	×	×	×	×	×	×	×		×	×	×
Light snow forecast	✓	×	×	✓	×	✓	✓	✓	✓	✓		×	×	×

Key: ✓ Conditions reported × Conditions not reported

3.3.3 Analysis method

In order to assess how Service Providers are implementing the treatment matrix, an analysis was carried out of the precautionary spread rates used for the forecast minimum road surface temperatures (RST) and weather conditions as recorded in WRF1. Further information on the policy and implementation for each Area was obtained from the questionnaire responses reported in Section 3.2

WRF1 is where Service Providers are required to record the forecast minimum road surface temperatures and weather conditions at the time the decision was made.

WRF1 does not directly record the road wetness, i.e. dry, damp or wet. A summary of the weather forecast is commonly included in the reports submitted to WRF1 by the Service Provider but this can only give a general indication of the expected wetness of the roads.

The spread rates used in each of the six Areas were analysed for treatments made in December 2011 and February 2012, and the spread rates used are summarised in Sections 3.3.3 to 3.3.9 with further details provided in Appendix B. These most recent cold months were selected for analysis to enable the current level of acceptance of the spread rates in the treatment matrix to be assessed. Conditions in December were typical winter conditions for the UK, while colder temperatures were experienced on the network in February, hence allowing treatments under all conditions, with the exception of wet roads within the coldest temperature band of -5°C or below, to be assessed.

For each Area, the number of turnouts at each spread rate were totalled for each of the temperature bands in the current matrix:

- RST at or above -2°C
- RST below -2°C and above -5°C
- RST at or below -5°C and above -10°C

For each Area, the results are displayed in a separate bar chart for each temperature band. The following colour code has been used for the bar chart to identify the following spread rates:

Green – for dry and pre-wetted spread rates in accordance with the treatment matrix guide

Red – for dry and pre-wetted rates that are greater than the treatment matrix guide

Blue - for dry and pre-wetted rates that are less than the treatment matrix guide.

Black – for no action or dry rates at $20\text{g}/\text{m}^2$ where snow or ice is reported

It should be noted that WRF1 does not explicitly state when treatments are precautionary or are to be carried out on ice that has formed or lying snow. The treatment matrix guide states that dry salt is the preferred treatment method for non-precautionary treatments.

3.3.4 Area A

Figure 12, Figure 13 and Figure 14 show the treatments carried out during the analysis period for each temperature range given in the treatment matrix guide.

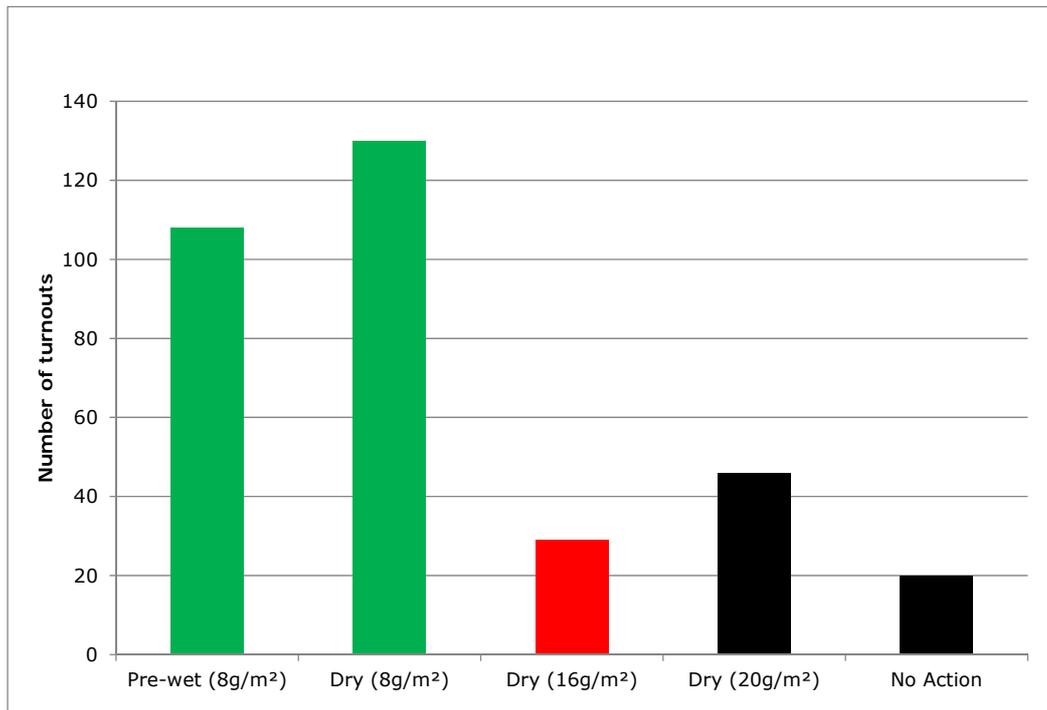


Figure 12 Types of treatments carried out for temperatures at or above -2°C

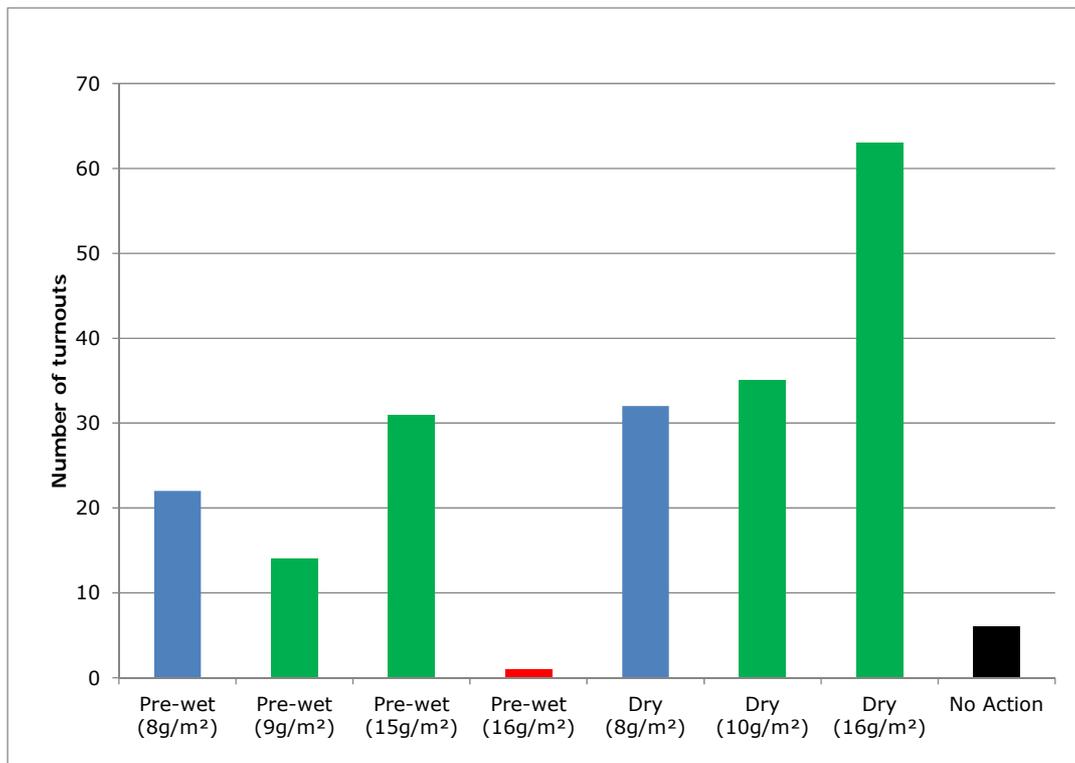


Figure 13 Types of treatments carried out for temperatures below -2°C and above -5°C

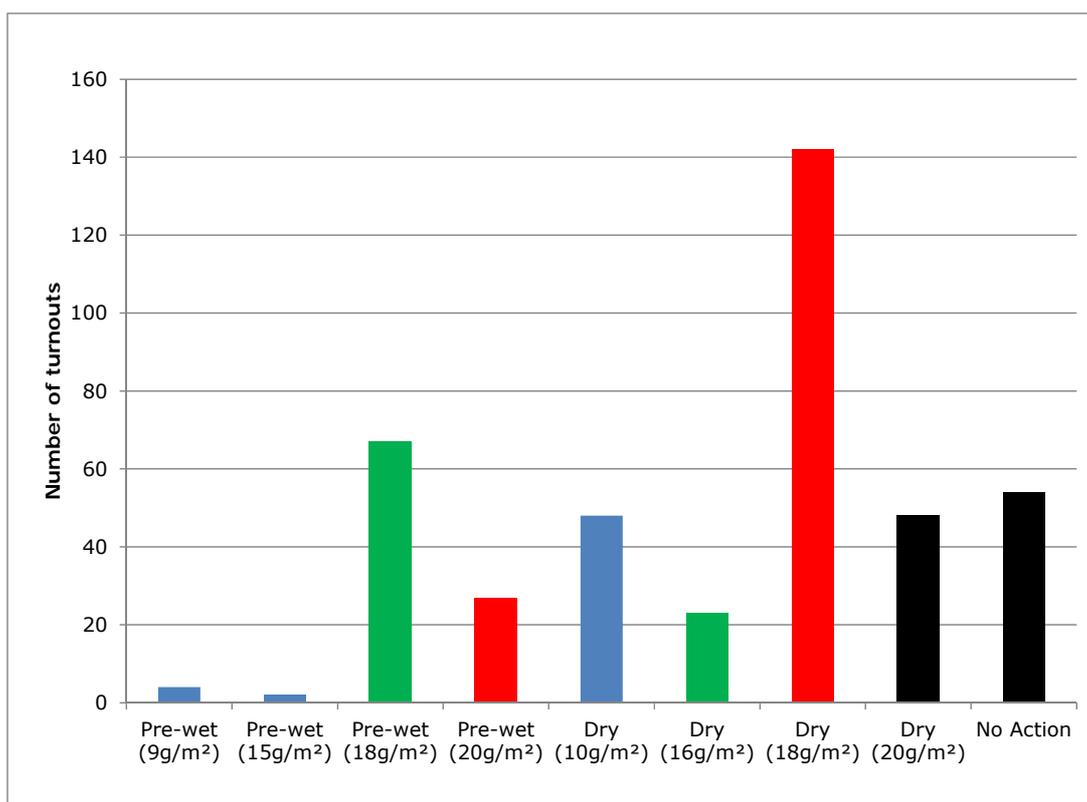


Figure 14 Types of treatments carried out for temperatures at or below -5°C and above -10°C

The full range of spread rates were used during the analysis periods, with the exception of the double treatment, 2x15g/m², for the lowest temperature band of -5°C to -10°C on a wet road.

For all turnouts when spreading dry salt at 20g/m², ice or snow was included in the forecast, hence these were not considered as precautionary treatments.

Table 4 shows the proportion of precautionary treatments carried out with pre-wetted salt (at, above and below the recommended rate) and dry salt.

Table 4. Summary of precautionary turnouts in Area A

Temperature band	% of turnouts			
	Pre-wet Correct rate	Pre-wet Lower rate	Pre-wet Higher rate	Dry salt*
At or above -2°C	41	0	0	59
Below -2°C and above -5°C	22	11	1	65
At or below -5°C and above -10°C	21	2	8	68

* Where pre-wetted salt recommended

On many turnouts, dry salting was used on the majority of routes and dry salting comprised over half the turnouts for each temperature band during the analysis period.

It is not clear from the WRF1 data what the reasons are for this high proportion of dry salting.

The conditions during turnouts where treatments did not match the guidance were analysed in further detail:

- For treatments carried out for forecast temperatures between -2°C and -5°C , a significant number of treatments were carried out with $8\text{g}/\text{m}^2$ of pre-wetted/dry salt, which are lower than the guidance rates. These occurred where the temperatures reported on WRF1 were close to -2°C , the boundary temperature with the lower treatment range.
- For treatments carried out for forecast temperatures less than -5°C , there were some treatments made using dry salt at $10\text{g}/\text{m}^2$, with some routes treated with pre-wetted salt at $9\text{g}/\text{m}^2$. This rate is less than the rate given in the treatment matrix. The treatments were made following several successive days of treatment at higher rates and comments on the report submitted to WRF1 stated that the treatments were due to prolonged freezing temperatures.

3.3.5 Area B

Figure 15, Figure 16, and Figure 17 show the treatments carried out during the analysis period for each temperature range given in the treatment matrix guide.

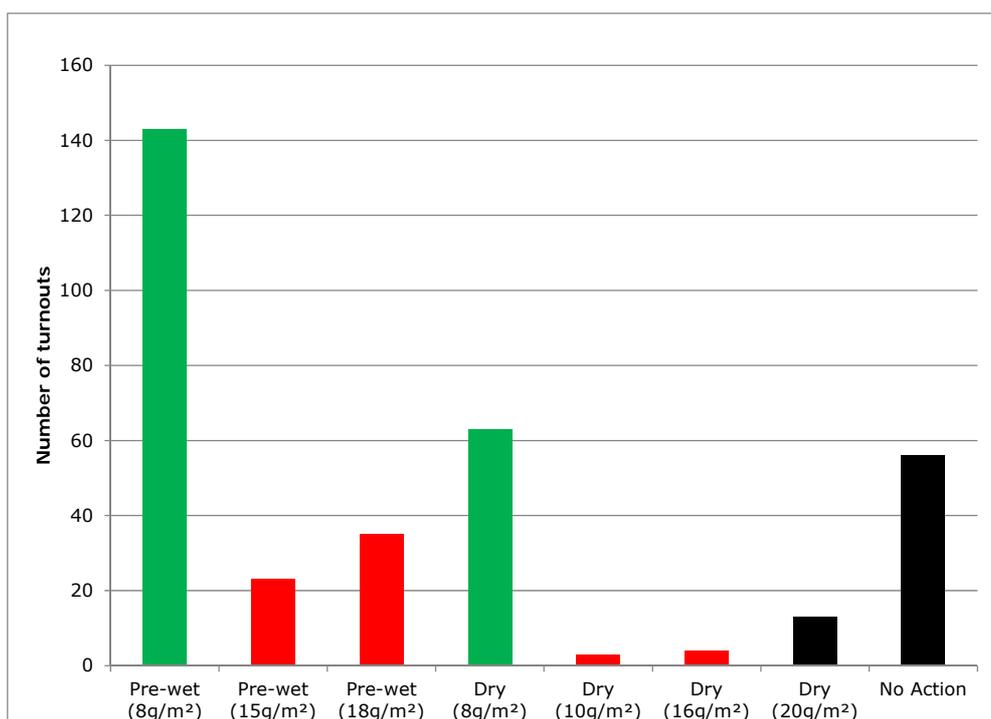


Figure 15 Types of treatments carried out for temperatures at or above -2°C

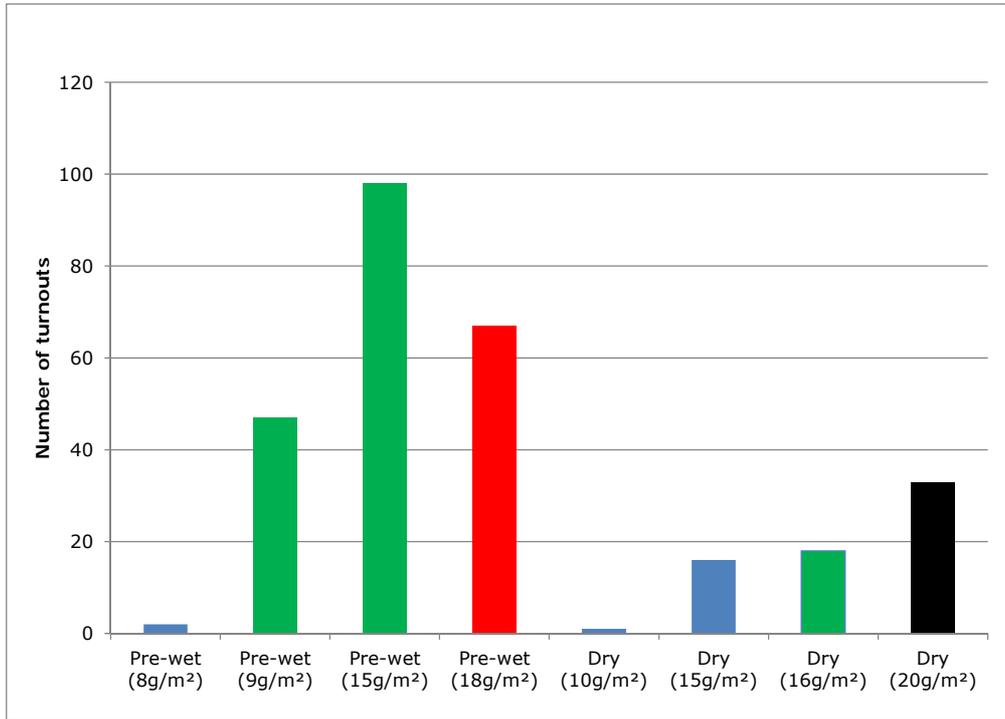


Figure 16 Types of treatments carried out for temperatures below -2°C and above -5°C

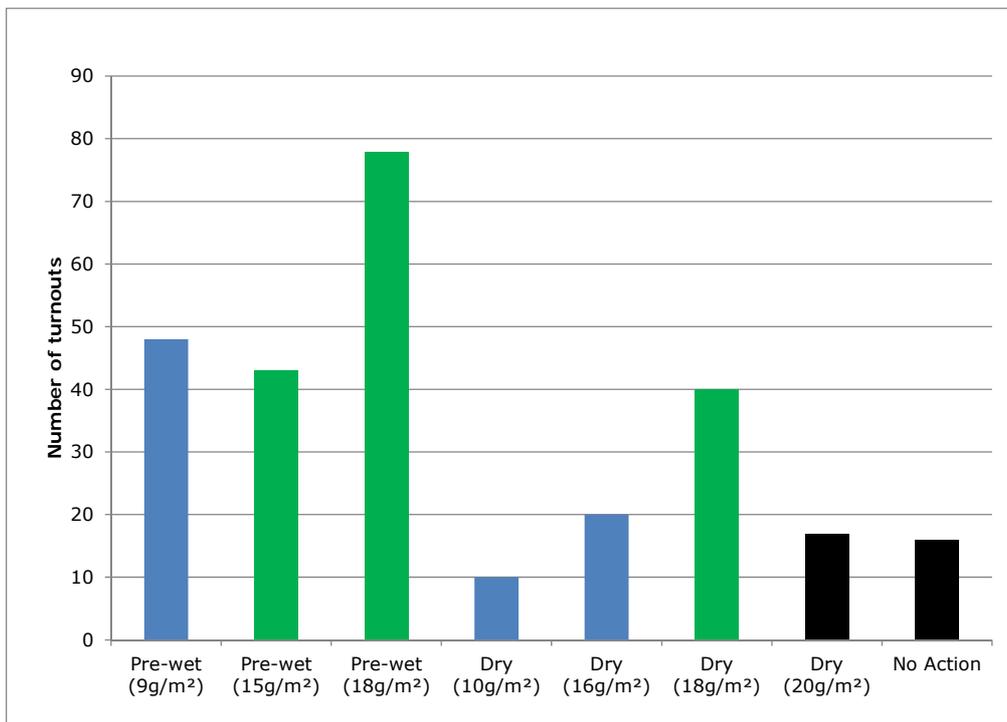


Figure 17 Types of treatments carried out for temperatures at or below -5°C and above -10°C

For all turnouts when spreading dry salt at 20g/m², ice or snow was included in the forecast, hence these were not considered as precautionary treatments.

Table 5 shows the proportion of precautionary treatments carried out with pre-wetted salt (at, above and below the recommended rate), dry salt and no action.

Table 5. Summary of precautionary turnouts in Area B

Temperature band	% of turnouts			
	Pre-wet Correct rate	Pre-wet Lower rate	Pre-wet Higher rate	Dry salt*
At or above -2°C	53	0	22	25
Below -2°C and above -5°C	58	1	27	14
At or below -5°C and above -10°C	33	38	0	29

* Where pre-wetted salt recommended

The full range of spread rates were used during the analysis periods, with the exception of the double treatment, 2x15g/m², for the lowest temperature band of -5°C to -10°C on a wet road.

On many turnouts, dry salting was used on the majority of routes, when pre-wetting salt was available and would be the recommended option by the treatment matrix guide.

During December a small number of treatments were carried out with dry salt, when snow was recorded on WRF1. It was noted that one particular route was treated with dry salt for every treatment in this period.

In February 2012 the full range of spread rates was used during the month, with the exception of 2x15g/m². Dry salting was used on some routes.

The conditions during turnouts where treatments did not match the guidance were analysed in further detail:

- For treatments carried out for forecast temperatures between -5°C and -10°C, a significant number of treatments were carried out with 9g/m² of pre-wetted salt, lower than the guidance rates. These occurred where the temperature reported on WRF1 were close to -5°C, the boundary temperature with the next treatment range.

3.3.6 Area C

Figure 18, Figure 19 and Figure 20 show the treatments carried out during the analysis period for each temperature range given in the treatment matrix guide.

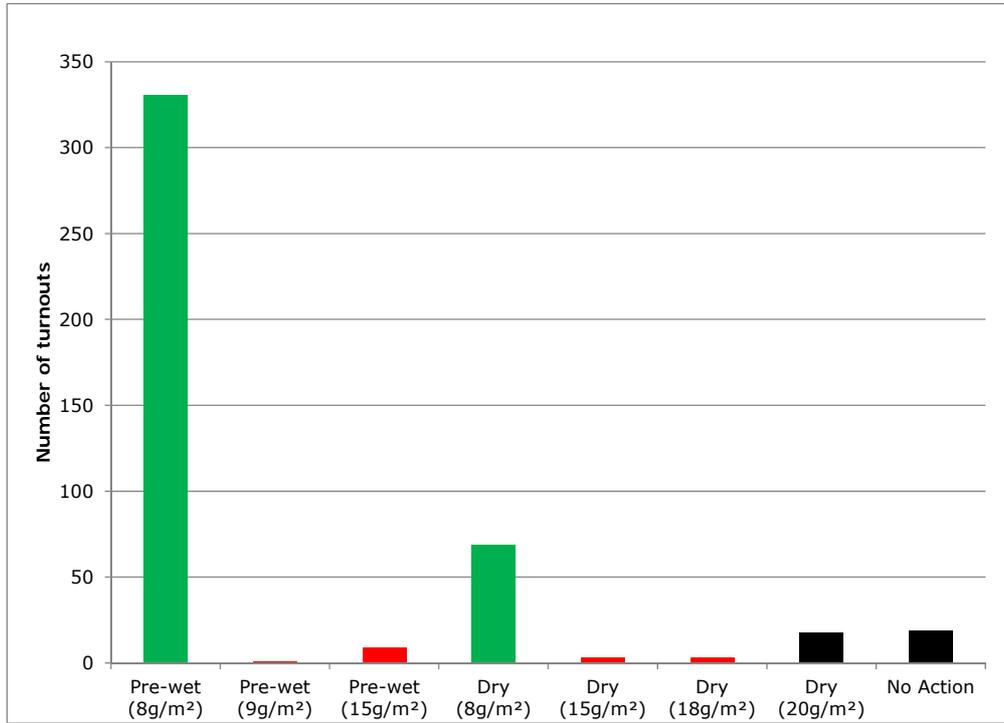


Figure 18 Types of treatments carried out for temperatures at or above -2°C

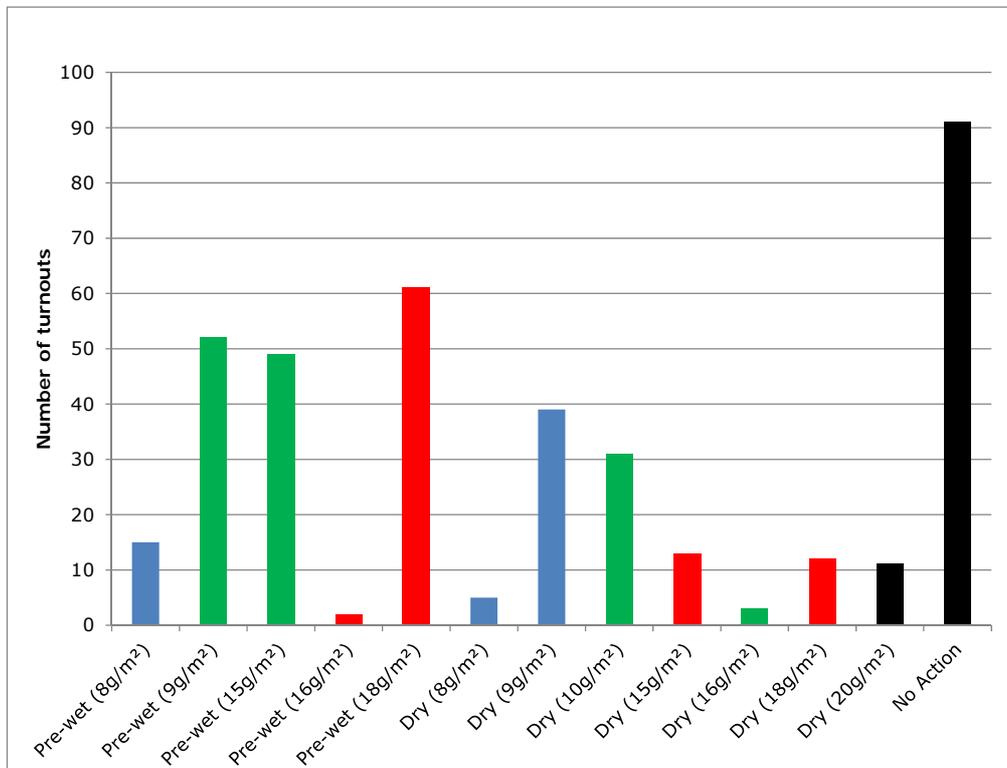


Figure 19 Types of treatments carried out for temperatures below -2°C and above -5°C

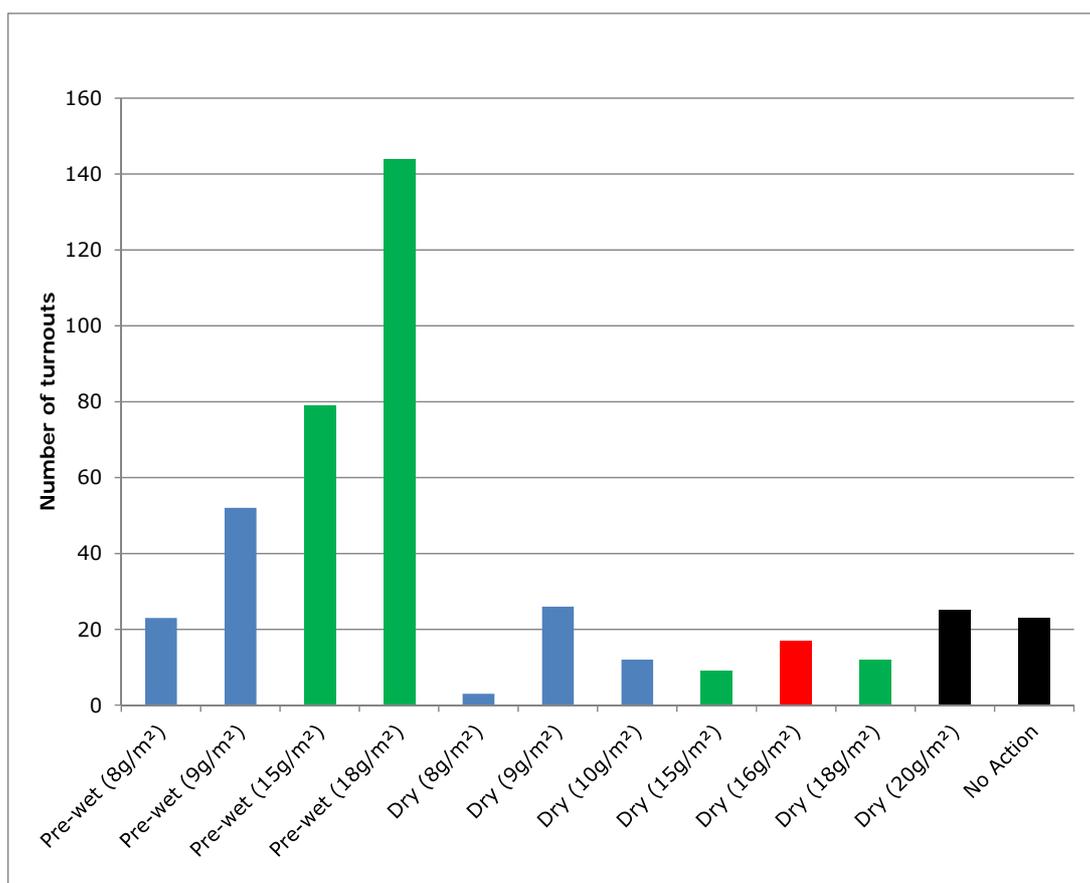


Figure 20 Types of treatments carried out for temperatures at or below -5°C and above -10°C

For all turnouts when spreading dry salt at 20g/m², ice or snow was included in the forecast, hence these were not considered as precautionary treatments.

Table 6 shows the proportion of precautionary treatments carried out with pre-wetted salt (at, above and below the recommended rate), dry salt and no action.

Table 6. Summary of precautionary turnouts in Area C

Temperature band	% of turnouts			
	Pre-wet Correct rate	Pre-wet Lower rate	Pre-wet Higher rate	Dry salt*
At or above -2°C	80	0	2	18
Below -2°C and above -5°C	36	5	22	37
At or below -5°C and above -10°C	38	41	0	21

* Where pre-wetted salt recommended

In December 2011, all the spread rates with the exception of the maximum rates of 18g/m² and 2x15g/m² for minimum RST between -5°C to -10°C, were used during the

month. Spread rates were mostly in agreement with the matrix, with dry salting occasionally used.

In February 2012 the full range of rates were used with the exception of $2 \times 15 \text{g/m}^2$. Again, pre-wetted salt was used predominantly. Snowfall occurred on a number of days in the month, and dry salt was used on a number of routes on each of these days.

Spread rates were mostly in agreement with the matrix. Treatments where the spread rates differed from the matrix were:

- Treatments made using 9g/m^2 of pre-wetted or dry salt at 19.00, with a minimum forecast RST of -8°C . A follow up treatment was made at 03.00 the following morning at the same rates, with the same forecast temperature. In these conditions, the treatment matrix specifies 18g/m^2 of pre-wetted or dry salt. There had been 10 days of continuous spreading before this treatment, with a treatment of 18g/m^2 (pre-wetted) and 20g/m^2 (dry) at 04.00 in the morning.
- A treatment was made using 9g/m^2 of pre-wetted or dry salt at 19.00 on each route, with a minimum forecast temperature of -9°C . In these conditions, the treatment matrix specifies 18g/m^2 of pre-wetted or dry salt. A follow up treatment was made at 00.00, using 18g/m^2 of pre-wetted or 20g/m^2 of dry salt.
- Some routes were treated using dry salting, spreading at both 9g/m^2 and 10g/m^2 for a forecast temperature of -4.5°C . For dry salting, the matrix specifies using 10g/m^2 in these conditions.

3.3.7 Area D

Figure 21, Figure 22 and Figure 23 show the treatments carried out during the analysis period for each temperature range given in the treatment matrix guide.

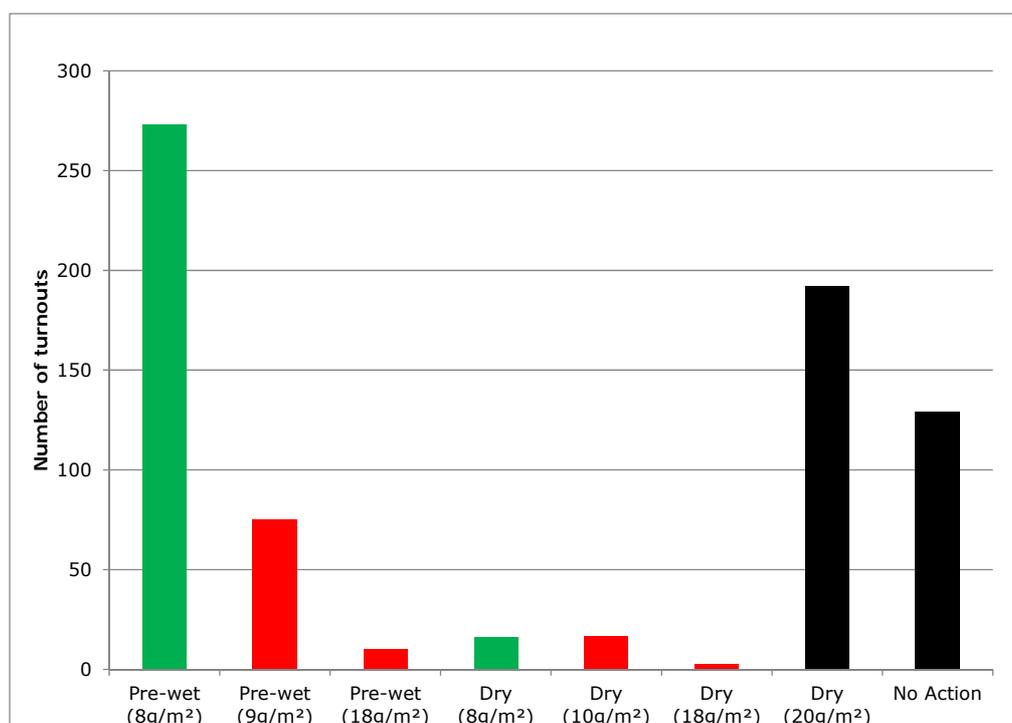


Figure 21 Types of treatments carried out for temperatures at or above -2°C

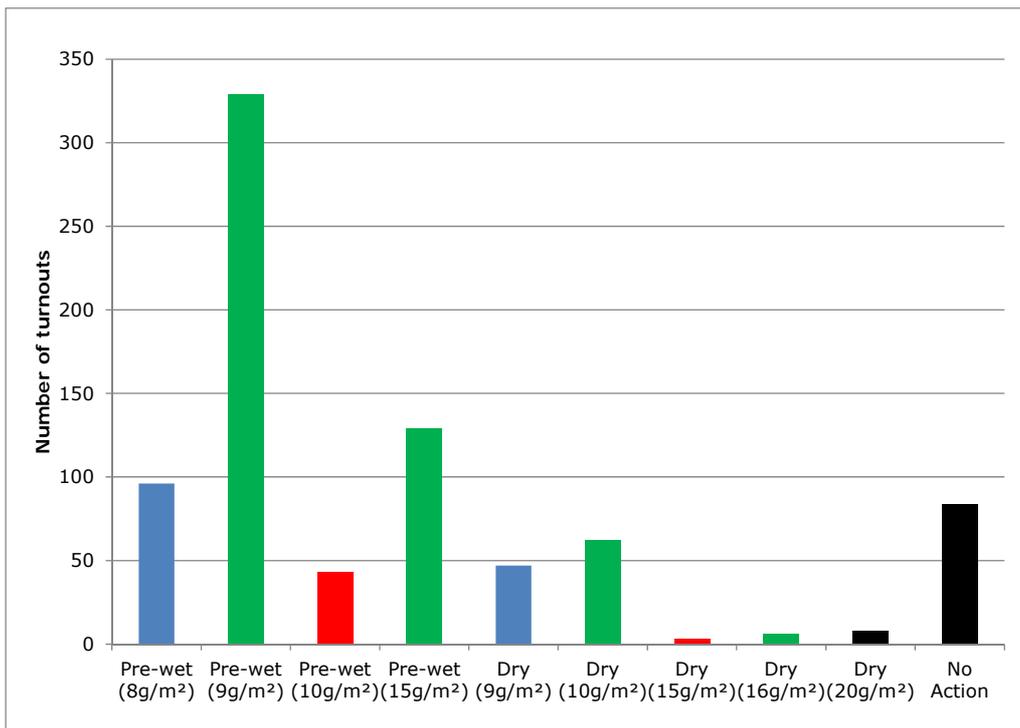


Figure 22 Types of treatments carried out for temperatures below -2°C and above -5°C

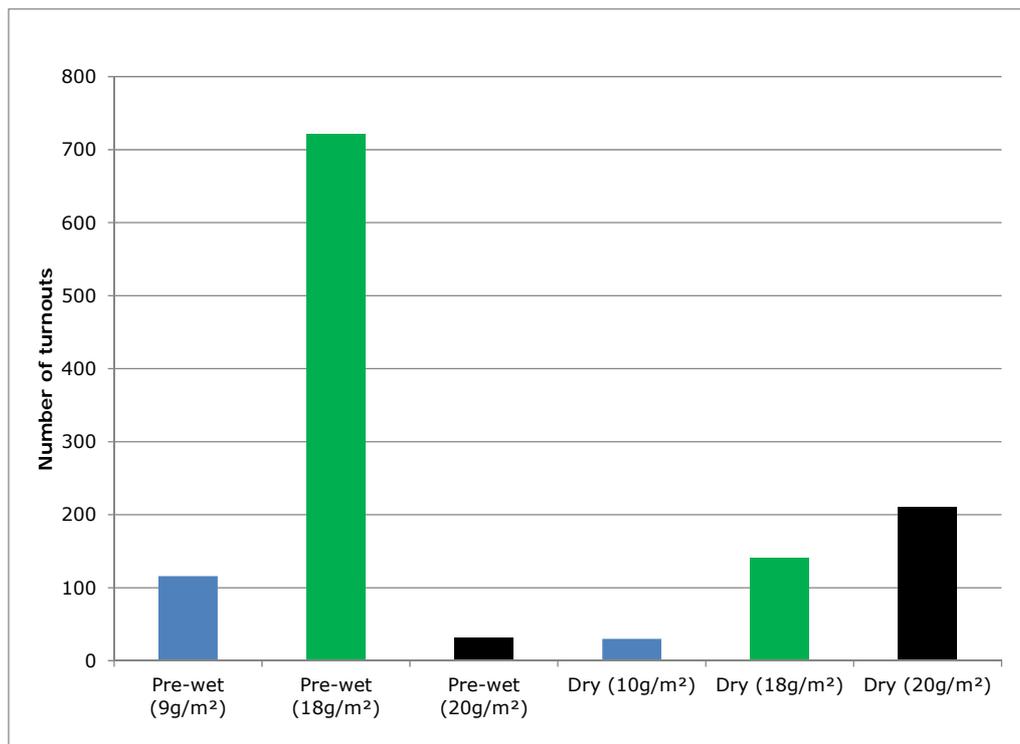


Figure 23 Types of treatments carried out for temperatures at or below -5°C and above -10°C

For all turnouts when spreading dry salt at 20g/m², ice or snow was included in the forecast, hence these were not considered as precautionary treatments.

Table 7 shows the proportion of precautionary treatments carried out with pre-wetted salt (at, above and below the recommended rate), dry salt and no action.

Table 7. Summary of precautionary turnouts in Area D

Temperature band	% of turnouts			
	Pre-wet Correct rate	Pre-wet Lower rate	Pre-wet Higher rate	Dry salt*
At or above -2°C	69	0	21	9
Below -2°C and above -5°C	68	14	0	18
At or below - 5°C and above -10°C	70	11	3	16

* Where pre-wetted salt recommended

In December 2011, all the spread rates, with the exception of the maximum rates of 18g/m² and 2x15g/m² were used during the month. Spread rates were in agreement with the matrix, with dry salting occasionally used.

In February 2012, the full range of rates was used during the month with the exception of the maximum rate of 2x15g/m². Spread rates were in agreement with the matrix, with dry salting frequently used.

3.3.8 Area E

Figure 24, Figure 25 and Figure 26 show the treatments carried out during the analysis period for each temperature range given in the treatment matrix guide.

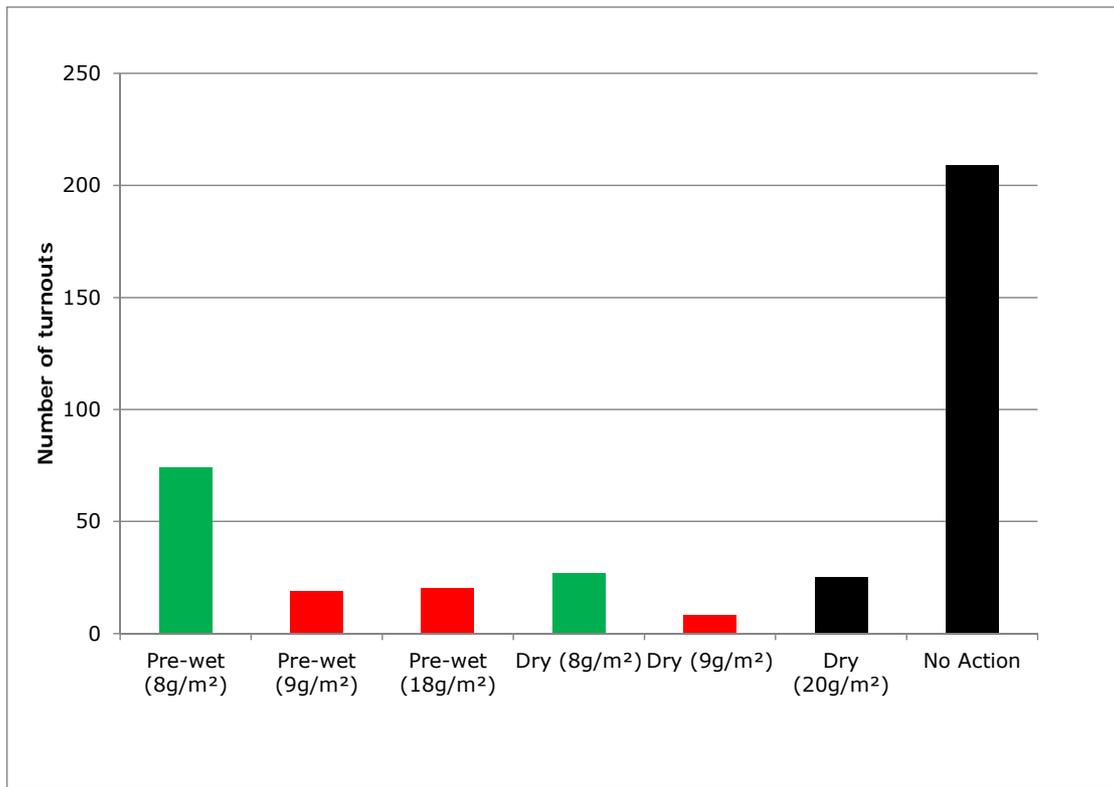


Figure 24 Types of treatments carried out for temperatures at or above -2°C

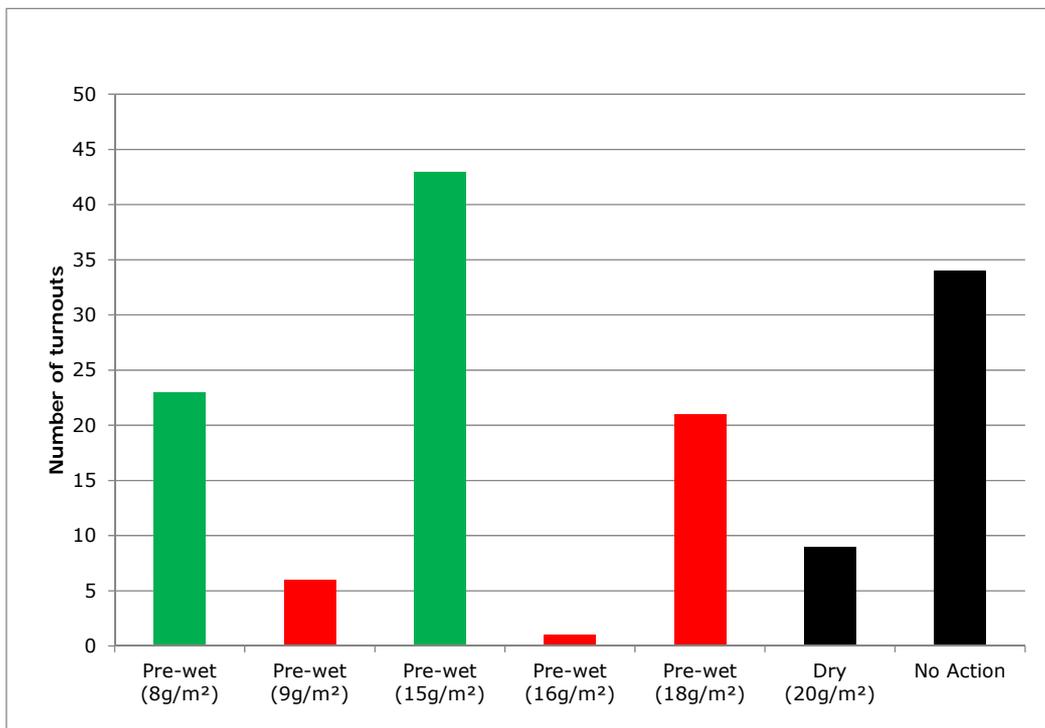


Figure 25 Types of treatments carried out for temperatures below -2°C and above -5°C

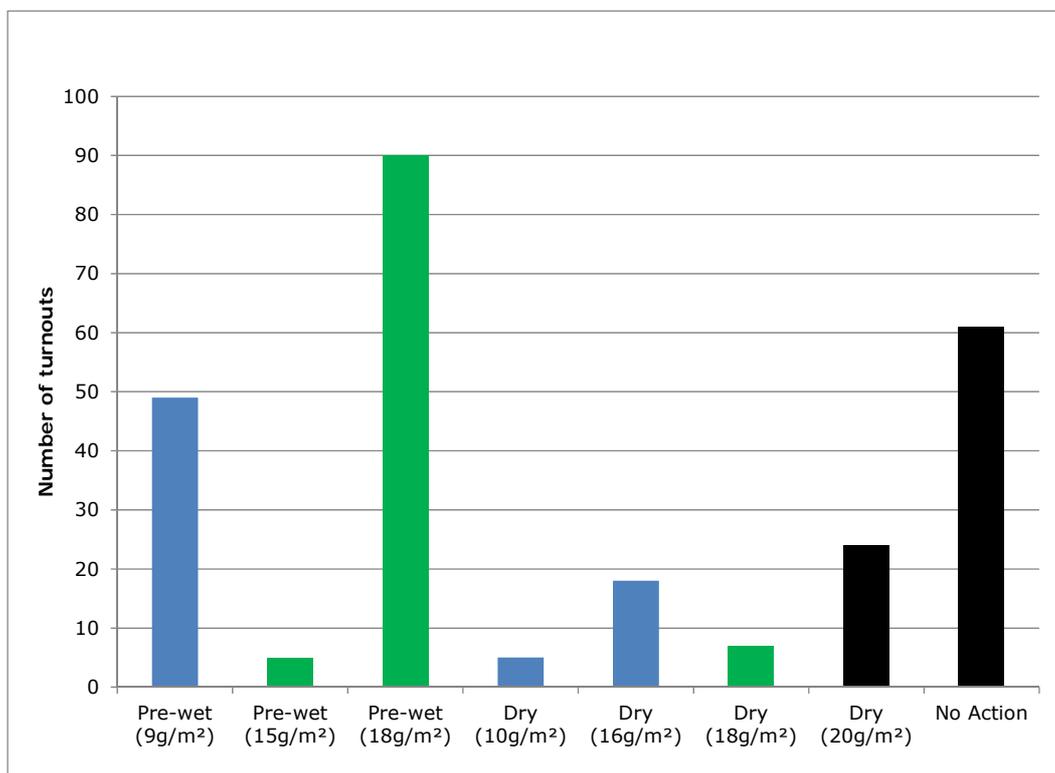


Figure 26 Types of treatments carried out for temperatures at or below -5°C and above -10°C

For all turnouts when spreading dry salt at 20g/m², ice or snow was included in the forecast, hence these were not considered as precautionary treatments.

Table 8 shows the proportion of precautionary treatments carried out with pre-wetted salt (at, above and below the recommended rate), dry salt and no action.

Table 8. Summary of precautionary turnouts in Area E

Temperature band	% of turnouts			
	Pre-wet Correct rate	Pre-wet Lower rate	Pre-wet Higher rate	Dry salt *
At or above -2°C	50	0	26	24
Below -2°C and above -5°C	53	0	47	0
At or below - 5°C and above -10°C	50	30	0	20

* Where pre-wetted salt recommended

In December and February, the full range of spread rates was used during the month except for 2x15g/m².

In December, spread rates were mostly in agreement with the matrix. In February 2012, treatments where the spread rates differed from the matrix were:

- On two consecutive days, pre-wetted salting was carried out at 9g/m² and dry salting at 10g/m² for a minimum forecast RST less than -7°C, as compared to 18g/m² in the

treatment matrix for these temperatures. This spreading was carried out following a number of successive days of treatment (where 2 treatments had been carried out at 04.30 and 17.00 each day) with no precipitation occurring. A few days later, after snow showers, precautionary spread rates were back in line with the matrix i.e. 15g/m² when spreading between -2°C and -5°C.

- A treatment carried out on a particular day at 06.00, where routes were treated with 9g/m² of pre-wetted salt for a forecast minimum temperature of -7°C, as compared to 18g/m² in the treatment matrix for these temperatures. This followed a treatment at 18g/m² the previous evening.

3.3.9 Area F

Figure 27, Figure 28 and Figure 29 show the treatments carried out during the analysis period for each temperature range given in the treatment matrix guide.

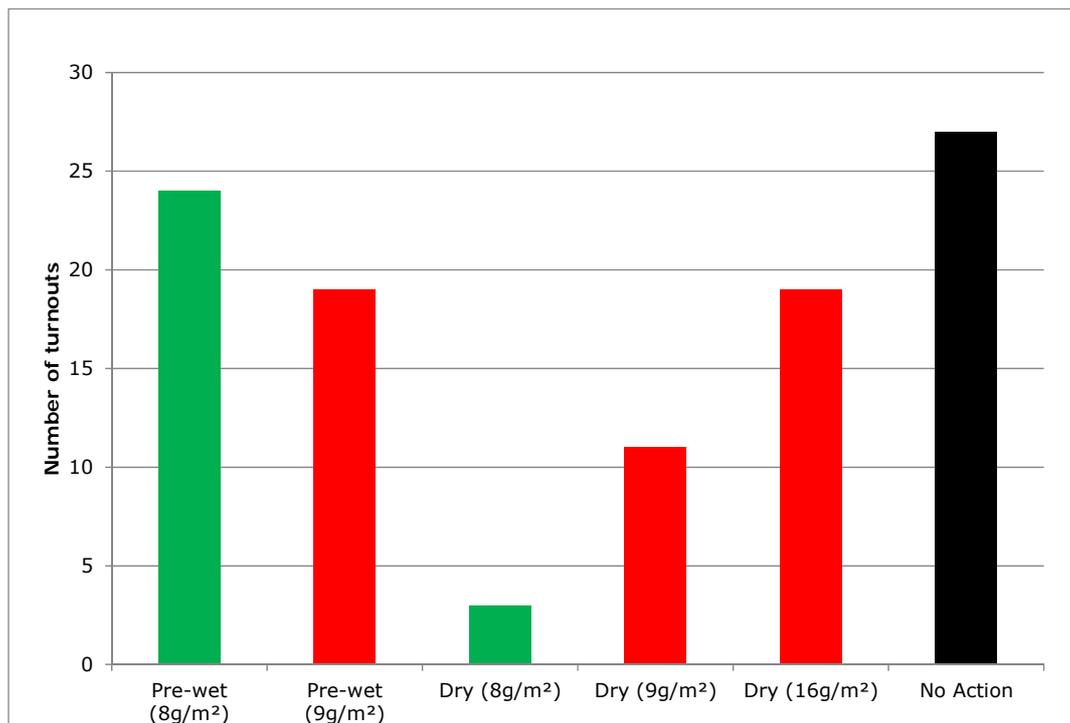


Figure 27 Types of treatments carried out for temperatures at or above -2°C

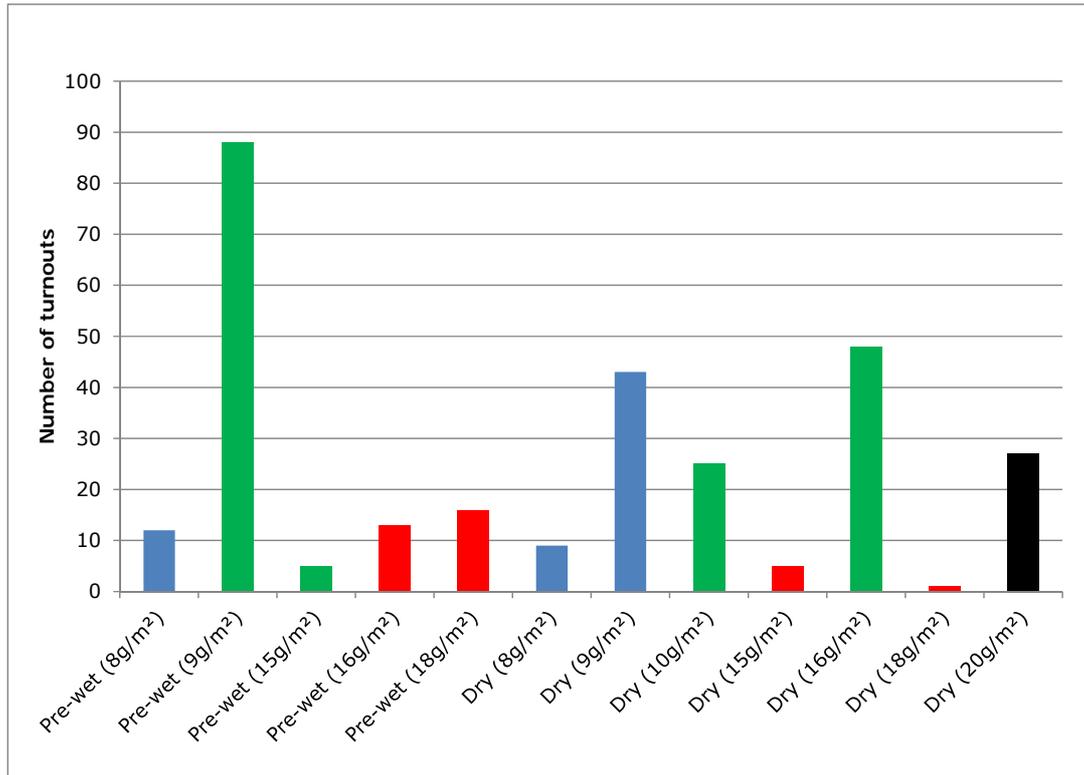


Figure 28 Types of treatments carried out for temperatures below -2°C and above -5°C

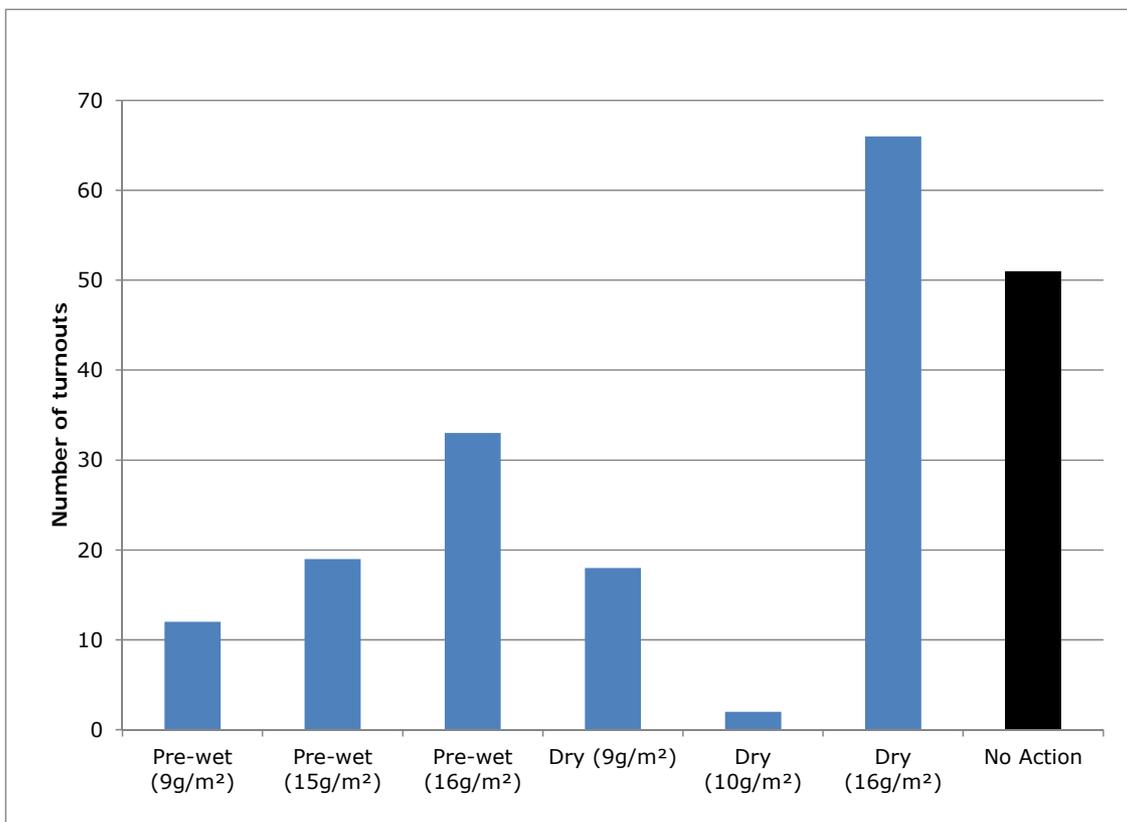


Figure 29 Types of treatments carried out for temperatures at or below -5°C and above -10°C

For all turnouts when spreading dry salt at 20g/m², ice or snow was included in the forecast, hence these were not considered as precautionary treatments.

Table 9 shows the proportion of precautionary treatments carried out with pre-wetted salt (at, above and below the recommended rate), dry salt and no action.

Table 9. Summary of precautionary turnouts in Area F

Temperature band	% of turnouts			
	Pre-wet Correct rate	Pre-wet Lower rate	Pre-wet Higher rate	Dry salt*
At or above -2°C	32	0	25	44
Below -2°C and above -5°C	35	5	11	49
At or below -5°C and above -10°C	0	43	0	57

* Where pre-wetted salt recommended

A significant proportion of treatments were carried out with dry salt for all the temperature bands.

Examples where the spread rates differed from the matrix were:

- Pre-wetted treatments were carried out at 16g/m² when the forecast minimum temperature was -7°C and -8°C respectively. The treatment matrix specifies 18g/m² in these conditions.
- Dry spreading carried out at 9g/m² on a number of occasions – the treatment matrix does not specify this rate for dry salt.

3.4 Discussion

3.4.1 Use and understanding of the Treatment Matrix

Table 10 shows the proportion of precautionary treatments carried out with pre-wetted salt (at, above and below the recommended rate) and dry salt, averaged for all the Areas analysed.

Table 10. Summary of precautionary turnouts, average for Areas A to F

Temperature band	% of turnouts			
	Pre-wet Correct rate	Pre-wet Lower rate	Pre-wet Higher rate	Dry salt*
At or above -2°C	54	0	16	30
Below -2°C and above -5°C	45	6	18	31
At or below -5°C and above -10°C	35	28	2	35

* Where pre-wetted salt recommended

The review of WRF1 has shown that the majority of pre-wetted treatments in the analysis period were consistent with the treatment matrix guide (for the forecast minimum RST and weather conditions reported on WRF1) for treatments at or above -2°C. For the colder temperature bands, spread rates are dependent on an assessment of the road wetness. Within each temperature band, it was not possible to assess how accurately spread rates took account of road surface wetness due to the lack of information on road wetness within WRF1. For the colder temperature bands, Table 10 therefore does not distinguish between the rates for dry/damp and the rates for wet, but reports the % of treatments made at either of the rates for the different wetness. The facility to record more information on WRF1 for each individual route e.g. road wetness, temperature, would allow the treatment decisions to be more fully assessed.

For the colder temperature bands the proportion of treatments at the correct rates reduces with a wider range of spread rates used. Averaged over all Areas, 79% of pre-wetted treatments were at rates specified in the guidance above -2°C, 65% below -2°C and above -5°C and 54% at or below -5°C and above -10°C.

From the results, it was clear that within the temperature band below -2°C and above -5°C, spread rates specified for both dry and wet conditions have been used. Averaged over all the Areas analysed, 33% of pre-wetted treatments were made at 9g/m² and 32% at 15g/m² within this temperature band.

The even split between the dry and wet spread rates might indicate that Service Providers are conservative in assessing the road wetness, as dry/damp conditions should be more prevalent than wet conditions on the network. The questionnaire issued to Service Providers sought information on how road wetness was assessed and problems encountered when assessing the road wetness. As reported in Section 3.2.4, assessment is primarily based on information from the weather forecasts and local knowledge of runoff risks. Some Service Providers indicated that road sensors are not sufficiently accurate to determine if the road is wet or dry and six of the Service Providers indicated that reliable weather information was not available, however further comments were not given on the particular aspects that were not reliable. Better weather information and improved use of HAWIS could improve decision making with

regard to surface wetness, resulting in lower spread rates and greater efficiencies in salt use.

The full range of spread rates was used in each Area in the analysis period with the exception of the double treatment, $2 \times 15 \text{g/m}^2$, specified for the lowest temperature band on wet roads. The maximum rate used for any single treatment in the analysis period was 20g/m^2 . In this lowest temperature band, the majority of precautionary treatments were with made with 18g/m^2 of pre-wetted or dry salt, even during periods where snow showers were experienced. There has been no specific feedback from Service Providers on why this treatment, specified for these particular conditions, has not been used.

Within an Area, local factors will come into play regarding the treatment decisions made for particular routes. The temperature and weather conditions reported in WRF1 are not broken down by route, hence is to be expected that there will be some variation in the spread rates used from those specified based on conditions as reported.

Where treatments are not in agreement with the treatment matrix, further analysis has shown this is often where the temperature reported on WRF1 is near to the boundary with another temperature band in the guide. For example, where WRF1 reports a minimum temperature just below -2°C , some routes are treated with the spread rate specified for the temperature band higher than -2°C . When the temperature is just above -5°C , spread rates on some routes are specified for the temperature range between -5°C and -10°C .

When spread rates used by Service Providers do not match the matrix guidance, this can be a result of Service Providers taking account of residual salt levels. Feedback from the questionnaire has indicated that spread rates can be reduced to take account of residual salt after treatments on successive days. Following successive treatments, Service Providers reported in the questionnaire that they may reduce rates to those for a higher temperature band or delay treatments outside peak hours. In some cases, Service Providers stated that treatments are not made at all, based on the amount of residual salt estimated. Turnouts have been identified in the analysis periods where lower rates have been used after successive days spreading, or where no action has been taken in frost conditions.

The frequency of treatment is an important factor with regards to the residual levels of salt on the road. The matrix guide does not recommend a time for treatment frequency, and feedback from Service Providers has indicated that further information would aid their decision making process. As discussed in the report, a common treatment regime is to spread in the early evening and early morning when temperatures remain below freezing from evening through the following morning's rush hour. There has been feedback from Service Providers and evidence in the WRF1 review that combinations of treatments can be used to achieve recommended spread rates e.g. when it is assumed that temperatures will not fall to the minimum straight away, two treatments at reduced rate to put down required dosage and cover risk at both ends of the treatment period.

A maximum time of 12 hours appears to be accepted by Service Providers before repeat treatment is required during sustained freezing. These conditions include:

- Frost in early evening with continued freezing temperatures through the following morning rush but temperatures rising above freezing during the day
- Sustained freezing over one or more days, with the temperature remaining below freezing during the day

To inform the guidance on repeat treatments, further work is required to better understand appropriate rates and timing for repeat treatments in periods of sustained freezing, in order to optimise the use of salt while providing adequate treatment in these conditions. For example, how can the spread rate and frequency of treatment take account of the following factors:

- Different temperature-time profiles after carrying out treatments
- Changes in surface wetness during sustained freezing
- Residual salt levels

It is recommended that further investigation be made of the use of HAWIS to improve decision making, in particular with regard to the above factors.

The review has shown that dry salting is frequently used for precautionary treatments in all the temperature bands specified in the guide when pre-wet salting is available and would be the recommended option. Both pre-wetted and dry salting were frequently used across an Area for the same turnout, with the dry and pre-wetted salt spread at the precautionary rates in the matrix guide i.e. 8, 10, 16 and 18g/m². On a number of occasions, dry salt was also spread at rates not specified in the guidance e.g. 9g/m².

The matrix guide recommends that pre-wetted salt is the preferred option for precautionary treatments, including for treatments before light snow. Dry salt is recommended as a remedial treatment (even when pre-wet salting is available) when ice has formed, or snow is lying. Based on the matrix guide, the use of dry salt is therefore only recommended at 20g/m², either as a single or successive treatment.

It is apparent that dry salt is frequently used where pre-wetted salting is available and would be the recommended option from the treatment matrix. It would therefore appear that, in certain conditions, Service Providers consider the use of dry salt for reasons not stated in their responses. Sometimes the facilities for producing brine may not be available, e.g. if a saturator is out of order, and dry salting will be carried out as a result. When this is the case, this is often recorded on the reports submitted to WRF1.

The use of dry salt results in more salt being spread and the increased loss of the dry salt, particularly on dry or damp roads. It is considered by TRL, that the better distribution of pre-wetted salt should make this the recommended choice whenever pre-wetted spreading is available for precautionary salting. In the colder temperatures, near to -10°C, the pre-wetted salt will also help the dissolution of salt, again in particular for dry or damp roads.

It should be noted that the spread rates were developed for treatments on roads after trafficking had dispersed water. For treatments on very wet roads and when precipitation has occurred after spreading, repeat treatments are required and spreading dry salt in these circumstances has no advantages as it will not prevent the need for these repeat treatments. This requirement for repeat treatments is also likely to be the case for a very heavy hoar frost, where a lot of moisture is precipitated out of the atmosphere. There has been no feedback from Service Providers on why dry salting is preferred, and this area would warrant further investigation as there are implications for economy, environmental impacts and resilience.

3.4.2 Effectiveness of spread rates

Feedback was obtained from Service Providers on the treatment matrix guide, to identify any conditions (weather and traffic) when the rates were considered to be too low or too high. Further feedback was obtained on how specific road and weather conditions are taken into account in the decision making process.

From the questionnaire responses, the conditions identified where the rates were considered too low included:

- None (6 out of 15)
- Freezing soon after rainfall (4 out of 15)
- Heavy hoar frosts (6 out of 15)

Feedback from the questionnaire and meetings with Service Providers highlighted some other conditions that were of concern to Service Providers. These included

- Regarding the spread rates required on thin surfacing, there was feedback in the winter community meeting about the perceived need to treat a particular identified section of thin surfacing at 40g/m² every 2 hours. This particular section of open textured surfacing was wetter than other parts of the network and required increased level and frequency of treatment to maintain the residual salt levels. However, it was clear that this was a "special case" combining the open texture and apparently poor drainage, conditions which are considered in the guidance notes.
- Increased risk of incidents in low traffic conditions, especially on Sunday mornings. It was commented that there was a need for guidance on treatments in these conditions.
- Low rates reducing some of the factor of safety, for example when there are errors in the forecast.

These concerns are mainly related to conditions where the amount of moisture on the road surface at the time a treatment is carried out is significantly greater than that assumed in developing the rates, for example spreading immediately after rainfall or in low traffic where water has not been dispersed. It should be noted that these conditions have always been problematic and are not new issues arising from use of the reduced spread rates.

Due to the wide range and variability in conditions and local factors it is not practical to give definitive guidance, i.e. specifying exact spread rates and treatment timing for each problem condition. Treatment decisions will need to be based on broad guidance and advice to aid the experience and judgment of the decision maker.

Service Providers should be made aware that the spread rates in the treatment matrix guide are not applicable for spreading on very wet roads or for very heavy hoar frosts. Further guidance can then be included to help assess when roads are too wet, etc along with information on the specific problem (i.e. dilution of the brine so it is not effective, washing away, brine dispersed from road by traffic spray, etc.) and the types of action that can be considered. Regarding the statement that lower rates reduce the factor of safety, the spread rates in the Treatment Matrix do not account for significant errors in the forecast temperatures or road wetness. For each temperature band, the rates are calculated to provide protection to the minimum temperature in that band. The rates are based on assumptions regarding the spreader performance and, if spreaders are

calibrated and the performance monitored to ensure this spreading performance is achieved. Therefore, it is considered that the main risks are due to local factors e.g. wet areas from run off etc.

4 Capability of the winter fleet

4.1 General

The principal objective of this task was to determine whether spreading vehicles have been calibrated properly and can deliver the spread rates accurately.

Following calibration, spreader performance will change as a result of many factors. As well as physical changes to the spreaders through wear and tear or maintenance, there may be variations in the condition of the salt, which will impact on the amount spread and its distribution. Details of the amount of salt discharged during spreader turnouts were obtained for the new winter fleet, to make an assessment of the performance of spreaders in delivering the new spread rates.

The Agency tracks and monitors the winter fleet using Cybit's Fleetstar GPS vehicle tracking system. This system records each vehicle's position and a wide range of other information on the vehicle's operations. Information reported on spreading, relevant to this study, includes the times when vehicles are spreading, the rate and pattern of the spreading, the amounts of salt and brine spread, spread width, lane position and if vehicles are ploughing.

Details of the amount of salt discharged during spreading turnouts were obtained from the Fleetstar GPS tracking system with the aim to determine how the amount of salt being discharged compared with the target amount. Records were also obtained, for a sample of Service Providers, of measurements recorded manually by the Service Provider of the amount of salt discharged during spreading turnouts, to further assess spreader performance and for comparison with the data reported by Fleetstar.

4.2 Background

Romaquip and Schmidt, the suppliers of the new winter fleet spreaders, were required to carry out contractual performance trials to demonstrate that the amount of salt discharged and the salt distribution profile achieved by their spreaders satisfied a number of performance requirements. The trials were carried out with dry, pre-wetted and treated salt and the requirements are described in Appendix C.

Standard spreader settings which influence the salt distribution profile were identified for indigenous salt in the contractual performance trials and were established across the fleet. The same settings have been used for other salts of similar grading, although there may be some local variations. During the calibration of each spreader, the amount of salt discharged is adjusted for each de-icer to be spread.

In calculating the new spread rates, a number of assumptions were made as shown in Table 11. Although the minimum lane coverage required in the dynamic tests of the contractual performance trials was 70% of the target spread rate, in most of the dynamic tests the lane coverage was generally far more, with the amount of salt being spread at least 10% of the target. On this basis and allowing for some redistribution by

trafficking, it was assumed that the lowest lane coverage when spreading with the new winter fleet would be within 10% of the target spread rate.

The corollary to this is that higher spread rates are required if the actual salt distribution is less uniform than assumed or less salt is being discharged i.e. poor calibration/performance or poor salt condition.

Table 11 Assumptions made to determine precautionary spread rates

Parameter	Dry salting	Pre-wetted salting
Dry salt sodium chloride concentration allowing for impurities and moisture content (%)	90	90
Brine concentration (% sodium chloride)	-	23
Minimum lane coverage as percentage of target spread rate (%)	80	90
Brine percentage loss after spreading due to heavy trafficking (%)	-	15
Dry salt percentage loss after spreading due to heavy trafficking (%)	60	50
Brine percentage loss after spreading due to light trafficking (%)	-	10
Dry salt percentage loss after spreading due to light trafficking (%)	40	30
Water film thickness for a dry or damp road that is well trafficked	0.03mm	0.03mm
Water film thickness for a damp road with little traffic or a well trafficked road at least one hour after rainfall	0.05mm	0.05mm
Water film thickness for a wet road with little traffic	0.1mm	0.1mm

Based on previous work carried out by TRL, it has been shown that in one particular trial the total amount of salt and brine discharged varied from the target amount by as much as 20%. Details on this trial are provided in Appendix D. The tests were undertaken in one Area as part of the work to develop the new spread rates. Averaged over the four discharge tests, these results showed that approximately 18% more de-icer was discharged compared to that indicated on the salt and brine counters.

With this degree of variation, some spreaders set to spread 8g/m² would be spreading at nearly 10g/m² or conversely underspreading at about 6g/m². While it should be stressed this was one result, this highlights the importance of monitoring spreader performance and not relying solely on calibration to ensure good spreading performance.

4.3 Investigation of Fleetstar capability

4.3.1 Fleetstar report types

An initial investigation was carried out of the Fleetstar system to confirm what information can be obtained, and to what accuracy, regarding the amounts of salt and brine discharged in a spreading run.

The principal aim was to make a comparison between the amount of salt and brine discharged for each turnout when spreading each route and the 'target' amount that should have been spread on that route.

Standard reports can be generated by Fleetstar for a range of different aspects of the spreader operation. For the purposes of investigating the amount of salt and brine being spread, there were a number of reports that were available, as described below. It should be noted these include the word gritting meaning salting/anti-icing/de-icing treatments, grit is not used. Example reports generated from Fleetstar are included in Appendix D.

'HA Service Provider Summary Report'

This report details the amount of salt and brine discharged for each spreading turnout. The amounts reported are based on the settings on the spreader control head and hence provide a predicted amount rather than actual measurements of the amounts being spread i.e. the amount of salt that should have been discharged is calculated based on the length of time for which spreading is carried out. The amount of salt discharged is reported in tonnes to an accuracy of one decimal place. The amount of brine discharged is reported to the nearest litre.

'Highways Agency Gritting Summary Report'

Each vehicle in the winter fleet is fitted with an onboard weighing system. The salt hopper and brine tanks are mounted on load cells, and the system measures the combined weight of the salt hopper and brine tanks. The 'Highways Agency Gritting Summary Report' details the total amount of salt and brine discharged for each spreading run, calculated from the difference in onboard weight measurements taken on leaving and returning to the depot. The weights are recorded when the spreader passes a set reference point on entering and leaving the depot.

'Detailed Journey Report'

This report provides details of the location and speed of the spreading vehicle during spreading along a route.

'Detailed Gritting Report'

This report provides details on the current spreading status i.e. on/off, the spread rate and width currently in use and what type of spreading is being carried out i.e. pre-wet or dry. The information is recorded every minute during the spreaders' journey.

'Raw Extended Data Report'

During the spreader operation, the spreader control system continually transmits records containing information on the status of the vehicle and spreading operation. This report shows these records and the time at which they were generated. Based on this information, it is possible to obtain the counter readings and onboard weights throughout the spreader's journey.

4.3.2 Calculating the target amount of salt for each turnout

The trunk and motorway network for each Area is split into a number of Winter Service Routes. Details of the route layout are produced in the form of a route card, giving precise written details and a route plan showing the treated and non-treated run lengths. The route cards are included in the Severe Weather Plans produced by each Service Provider.

The spread width will typically vary a number of times during a route, and there will be sections where no treatment is carried out. While there is typically an indicative target amount of salt stated for each route (specified for a particular spread rate), for each turnout there will be some small variation in the amount of salt spread due to differences in the total length spread, resulting from variations in where the spreader is started and stopped throughout the route. Spot treatments are also commonly carried out during a route, which will increase the amount of salt and brine spread from the indicative target amount.

In order to carry out an accurate assessment of how a spreader has performed, it was necessary to determine an accurate target amount based on the lengths actually spread for each turnout. Initially, consideration was given to the use of the 'Detailed Journey Report' and 'Detailed Gritting Report'. From the 'Detailed Gritting Report' it was possible to identify at what times spreading was turned on and when any changes occurred in the rate or width of spread. The distance at which these changes occurred could then be calculated from the 'Detailed Journey Reports', by noting the distance travelled at each time when a change occurred. In principal, the distance spread at each rate and width, and hence a target amount, could then be calculated for each turnout. Calculating the target amounts was a time consuming manual process and was not a feasible, cost effective method for analysing large amounts of data. There were also issues with the accuracy of the spread lengths calculated due to the frequency at which the spreader status was updated on the reports. For example, the 'Detailed Gritting Reports' updated the spreader status every minute, while the 'Detailed Journey Reports' could have longer periods between updates.

During the investigation of the Fleetstar capability, it was clarified that the amounts of salt and brine reported on the 'Service Provider Summary Report' were based on the counter readings from the spreader control head i.e. a predicted amount of salt and brine discharged based on the spreader settings and length of time over which spreading was carried out. The weights recorded on the 'Gritting Summary Report' were taken from weights recorded on the onboard weighing system, recorded as the spreader passed a reference point on leaving and returning to the depot.

On this basis, the predicted amounts recorded on the 'Service Provider Summary Report' were used as the target amounts of salt and brine for each turnout, for comparison with the amount of de-icer discharged as measured from the onboard weighing system. This target amount would consequently be based on what should have been spread for that particular turnout, taking account of any variations from the route card.

4.3.3 Measuring amounts of de-icer discharged for each turnout

The investigation of the Fleetstar reports clarified that the weights recorded on the 'Gritting Summary Report' were taken from weights recorded on the onboard weighing system, automatically recorded as the spreader passed a reference point on leaving and

returning to the depot. Therefore, these records give the total weight of salt and brine discharged, for comparison with the target amounts.

4.3.4 Assessing accuracy of the data - Comparison of Fleetstar data with manual records

The onboard weights are measured with the spreader in motion and it is expected that this motion will cause some variation in the weights recorded due to the effect on the weight applied at any given moment to the load cells that measure the onboard weight. This variation will depend on a number of factors, including the speed of the vehicle, the effects of suspension damping, the smoothness of the road surface and if the vehicle is braking or cornering when the weight is measured.

The accuracy of the analysis method is also based on the assumption that the weights recorded by the spreader onboard weighing system are correct i.e. calibrated.

To investigate the degree of variation that might be expected in the results, records were obtained of measurements recorded manually by a Service Provider (Area D) of the amount of salt discharged during spreading turnouts, for comparison with the data reported by Fleetstar. The manual records allowed a comparison with the Fleetstar data to be made between the onboard weights taken from the moving spreaders, as reported on Fleetstar, and measurements made by the Service Provider for the same turnouts using the onboard weighing system but with the spreader stationary.

Records were also obtained of counter readings recorded for spreader turnouts by a Service Provider (Area C). These counter readings are based on the predicted amounts of salt and brine discharged, calculated based on the spreader settings and length of time for which spreading is carried out. The counter readings are based on the same data used to report the amount of salt and brine discharged in the 'Service Provider Summary Report'. A comparison was made between the counter readings and the readings as reported in the 'Service Provider Summary Report' for a sample of spreaders.

Variability was observed in the ratio between the onboard weights measured manually and recorded on Fleetstar, with a standard deviation in this ratio of 15% to 20% of the mean. As discussed, it is expected that this variation is principally a result of spreaders being in motion when the weights are recorded.

The comparison between the counter readings recorded by the Service Provider and the counter readings as reported on Fleetstar showed that on average 7% more de-icer was measured, as recorded by the Service Provider as compared to Fleetstar. Again, there was variation in the results, with a standard deviation in the ratio of 25% of the mean. This degree of variation was unexpected, as the data recorded by the Service Provider should be the same counter readings as reported by Fleetstar. The reasons behind this discrepancy are not currently clear and would require further investigation outside the scope of this work.

Based on the data obtained, there is clearly uncertainty in both the onboard weight and the counter readings recorded by Fleetstar. This results in an uncertainty in the comparison between the measured amount of salt discharged and the target amount of at least $\pm 20\%$. This would indicate that the spreader performance cannot therefore be assessed, using the information as currently collected, to the required level of accuracy to monitor the performance of spreaders over individual turnouts.

4.4 Comparison of measured and target amounts from Fleetstar

As discussed in Section 4.3.4, the spreader performance cannot currently be assessed, using just the Fleetstar data, to the required level of accuracy to monitor the performance over individual turnouts.

Analysis was carried out for selected Areas, to investigate the average performance of the spreaders within each Area.

Three Areas were selected, to allow analysis of data for both Schmidt and Romaquip spreaders and to include those Areas for which manual records were also available.

- Area C (Schmidt spreaders)
- Area D (Schmidt spreaders)
- Area G (Romaquip spreaders)

Area D Fleetstar reports were obtained for spreading in January and February 2012. Area C and Area G Fleetstar reports were subsequently obtained for spreading during February 2012. As discussed in Section 3.2, these periods covered the full range of spreading conditions.

For each Area, the onboard measurements of the total amount of salt and brine discharged for each turnout, taken from the 'Gritting Summary Report', were compared to the target amounts (combining the salt and brine amounts reported) taken from the 'Service Provider Summary Report'. A spread rate was also assigned for each turnout, based on information taken from WRF1. Comparison of a sample of records from the 'Detailed Gritting Report' with the same spreader turnouts reported on WRF1 indicated that the spread rate reported on WRF1 agreed with the rate set on the spreaders.

Only those records for turnouts using pre-wetted salt were included in the analysis. There were a number of dry spreading runs carried out in each Area where no brine was reported spread and these records were omitted from the analysis.

For each pre-wetted turnout, the ratio of the amounts of salt and brine discharged was calculated from the amounts reported on the Service Provider Summary Report. For spreading pre-wetted salt, the ratio should be 70:30 dry salt:brine by weight. Instances were noted where less brine was spread than if spreading at the 70:30 ratio. From further investigation of some of these instances, it was typically where a very short spread length had occurred i.e. a spreader carrying out spot treatments, and these records were omitted from the analysis.

It was found that the reports sometimes omitted data from the required data fields, and hence the ratio could not be calculated for that spreading run. Other occasional anomalies were encountered, and the records omitted where this was clearly an issue with the data logging rather than the spreader performance. For example the onboard weight was sometimes reported as greater before spreading as compared to after spreading, resulting in a negative ratio.

In summary, the ratio between the measured and target amounts of de-icer discharged were calculated for each precautionary, pre-wetted spreading run carried out in the analysis periods. Results were omitted where there were issues with the data recorded and it was clear that this was a result of the data logging and reporting rather than the spreader performance.

For each Area and analysis period, the average ratio between the measured and target amounts of de-icer discharged was calculated, shown in Table 12. The distribution in the ratio was analysed by calculating the standard deviation.

A breakdown of the average ratio for each spreader, calculated for each spread rate and also in total over all turnouts analysed, is included in Tables E1 to E4 in Appendix E.

Figure 30 to Figure 33 show the distribution in the ratio between the onboard weight measurement and target amount of de-icer discharged for all turnouts analysed. The standard deviation of the distribution was calculated and is included in Table 12.

Table 12. Average, Median and Standard deviation of the ratio distribution between the onboard measurement and target amounts of de-icer discharged

Area	Month	Average ratio	Standard deviation of distribution
C	February	0.89	0.20
D	January	1.08	0.20
D	February	1.09	0.20
G	February	0.75	0.30

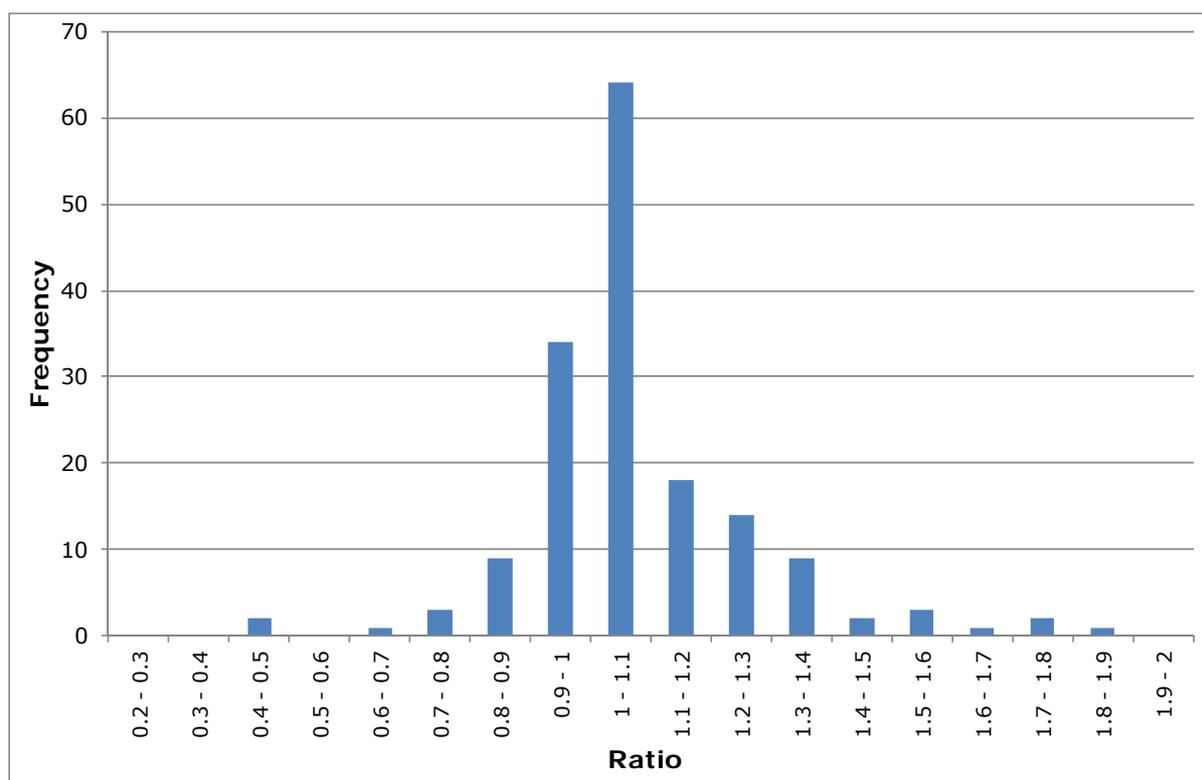


Figure 30. Frequency distribution of the ratio of onboard weight to target amount, for Area D in January 2012

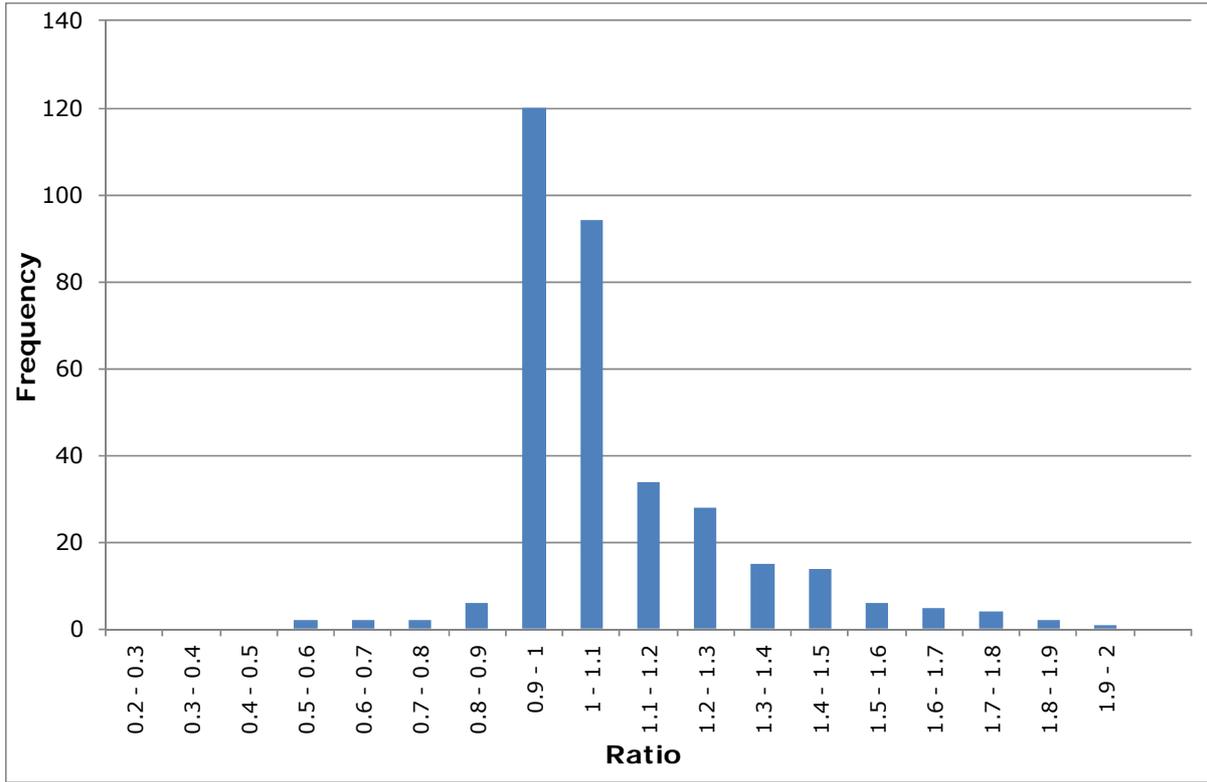


Figure 31. Frequency distribution of the ratio of onboard weight to target amount, for Area D in February 2012

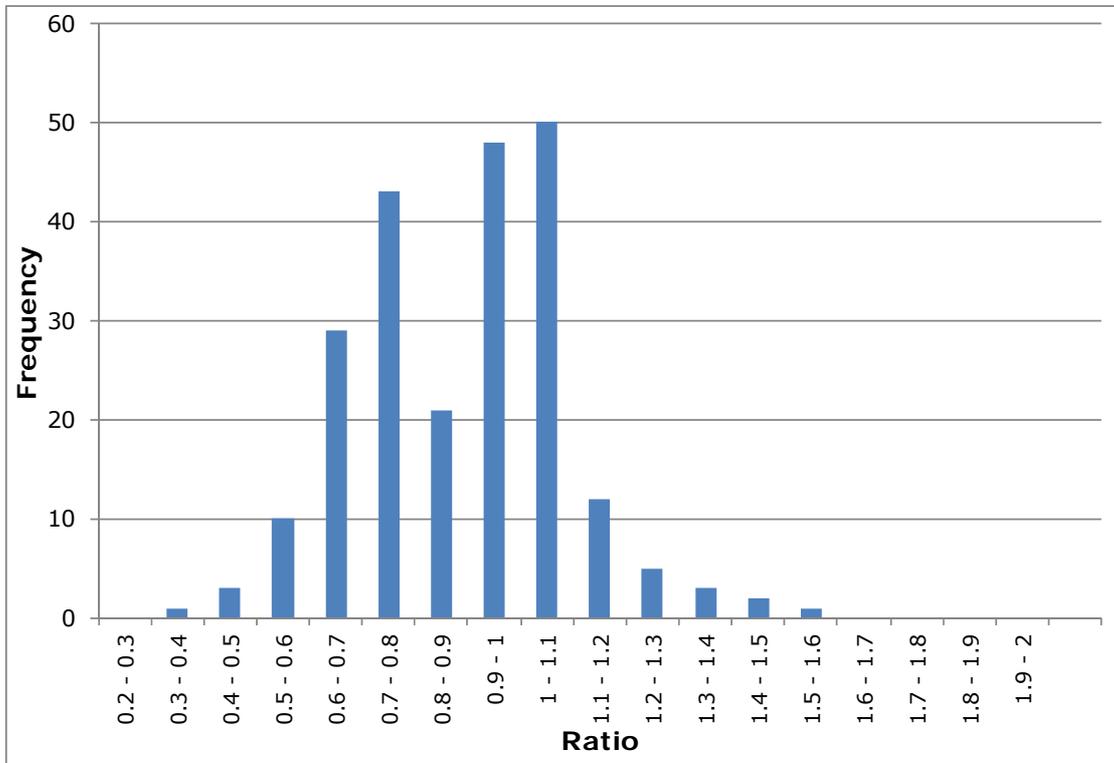


Figure 32. Frequency distribution of the ratio of onboard weight to target amount, for Area C in February 2012

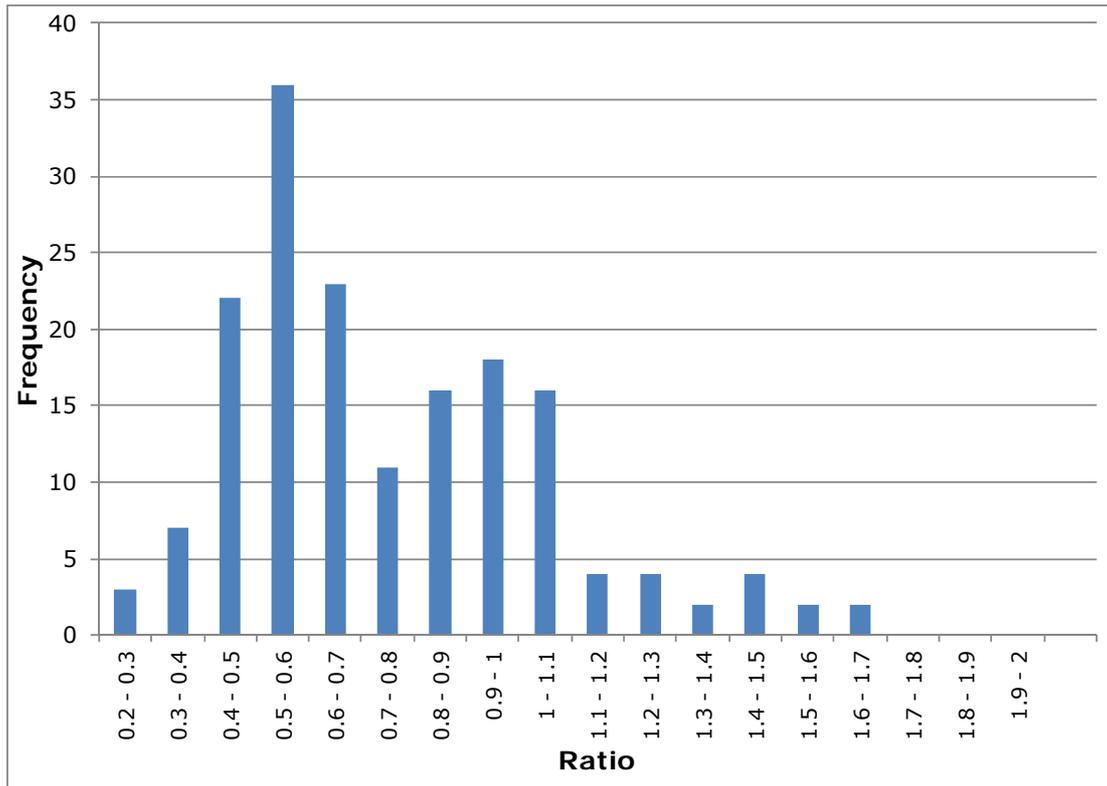


Figure 33. Frequency distribution of the ratio of onboard weight to target amount, for Area G in February 2012

Based on the data reported on Fleetstar, the average amount of salt discharged over all turnouts in Areas C, D and G showed variation from the target amount of between 8 and 25%. The variation of the mean from the target amount is greater than would be expected, if assuming the correct amount of de-icer is spread with a measurement uncertainty of $\pm 20\%$. This may indicate that there is variation in the spreader performance or that there is greater uncertainty in each measurement than assumed.

Analysis of the distribution in the amounts discharged over individual turnouts, as displayed in Figure 30 to Figure 33, showed there was also a significant spread in the results obtained, in particular for Areas C and G. Variation in the ratio was expected, even for spreaders performing correctly, as a result of the issues regarding measurement accuracy discussed in Section 4.3.4. However, the range in the ratio was larger than expected, in particular for Area G where a significant number of outturns showed less than half the target amount of de-icer discharged. Further investigation would be needed to ascertain the reasons behind the large variations seen in Area C and G. It was not considered feasible that the amounts of salt discharged could vary by as much as was measured in these Areas in this analysis, and the variation appears greater than can be attributed to uncertainties in the onboard weights and counter readings.

4.5 Discussion

A method was identified by which, using data reported on Fleetstar, the measured amount of salt and brine discharged could be compared with the target amount i.e. the amount that should be discharged if spreading at the correct spread rate.

In the spreader performance trials for the new winter fleet, the amount of de-icer discharged was required to be within $\pm 6\%$ of the target amount. It is therefore important to be able to assess the amount of salt discharged to an accuracy greater than 6%, to have confidence that individual spreaders are performing within acceptable limits. The NWSRG Practical Guidance section 'Spreader Calibration' states that, for accuracy in salt discharge tests, sufficient salt should be discharged such that the resolution does not result in a measurement error greater than 3%.

If robust conclusions are to be drawn from the data reported from Fleetstar it is important to have confidence in the accuracy of results obtained from the onboard weighing system and counter readings. Comparing measurements and records obtained manually by Service Providers and reported by Fleetstar has allowed an indication of the reliability of the Fleetstar analysis method to be obtained.

As reported in Section 4.4, variability was observed in the ratio between the onboard weights and counter readings recorded manually by the Service Provider and recorded on Fleetstar, which indicated an uncertainty in the comparison between the measured amount of salt discharged and the target amount of at least $\pm 20\%$. The spreader performance cannot therefore be assessed, using the information as currently collected, to the required level of accuracy to monitor the performance of spreaders over individual turnouts.

The variation of the mean from the target amount, measured for the selected Areas, was also greater than would be expected if assuming the correct amount of de-icer is spread with a measurement uncertainty of $\pm 20\%$. As discussed, this may indicate that there is variation in the spreader performance or that there is greater uncertainty in each measurement than assumed.

In summary, the investigation of the information reported from Fleetstar has indicated there may be variation in the spreader performance however it cannot be assessed if the variation is within acceptable limits using the accuracy of the data available at present. Using the data as reported is also a time consuming process and is not a practical method to implement.

A method for measuring spreader performance to a greater accuracy is required before any firm conclusions can be made. For the purposes of monitoring spreader performance on a day to day basis, it is important to have a method that can accurately monitor the spreader performance over individual turnouts, to quickly identify any issues with spreading performance. As an example, if tunnelling had occurred in the spreader hopper resulting in significant under spreading on a route, this should be immediately highlighted by the monitoring procedure.

4.6 Recommendations for use of Fleetstar data

National guidance documents, including the NWSRG Practical Guidance, give recommendations that spreader performance should be routinely monitored and recorded during the winter season. This monitoring should quickly highlight any problems so that re-calibration of spreaders can be carried out where necessary.

The analysis of the information reported from Fleetstar has highlighted that the spreader performance cannot be assessed, using the information as currently collected, to the required level of accuracy. Using the data as reported is also a time consuming process and is not a practical method to implement at present.

Using the Fleetstar data logging system to make an accurate assessment of the amounts of de-icer discharged, as investigated in this study, was not part of the specification for the data logging system. At the time of reporting, in June 2012, an assessment of the current data logging system is taking place as part of the Highways Agency winter review and this will help support future decisions after the current contract finishes in June 2013. It is considered that use of the data logging system would offer the most cost effective method of monitoring the spreader performance and recommendations can be made how this could be achieved, for consideration in the review of the data logging system

The onboard measurement and the target amounts of salt and brine discharged are both parameters that are currently reported in Fleetstar. A comparison of these values, e.g. the onboard weight measurement as a percentage of the target amount, could be incorporated into one of the standard report types.

To provide an accurate comparison, the onboard weight and counter readings should be recorded when the spreader is stationary and on a level area of ground. A recommendation, also suggested by the Area D Service Provider, was to have a button for the driver to press when the vehicle is stationary, in a designated 'parking zone' within the depot, prior to and after their run. The button would trigger the recording of the onboard weights and counter reading, for inclusion in the standard report.

Ideally, it is recommended that the onboard weighing system is calibrated for each spreader or that cross checks are made, for example with a calibrated weighbridge.

5 Effectiveness of Spread Rate Matrix for different salt types

5.1 General

The principal objective of this sub-task was to determine whether the spread rates in the Treatment Matrix guide are appropriate for the different types of salt used by the Agency, including indigenous, imported and strategic salt. In particular, the potential effect on the salt distribution when using different salt types was considered.

Feedback was obtained from Service Providers on the types of salt currently in use and the effect of changing salt type on the spreader performance.

Prior to this report, TRL has carried out salting trials on Romaquip and Schmidt spreaders from the new winter fleet with a number of different types of salt for the dry salt component of pre-wet spreading. The results from these trials have been collated in this report and the possible effect on the salt distribution profile relative to that obtained with indigenous salt has been assessed.

5.2 Type of salt used and feedback from Service Providers

The questionnaire issued to Service Providers sought information on the salt types currently in use. Figure 34 summarises the responses to the question: What types of salt do you use at your depots (excluding salt solely for brine production)?

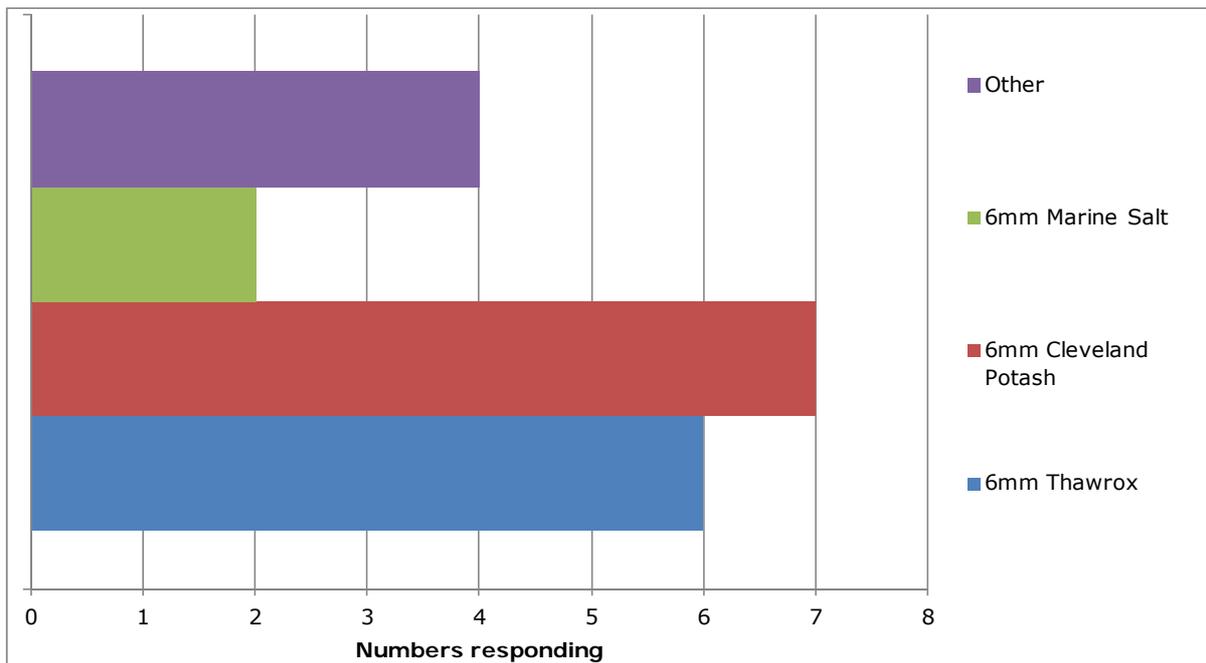


Figure 34 What types of salt do you use at your depots (excluding salt solely used for brine production)?

The other salt types in Figure 39 include 6mm rock salt from Irish Salt Sales, 10mm Thawrox, 6mm Thawrox Plus, 10mm EcoThaw treated rock salt (Cleveland Potash) and 10mm rock salt (Cleveland Potash)

Feedback included:

- All Areas responded that it had not been necessary to adjust the amount of salt discharged when changing from one salt type to another i.e. used the same settings for different salt types
- Some Areas noted that check calibrations had been made when different types of salt arrived in the Area. These Areas had indicated that no adjustment was required to spreader settings when changing salt type

Records were not available of when and where particular salt type has been spread on the network.

5.3 Factors that can effect spreader performance

The factors that affect the amount of salt discharged and the uniformity of the salt distribution profile, related to the type of salt used, are:

- The density of the dry salt component
- The moisture content of the dry salt component
- The grading of the dry salt component

The moisture content of the salt can influence the amount of the dry salt component that is discharged. However, the salt spread on the Agency's network is mostly stored under cover and does not vary greatly from day to day. For salt in good condition any slight change in moisture content is likely to have little effect on the uniformity of the salt distribution profile compared to the effects of the pre-wetting process.

6.3mm Thawrox rock salt is normally supplied with the grading corresponding to the mean of the upper and lower limits of the grading envelope (see Section 5.4). The grading can then become slightly coarser if the moisture content increases and/or become slightly finer each time it is handled.

Marine salts often have a different grading to rock salts of the same maximum particle size because they are de-dusted to remove the finer particles (see Section 5.4).

5.4 Comparison of results from trials with indigenous and other salt types

This section compares the salt distribution profiles obtained in the contractual performance trials carried out by Schmidt, which used indigenous rock salt, with trials that have been carried out by TRL with other imported salts.

It was evident in the TRL trials that the total amount of salt collected sometimes differed from the target amount by more than $\pm 10\%$. It was concluded that this was because the settings for the amount of salt discharged had not been adjusted for the de-icer being spread.

In order to simplify comparison of the salt distribution profiles, the profiles shown below were scaled such that the total amount of salt collected was made equal to the target amount.

Table 13 gives details of the type of salt and spreader (Schmidt 4x4 or Schmidt 6x4) used in each trial, whether Schmidt or TRL conducted the trial, the target spread rate,

the total amount of salt collected relative to the target amount, and the salt coverage in Lanes 1 to 3.

The wind speed ranged from 2.6 to 2.9m/s in the Schmidt trials, although its direction was not reported by Schmidt. There was no wind in the other trials.

Table 13 Lane coverage in salting trials

Trial type (Spreader type)	Salt type	Spread rate (g/m ²)	Amount collected (% of target)	Coverage (% of target)			
				Lane 1	Lane 2	Lane 3	Lanes 1 to 3
Schmidt pre-wetted (4x4)	6.3mm Thawrox	10	100.3	82.1	99.4	100.5	94.0
TRL pre-wetted (4x4)	6.3mm Thawrox	10	135.3	109.1	106.8	70.9	95.6
Schmidt dry (6x4)	6.3mm Thawrox	20	101.7	87.6	90.6	114.2	97.5
TRL dry (6x4)	6/8mm marine	20	117.2	94.4	113.4	87.5	98.4
TRL pre-wetted (4x4)	6mm New Orleans rock	8	127.6	93.8	110.0	86.0	93.0
TRL pre-wetted (4x4)	6mm New Orleans rock	15	123.7	104.0	96.7	46.1	82.3
TRL pre-wetted (4x4)	6mm Egyptian marine	15	96.6	108.3	110.5	60.2	96.6
Schmidt pre-wetted (4x4)	6.3mm Thawrox	20	99.9	89.9	92.3	95.2	92.5

Figure 35 shows normalised salt distribution profiles obtained in the Schmidt and TRL trials when pre-wetted salting with 6.3mm Thawrox at 10g/m². Each profile is the mean of two runs. In the performance trials, the total amount of salt collected was only 0.3% above the target amount. However, in the TRL imported salt trials (TRL trials), the amount collected was 35.3% above the target.

Figure 36 shows the grading of the 6.3mm Thawrox that was used for the dry salt component of the pre-wetted salt in the performance and TRL trials. Although different sieve sizes were used for the gradings, it can be seen that the salt used in the performance trials was slightly finer than the salt used in the TRL trials. Furthermore, the grading of the salt used for the TRL trials was coarser than the mean grading of the 6.3mm Thawrox that has been used for other TRL trials with 6.3 Thawrox and labelled 'Typical' in Figure 36. The salt distribution for the coarser salt was offset slightly to the left and the (normalised) coverage in Lane 3 was 70.9% of the target (Table 13). The lowest normalised lane coverage in the Schmidt trials was 82.1% in Lane 1.

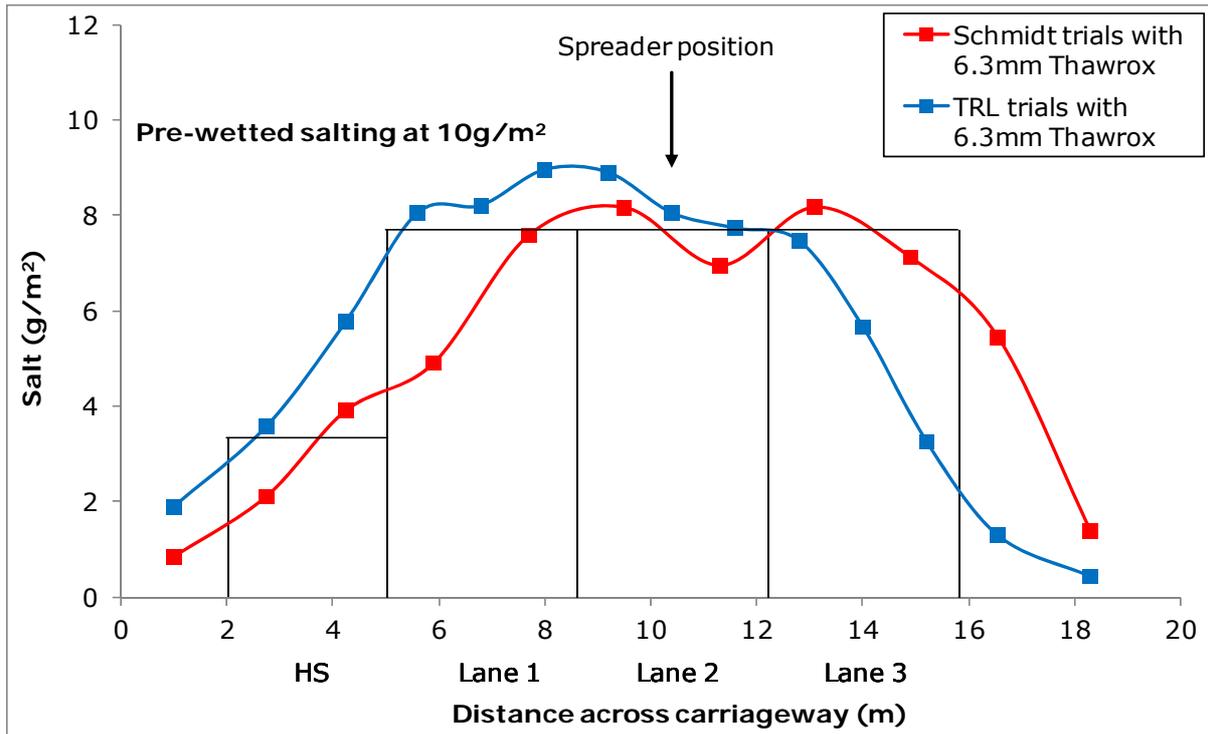


Figure 35. Normalised salt distribution profiles obtained in the Schmidt and TRL trials when pre-wetting salting with 6.3mm Thawrox at 10g/m²

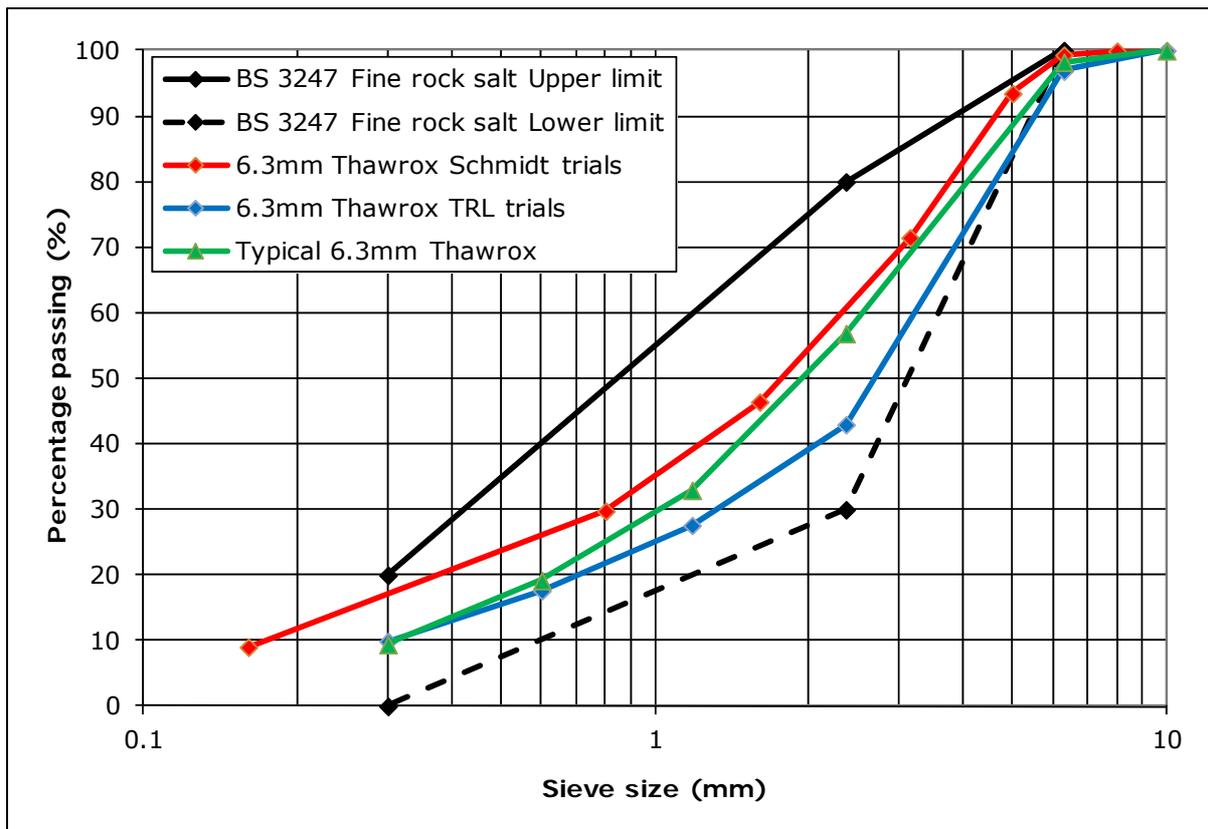


Figure 36. Grading of 6.3mm Thawrox used in Schmidt and TRL trials when pre-wetting salting at 10g/m² (see Figure 35)

Figure 37 shows normalised salt distribution profiles obtained in Schmidt trials when dry salting with 6.3mm Thawrox and TRL trials when dry salting with 6/8mm marine salt. In both trials, the target spread rate was 20g/m². In the performance trials, the total amount of salt collected was 1.7% above the target amount. In the TRL trial, the amount collected was 17.2% above the target.

Figure 38 shows the grading of the two salts used in the trials, as well as the typical grading for 6.3mm Thawrox. The marine salt had few fine particles and was therefore much coarser than the 6.3mm Thawrox. The salt distribution of the 6.3mm Thawrox was offset slightly to the right, although the lowest lane coverage was 87.6% in Lane 1. The salt distribution of the coarser marine salt was offset slightly to the left of the distribution for the 6.3mm Thawrox. The lowest lane coverage was 87.5% in Lane 3. It was concluded from these trials that a satisfactory salt distribution profile could be obtained when 6/8mm marine salt is spread using the settings for 6.3mm Thawrox.

Figure 39 and Figure 40 show normalised salt distribution profiles obtained in TRL trials with 6mm New Orleans rock salt and 6mm Egyptian marine salt. Figure 39 shows that a satisfactory salt distribution was achieved with 6mm New Orleans rock salt when the target spread rate was 8g/m²; the minimum normalised lane coverage was 86% in Lane 3. However, the distribution was offset to the left when the target spread rate was 15g/m²; the normalised lane coverage was 46.1% in Lane 3 (Figure 40). The total amount of salt collected was 23.7 and 27.6% above the target amount when the spread rate was 8 and 15g/m², respectively.

The distribution was also offset to the left when 6mm Egyptian marine salt was spread at 15g/m². The minimum normalised lane coverage was 60.2% in Lane 3. The total amount of salt collected was 3.6% below the target amount.

Figure 41 shows the grading of the 6mm New Orleans rock salt and the 6mm Egyptian marine salt. The grading of the 6mm New Orleans rock salt was coarser than that of the typical 6.3mm Thawrox. It was similar to that used in the TRL trials when pre-wetted salting at 10g/m² with 6.3mm Thawrox (Figure 36).

The grading of the 6mm Egyptian marine salt was similar to that of the 6/8mm marine salt tested by TRL (cf. Figure 36 and Figure 41). However, the tendency for the salt distribution to be offset to the left was greater for the former.

Figure 42 shows normalised salt distribution profiles obtained in Schmidt trials with 6.3mm Thawrox at target spread rates of 10 and 20g/m². The distribution was offset slightly to the right when the target spread rate was 10g/m², but the minimum normalised lane coverage was 89.9% in Lane 1 (Table 13). The total amount of salt collected was almost identical to the target amount at both spread rates.

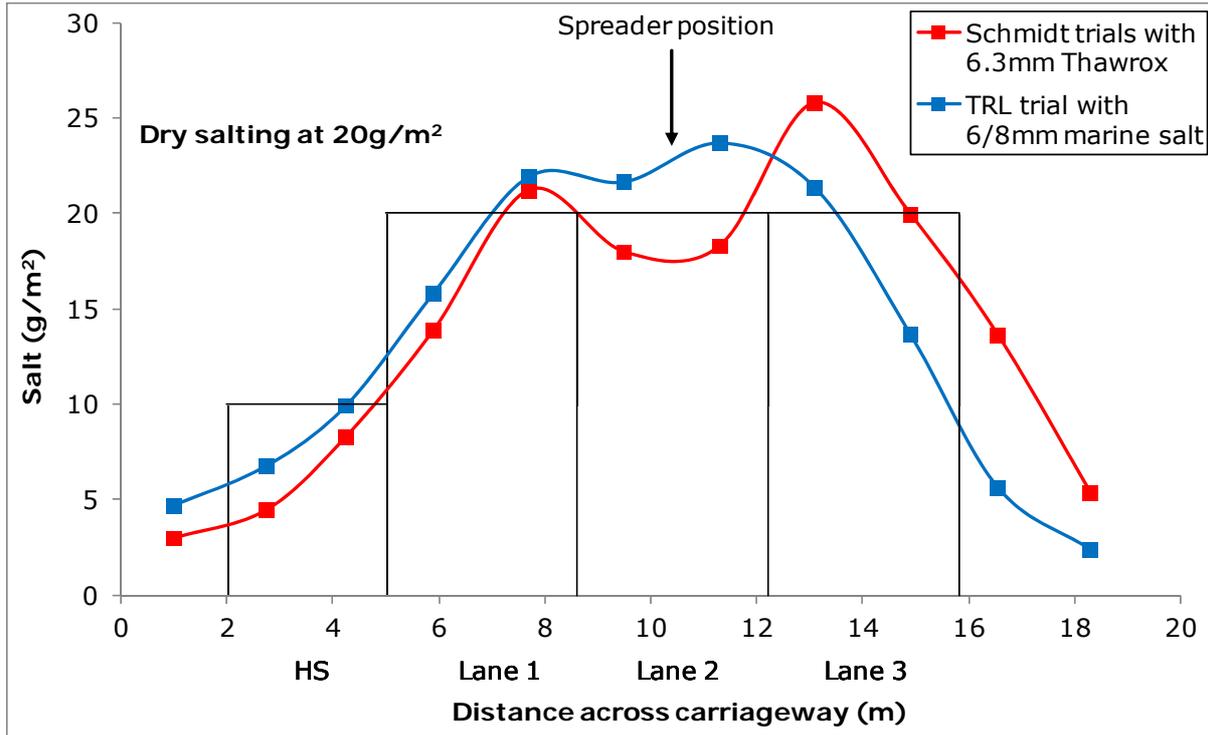


Figure 37. Normalised salt distribution profiles obtained in the Schmidt and TRL trials when dry salting with 6.3mm Thawrox at 20g/m²

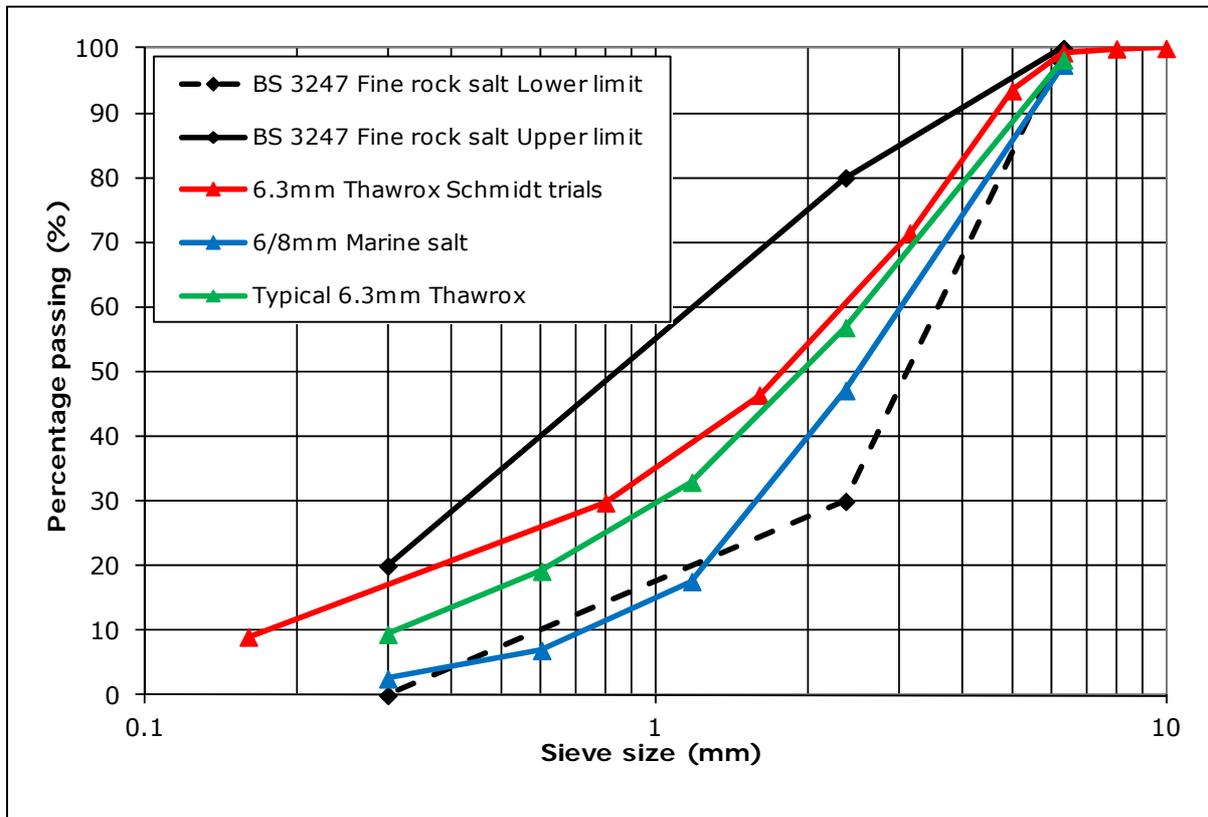


Figure 38. Grading of salts giving salt distribution profiles in Figure 37

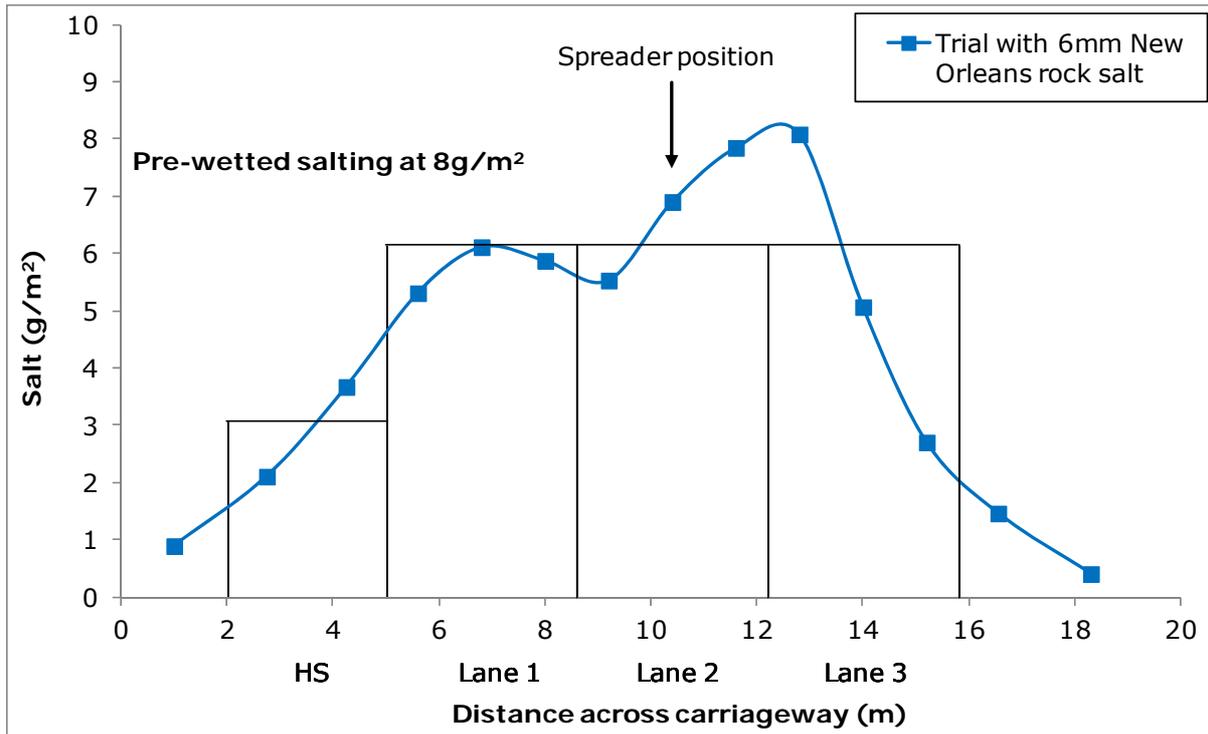


Figure 39. Normalised salt distribution profiles obtained in TRL trials when pre-wetting salting with 6mm New Orleans rock salt at 8g/m²

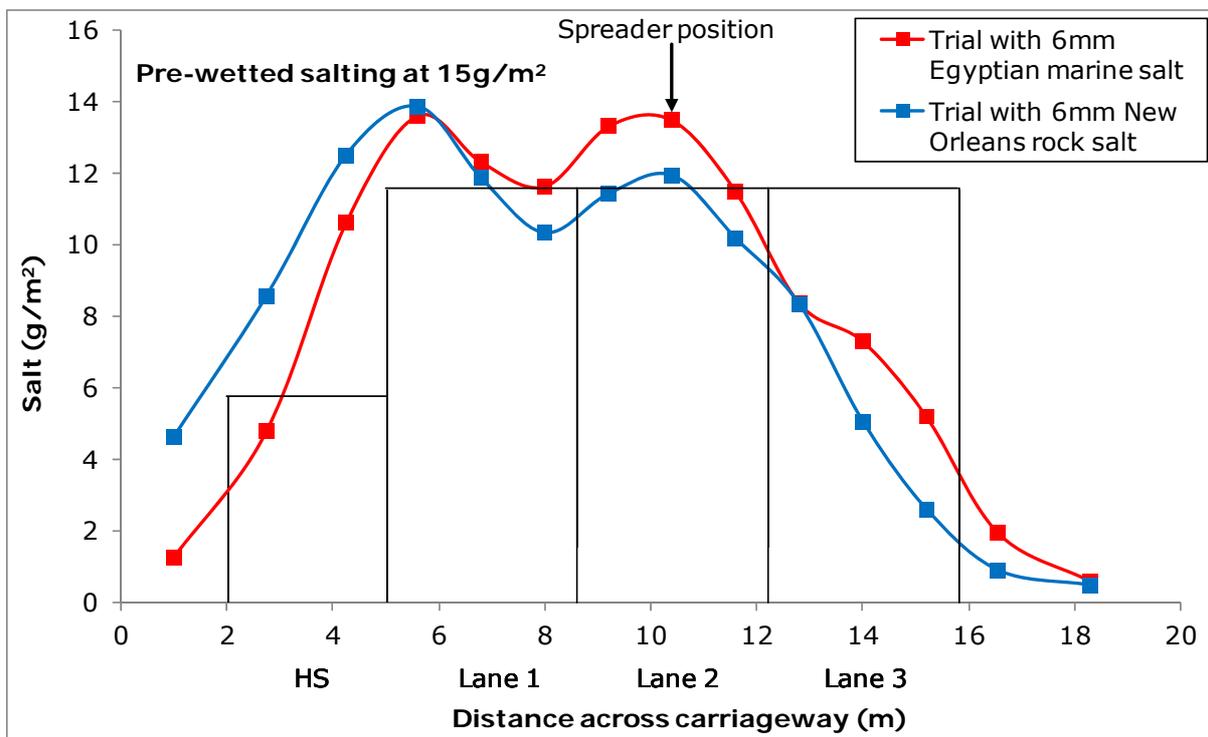


Figure 40. Normalised salt distribution profiles obtained in TRL trials when pre-wetting salting with 6mm Egyptian marine salt and New Orleans rock salt at 15g/m²

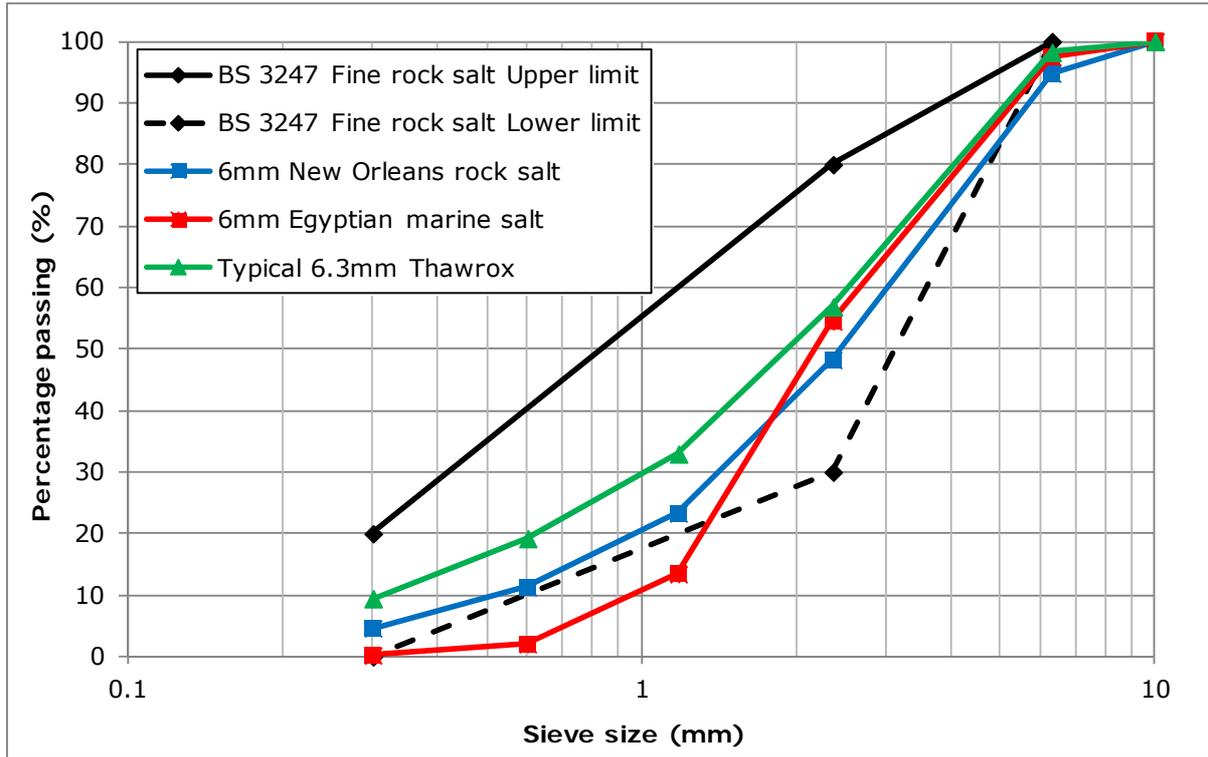


Figure 41. Grading of salts giving salt distribution profiles in Figure 39 and Figure 40

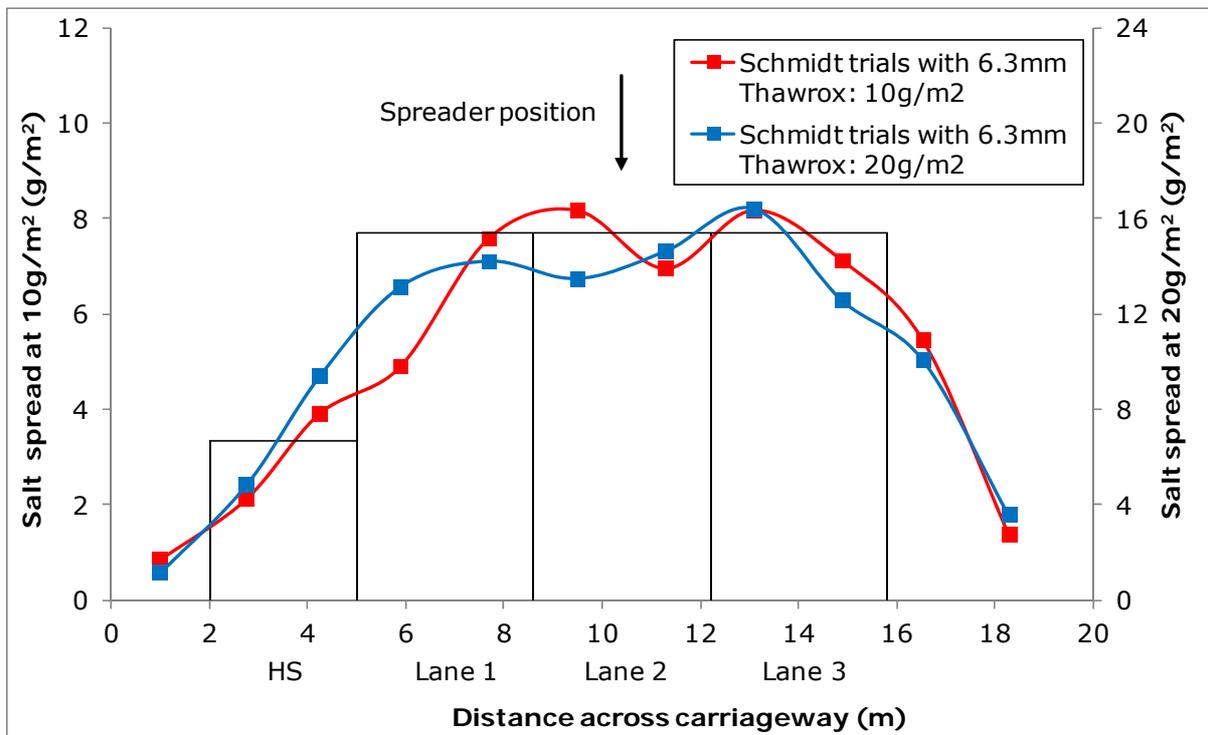


Figure 42. Normalised salt distribution profiles obtained in the Schmidt trials when pre-wetting salting with 6.3mm Thawrox at 10 and 20g/m²

5.5 Discussion

Service Providers are clearly using salt types other than the indigenous 6mm rock salt. Evidence when particular salt types have been used on the network is not available and there is insufficient evidence to make firm conclusions on whether spreading the alternative de-icer types is fully effective. Service Providers have indicated that no changes to spreader settings are needed when spreading different salt types, with some Areas carrying out calibration checks.

Using the settings for 6.3mm Thawrox, the amount of salt collected was more than 10% greater than the target amount in four of the five trials conducted by TRL. This confirms the fact that the amount of salt discharged should be checked/adjusted for each type of salt that is spread.

Although there are insufficient results to draw firm conclusions, it is possible to comment on the trends in the salt distribution profiles.

Figure 35 shows that even with the same de-icer (6.3mm Thawrox), the distribution tends to be offset to the left the coarser the salt. However, in the TRL trials, the lane coverage would have been within the contractual trial performance requirement if the target amount of salt had been collected.

An acceptable salt distribution was obtained when dry salting with 6/8mm marine salt, even though the distribution was offset slightly to the left compared to 6.3mm Thawrox (Figure 37). If anything, the distribution of the 6.3mm Thawrox was offset slightly to the right and that of the 6/8mm marine salt slightly to the left, thereby minimising the effect of the offset.

Poor distributions were obtained with 6mm New Orleans rock salt and 6mm Egyptian rock salt. Both these salts were coarser than typical 6.3mm Thawrox and the profiles were offset to the left such that the coverage in Lane 3 was low when the spread rate was 15g/m² (Figure 39). However, the distribution was reasonably uniform in Lanes 1 to 3 when 6mm New Orleans rock salt was spread at 8g/m² (Figure 40).

The effect of the spread rate on the salt distribution was investigated by comparing the distribution obtained by Schmidt when pre-wetted salting at 10 and 20g/m² (Figure 42). The distribution was uniform at both spread rates, although the distribution was at 20g/m² was offset slightly to the left of the distribution at 10g/m². The size of the offset was much less than that for 6mm New Orleans rock salt.

It should be noted that the above refers to spreading when the spread width is 13m. TRL is not aware of any measurements of the salt distribution profile when the new winter fleet is set up to spread two lanes, and most of the Agency's network requires only two-lane spreading. Romaquip and Schmidt identified appropriate settings which were again adopted across the fleet for two-lane spreading. TRL considers that the effect of the factors listed above is likely to be less for two lane spreading than for three lane spreading so it is appropriate to concentrate on the latter.

In summary, the comparison of the results from trials carried out with the different salt types shows that the amount of salt discharged and the salt distribution profile can vary significantly with the salt type and the grading. The results have highlighted the importance of spreaders being calibrated for the particular type of salt being spread, to provide confidence that the required amounts of salt are actually being spread within the lanes.

To provide confidence that the spread rates in the treatment matrix guide are appropriate for the different salt types, it is recommended that

1. Service Providers calibrate each spreader for the salt type being spread.
2. Periodic visual checks are made of the salt distribution when using non indigenous salt types to confirm sufficient coverage of the full spread width required.

6 Investigation of winter incidents

6.1 Introduction

The aim of this task was to assess whether there was any effect on incidents following the change to the new spread rates. Data on incidents on the Agency's network were analysed with the aim to identify any trends or characteristics of winter incidents before pre-wetted salting was introduced and with pre-wetted salting with the current spread rates which were introduced in January 2010.

The first part of this task, reported in Section 6.3 was an overview of the winter incidents on the strategic road network covering the period from the use of dry salting with the old winter fleet through to the use of the current reduced rates with pre-wetted salt. This overview compared the total number of incidents per quarter before and after the introduction of the new pre-wetted spread rates, in comparison to the general trend of decreasing incidents over this period.

In the second part of the task, reported in Section 6.4, WRF1 was used to collate information on the precautionary treatments used on each day on each road in each Area. Information from the WRF1 database was then combined with the Stats19 collision data to enable analysis of trends and characteristics of collisions on routes with different precautionary treatments. i.e. comparison between dry and pre-wetted precautionary treatments.

6.2 Data sources for road incidents

6.2.1 *STATS19*

The STATS19 database of reported collisions involving personal injury on the Agency's network was used to investigate trends and characteristics of winter collisions. STATS19 data was used as this provides a comprehensive and reliable source of information across the whole of the country. However, it must be noted that the data only includes collisions involving injury that become known to the police and is therefore an incomplete record of all road incidents and casualties.

The Stats19 database contains information on injury collisions that are reported to and by the police. The database includes the following:

- Circumstances
 - For example, date, time, road, weather, road surface condition
- Vehicle details
 - For example, vehicle type, vehicle manoeuvre, skidding
- Casualty details
 - For example, casualty severity,
- Contributory factors
 - Up to six factors (out of 77 options) per collision which, in the opinion of the reporting police officer contributed to the collision

Further details of STATS19 data can be found in Stats20 guidelines for completion of Stats19 (DfT, 2004).

Validated STATS19 data were available for 2006 to 2010; provisional STATS19 data was available for use on this project up to September for 2011

6.2.2 Other data sources

Sources of data that were considered for use in this analysis included hospital, survey and compensation claims databases and Highways Agency Traffic Officer records. Hospital and claims data is difficult to obtain, fragmented in nature and not readily verifiable in terms of cause. Traffic Officer records are limited to those incidents reported to or observed by Traffic Officers and the data only contains a small number of fields providing additional information limiting its usefulness in this analysis. The cost of collecting, auditing and analysing these sources of data was considered to outweigh any benefits, particularly as the data would be inherently unreliable.

6.3 Overview of winter collisions

6.3.1 Overall trend

The STATS19 data for the strategic road network were examined to identify trends and characteristics of winter collisions for periods before pre-wetted salting was introduced (i.e. when there was dry salting with the old fleet of Foden spreaders) and with pre-wetted salting with the current spread rates which were introduced in January 2010.

Figure 43 shows the number of collisions by quarter and year.

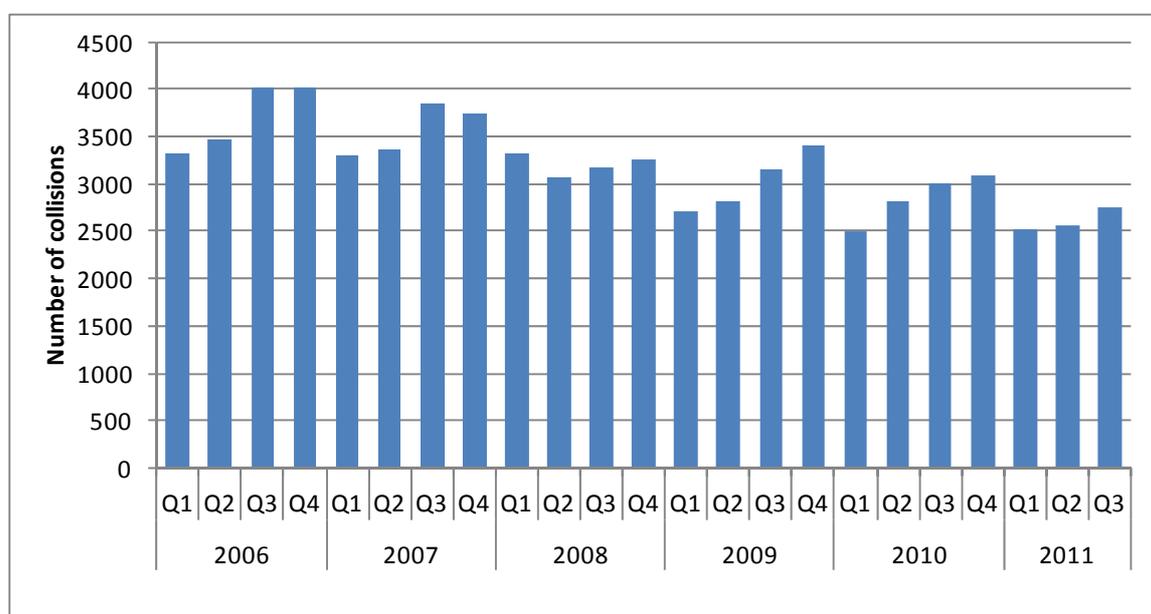


Figure 43. Number of collisions by quarter and year, 2006-2011 (unvalidated data for 2011)

The total number of collisions has shown annual reductions over the period, and in most of the years the number of collisions in each quarter increases from the previous quarter.

6.3.2 Comparison between dry and pre-wetted periods

In order to compare the number of collisions occurring in the periods where dry salting and pre-wetted salting were used, it was necessary to allow for general trends in collisions across the time period studied. The following before/after analysis is based on the assumption that pre-wetted salting with the reduced spread rates was introduced at the beginning of 2010 in all areas. Since the change in treatment was introduced across the whole strategic route network no comparison routes (where the dry salting treatment was continued) were available for use as a control. As a result, summer collisions were selected to be used as control data.

The Foden spreaders were replaced in some areas in the winter of 2008/09 and over the next two seasons in other areas. The data for the 2006/2007 winter and the 2007/2008 winter were analysed as the period where dry salting was used ('dry' winter) and the data from Quarter 1 2010 and the 2010/2011 winter were analysed as the pre-wetted salting period ('wet' winter); the winter period of 2008/9 and 2009 Q4 were not included in the analysis because over this period there was a gradual transition of the type of spreaders used and the reduced spread rates had yet to be implemented

Data for the summers of 2006 and 2007 ('dry' summer) were used as control data for the dry salting period and data for the summers of 2009 and 2010 ('wet' summer) were used as the control data for the pre-wetted salting period. Table 14 shows the periods selected for analysis.

Table 14: Periods used for National STATS19 collision data analysis

	2006	2007	2008	2009	2010	2011
Dry summer (control)	■	■				
Dry winter (experiment)		■	■			
Wet summer (control)				■	■	
Wet winter (experiment)					■	■

Due to the differing lengths of the dry salting and pre-wetted salting periods, collision numbers were averaged per quarter. There were four quarters of data for each of the summer periods and for the dry salting winter period, and three quarters of data available for the pre-wetted salting winter period.

Table 15 shows the average collisions per quarter by road type in each of the periods and the percentage change between the two summer periods and the two winter periods.

Table 15: Average collisions per quarter by road type

Road Class	'Dry' summer	'Wet' summer	'Dry' winter	'Wet' winter	% change summer	% change winter
Motorway	1,837	1,467	1,846	1,362	-20.1%	-26.2%
A-road	1,840	1,481	1,750	1,335	-19.5%	-23.7%
Total	3,677	2,948	3,596	2,698	-19.8%	-25.0%

As Table 15 shows, there were 25% fewer collisions in the winter months when pre-wetted salting was available than in the winter months with dry salting whereas the summers of 2009 and 2010 had 20% fewer collisions than the summers of 2006 and 2007. On both motorways and A-roads there was a greater reduction in collisions in the winter compared to the summer.

Further analysis of the data was carried out, included in Appendix H, to investigate factors such as severity of collisions, road surface condition, skidding and where slippery road were a contributory factor.

6.4 Comparison of collisions on routes with dry and pre-wetted precautionary treatments

6.4.1 Analysis method

WRF1 was analysed to collate information on the precautionary treatments used on each day on each road in each Area in the analysis periods. The WRF1 database showed that dry salting (including precautionary) was used throughout the analysis periods (see details in Appendix I). Therefore, the analysis in Section 6.3 is not robust since the 'after' period includes both significant amounts of dry as well as pre-wetted salting.

Combining information from the WRF1 database and Stats19 collision data would enable analysis of trends and characteristics of collisions on routes with the different precautionary treatments. Therefore, the next stage of the analysis was to analyse the collisions which occurred on routes where the treatment was known from WRF1. This required matching collision records in the STATS19 database with the entries in WRF1.

6.4.2 Matching WRF1 and STATS19 data

Data were available from WRF1 detailing on which days Service Providers treated the Winter Service Routes their Area. Appendix I provides detailed information on the data available from WRF1.

STATS19 data provides the location of collisions by road and Area, and gives a grid reference. Ideally, a GIS map layer showing the routes would be used to match the collisions reported on STATS 19 with a particular route; however, this GIS data was not available and therefore roads and Areas were used to match as many collisions as possible with treatment types.

A route can cover more than one road number and a road number in an Area can be split into more than one route. For each day in the analysis period, treatment types were assigned to the roads in each Area as described in Appendix J. Where 'no treatment', 'to be advised' or 'completed' were used on the same area road day as a single type of specified treatment (dry, not used, prec and pre-wet), the former group were ignored and the specified treatment was assumed to apply to the whole area road day.

6.4.3 Summary of data available in WRF1 database

The WRF1 data were matched to the Stats19 collision data using the following process:

- Days where all routes in an area were treated the same
- Days where all of a road within an area was treated the same
- Days where multiple treatment types were made on a road within an area on the same day were excluded
- Areas which did not match with current Agency areas were combined or excluded

The number of area road days available for collision analysis was therefore those shown in the table below.

Table 16: Area road days available for collision analysis

Condition	Number of area road days
Number of area road days on routes where entire area was treated similarly	69,688
Number of area road days where treatment was mixed within the area but entire road within area was treated similarly	6,563
Area road days with only 'no treatment', 'to be advised' and 'completed'	11,598
Area road days with 'no treatment', 'to be advised' and 'completed' and single type of specified treatment	31,663
Total area road days in analysis	119,512

The treatments used on these days are shown in Table 35.

Table 17: Treatments used on area road days available for collision analysis with comparable areas

Treatment type	Number of area road days
No treatment	67,082
Prec	28,497
Pre-wet	4,972
Dry	5,872
Completed	117
To Be Advised	940
No treatment/completed/to be advised	11,598
Not used	434
Total	119,512

6.4.4 Comparison of collisions

The WRF1 data was combined with the Stats19 collision data in order to calculate the number of collisions on days with different treatment types.

A comparison was made between the number of collisions on days where the dry (precautionary) treatment was applied using the old winter fleet and the number on days

where the pre-wetted treatment was applied with the current spread rates. The general trend in the number of collisions was taken into account by comparing the number of collisions in the same analysis periods when no treatment was required.

The number of collisions which occurred on each area road day for which data were available was calculated. The time of the treatment was not compared with the time of the collision, so that the collision could have occurred before or after the treatment was made on that day.

Analysis of circumstances and contributory factors of the collisions which occurred on days with different treatment types is included in Appendix K

In order to make a comparison between the numbers of collisions on roads with different treatment types, the number of days/hours and the length of road treated with each type of treatment needs to be taken into account.

Table 18 shows the number of area road days, the lengths of those Area road days and the collisions per day per km. The length of roads within Areas was obtained from the DfT traffic survey data.

Table 18: Collision rates

	Treatment		No treatment	
	Before (dry precautionary)	After (pre-wet precautionary)	Before	After
Number of area road days	20,253	5,082	47,739	2,3532
Number of area road days km	793,764	172,933	1,736,936	835,997
Number of collisions	3,718	747	8,262	3,327
Number of collisions per day per 100km	0.47	0.43	0.48	0.40

6.4.5 Hauer 'before and after' collision analysis

In general, a Hauer 'before and after' study compares the number of collisions before and after a change in treatment, with a comparison period where no change was made. The method uses the comparison data to estimate the expected number of collisions in the 'after' period had the treatment not been changed. Expected values are then compared with their corresponding observed values, and in each case a statistical test is used to assess whether there is a significant difference between the observed and expected figures. Any significant difference may be assumed to be due to the change in treatment, given certain satisfied assumptions.

In this case, the number of collisions on days where the dry (precautionary) treatment was applied has been compared with the number on days where the pre-wet treatment was applied, taking into account the general trend in collisions over the same period (defined by the 'no treatment' groups).

The Hauer method used in this analysis uses the following assumptions:

- a) Any factors affecting the number of collisions have changed from the 'before' and 'after' periods in the same manner on both the trial and comparison groups.

- b) Any change in these factors influences the safety of the treatment and comparison groups in the same way.
- c) The distribution of the expected number of collisions follows a Poisson distribution.

Due to differences in the number of area road days and area road day kms available for collision analysis in the before and after periods, the analysis was performed on the collision rate (number of collisions per 100km).

The results show that although there was a decrease in the collision rate from 0.47 to 0.43 (Table 18) between the before period with dry precautionary treatments and the after period with pre-wetted treatments, the result was not significant. This indicates that, based on the data available, any difference between the collision rates on the treatment routes in the before and after period is likely to be due to the general trend in collision rates.

6.5 Discussion

The initial analysis of the STAS19 collision data for before and after the change in salting regime has shown that there has been a greater reduction in total number of collisions in the winter periods compared to the corresponding summer periods. The reason for this difference may be due to many factors, including changes to the type of treatment used.

While this initial overview can provide some indication that there has been no significant change in numbers of collisions, it is of limited use for assessing the effectiveness of the new precautionary spread rates, as both the winter analysis periods include all treatments made i.e. both precautionary and treatments for snow and ice. The winter period analysed after the introduction of the new rates also included a significant proportion of treatments with dry salting both as precautionary treatments and treatments for snow and ice. The only way of accounting for overall trends in collision rates was to use summer data as the control, however this was not ideal as conditions may be very different in the summer to winter.

To provide sufficient numbers of collisions for comparison, it has been necessary to use a broad set of data. Collisions have been compared on days where precautionary treatments have been made, but analysis has not been carried out for particular spread rates, weather conditions or taken account of any local factors e.g. areas prone to ice, which will reduce the number of collisions available for analysis. The time of treatment was not compared with the time of each collision. Data has been used from all Areas, and it has been assumed that spreaders are performing correctly.

The analysis of the collisions which occurred on roads where the treatment was known from WRF1 indicated that, based on the data used, any difference in the collisions rates between the period of dry precautionary salting and pre-wetted salting with the current rates falls within the general trend in collision rates.

Evidence was sought in the questionnaire issued to Service Providers on particular conditions of concern where spread rates were considered too low, and this identified areas, discussed in the report, that would not be identified from the analysis of collision data.

While it is considered that the data can provide an overall check that there are no obvious issues with the current spread rates, it has not been possible to identify

particular conditions or spread rates that are not effective or confirm that there has been no effect on the likelihood of incidents.

7 Recommendations

The review has shown that the new treatment guide and matrix is achieving the main aims of providing reliable winter service on the Agency's network while providing economies and reducing environmental damage. Further data from future years would be required to be able to give a firm view on any small change to incident rates, however no significant increase can be attributed to the changes in treatments to date. Some areas have been found where further information and guidance would benefit Service Providers. Recommendations have been made to address these and where further work would benefit delivery of the service and help manage risk to all stakeholders. The recommendations are as follows:

7.1 Greater emphasis on the use of pre-wetted salt

The responses received from Service Providers showed that many with pre-wet spreading capability were spreading dry salt when this was not the best option.

The current matrix guide contains the following note:

Note (2) When ice has formed or snow is lying dry salting is the preferred treatment unless the road is closed to traffic when pre-wetted salting may be used. Pre-wetted salting is the preferred treatment in advance of such conditions.'

It is recommended that an additional note be added before Note (2), to emphasise that pre-wetted salt is the preferred precautionary treatment method for all road and weather conditions:

'Pre-wetted salt should always be the preferred treatment for all precautionary treatments, including before snowfall'

Furthermore, it is recommended that the benefits of using pre-wetted salt should be outlined in the Severe Weather Plan Template (Section 5.2) and Network Management Manual. A statement such as the following could be inserted to highlight these benefits:

'The use of pre-wetted salt provides the following advantages over dry salting:

- *Better salt distribution across and along the carriageway*
- *Lower salt loss during spreading and due to trafficking after spreading*
- *Increased dissolution, in particular for colder temperatures*

For treatments on very wet roads and when precipitation has occurred after spreading, repeat treatments are required and spreading dry salt in these circumstances will not prevent the need for these repeat treatments.'

There has been no specific feedback from Service Providers on why dry salting is used instead of pre-wetted salt (where available) and this warrants further investigation by the Agency. For example, monitor the use of precautionary dry salt treatments and make further enquiries when it is used.

7.2 Further work to inform repeat treatments in sustained freezing

There has been feedback from Service Providers that further guidance is required on the treatment frequency and the timing of repeat treatments.

Service Providers typically carry out repeat treatments within 6 to 12 hours during sustained freezing. These conditions include:

- Frost in early evening with continued freezing temperatures through the following morning rush but temperatures rising above freezing during the day
- Sustained freezing over one or more days, with the temperature remaining below freezing during the day

It is recommended that further work be carried out to better understand appropriate rates and timing for repeat treatments in periods of sustained freezing, in order to optimise the use of salt while providing adequate treatment in these conditions. For example, how can the spread rate and frequency of treatment take account of the following factors:

- Different temperature-time profiles after carrying out treatments
- Changes in surface wetness during sustained freezing
- Residual salt levels

It is also important to consider how treatment rates and treatment frequencies can be optimised to minimise the amount of salt spread to meet the conditions. The results of this work should then be incorporated into guidance to the service providers.

7.3 Further guidance for problematic conditions

There are certain circumstances where the amount of moisture on the road surface at the time a treatment is carried out may be significantly greater than that assumed in developing the rates, for example spreading immediately after rainfall. These conditions have always been problematic and are not new issues arising from use of the reduced spread rates.

The problematic conditions include:

- Freezing soon after rainfall
- Heavy hoar frosts
- Treatment of some sections of thin surfacing
- Low traffic conditions, especially on Sunday mornings.

Due to the wide range and variability in conditions and local factors it is not practical to give definitive guidance, i.e. specifying exact spread rates and treatment timing for each problem condition. Treatment decisions will need to be based on broad guidance and advice to aid the experience and judgment of the Service Provider.

It is recommended that it be clearly stated that the spread rates in the treatment matrix guide are not applicable for spreading on very wet roads or for very heavy hoar frosts. Further guidance can then be included to help assess when roads are too wet, etc along with information on the specific problem (i.e. dilution of the brine so it is not effective, washing away, brine dispersed from road by traffic spray, etc.) and the types of action that can be considered.

The current matrix guide contains the following note (3), with a suggested amendment in bold:

Note (3) *Treatments should be carried out, whenever possible, after traffic has dispersed standing water. Successive half rate treatments (for both pre-wet and dry salt operations) should be considered for lightly trafficked roads, **or on more heavily***

trafficked roads at times of low traffic, at the lower end of temperature bands indicated'

It is recommended that a further note be added to emphasise that the rates are not applicable for very wet roads or very heavy hoar frosts, and the network should be closely monitored when these problem conditions are likely. The note should include that consideration be given to increasing the spread rate, carrying out successive treatments or both.

For example:

'The spread rates are not applicable to very wet roads, when there is standing water or spray generated, or for very heavy hoar frosts. In these conditions roads should be closely monitored and consideration given to increasing the spread rate, making successive treatments or both (insert reference to additional guidance in Plan)'

The Severe Weather Plan Template contains an appendix on 'Special Considerations'. It is recommended that this section be referenced in the notes in the treatment matrix.

7.4 Improved use of weather information (HAWIS)

The treatment matrix guide makes a distinction between spreading on dry/damp roads and spreading on a wet road. The review of the treatments made has shown that Service Providers are using the treatment matrix to adjust rates according to the surface wetness, resulting in more efficient use of salt.

Feedback from Service Providers has indicated that better information would help decision making. For example, over half the Service Providers responded that the road sensor data is not sufficiently accurate to assess road surface wetness.

Other feedback has shown that the prediction of the heaviness of hoar frost and the estimation of residual salt levels are also areas where better information would help the decision making process.

It is recommended that further investigation be made of the use of HAWIS to improve decision making, in particular with regard to:

- Accurate assessments of the road surface wetness
- Predictions for heaviness of hoar frosts
- Assessing residual salt

7.5 WRF1 reporting

The review of WRF1 has highlighted the difficulty in using the system to fully assess if the correct spread rates are being used.

Information in WRF1 is currently entered by Service Providers using an internet based reporting system. Data is entered by selecting appropriate values on a route basis from drop down menus on the reporting screen.

It is recommended that consideration be given to additional menu items. Key information for assessing the spread rates would be:

- Road wetness - dry/damp/wet
- Rate reduced for residual salt - yes/no

- Minimum forecast RST

The alternative liquid de-icers currently in use in some Areas should also be included as a treatment option.

7.6 Spreader calibration and monitoring

7.6.1 *Monitoring of spreader performance*

National guidance documents and the NWSRG Practical Guidance (which will form part of National Guidance shortly), include recommendations that spreader performance should be routinely monitored and recorded during the winter season. This monitoring will quickly highlight any problems so that re-calibration of spreaders can be carried out where necessary.

At the time of reporting, in June 2012, an assessment of the current Fleetstar data logging system is taking place as part of the Highways Agency winter review and this will help support future decisions after the current contract finishes in June 2013. It is considered that use of the data logging system would offer a cost effective method of monitoring the spreader performance. Recommendations can be made on how this can be achieved for consideration in the review of the data logging system.

The onboard measurement and the target amounts of salt and brine discharged are both parameters that are currently reported in Fleetstar. A comparison of these values, e.g. the onboard weight measurement as a percentage of the target amount, could be incorporated into one of the standard report types.

To provide an accurate comparison, the onboard weight and counter readings must be recorded when the spreader is stationary and on a level area of ground. It is therefore recommended that this should be a specific requirement for Service Providers.

A recommendation suggested by a Service Provider, which we support, is to have a button for the driver to press when the vehicle is stationary, in a designated 'parking zone' within the depot, prior to and after their run. The button would trigger the recording of the onboard weights and counter reading, for inclusion in the standard report.

7.6.2 *Calibration*

National guidance and the NWSRG Practical Guide clearly states that spreaders should be calibrated for each type of salt spread.

The comparison of the results from trials carried out with the different salt types shows that the amount of salt discharged and the salt distribution profile can vary significantly with the salt type and the grading. This confirms the importance of calibration to provide confidence that the required amounts of salt are being spread on the road. This is essential to provide an adequate service and minimise risk to all stakeholders.

The recommendations are that the guidance is extended to include:

1. Service Providers calibrate each spreader for the salt type being spread.
2. Visual checks are made of the salt distribution when using non indigenous salt types to confirm sufficient coverage of the full spread width required.

Where it is not practical to recalibrate the spreaders, e.g. In severe weather conditions, where alternative salt has to be sourced at short notice, then guidance on alternative treatment rates should be developed for the types of salt and the level of moisture content.

As an interim measure, a possible fall back option would be to increase the spread rates to allow a greater margin for error in the spreader performance. For example, using the recommended treatment rate for the next lower temperature band in the treatment matrix. However, it should be recognised that this would increase salt usage in times when resilience may be an issue. Some further work would be required to determine if this is adequate before such interim guidance was issued.

8 Conclusions

Use of the treatment matrix

1. The full range of spread rates was used in each Area in the analysis period, with the exception of the double treatment, 2x15g/m², which was not observed in any of the Areas investigated.
2. There were some apparent differences in practice between Areas e.g. some Areas carry out a greater proportion of spreading using dry salt when pre-wet salting is available, the reasons for this have not been determined.
3. Averaged over all Areas:
 - a. 79% of pre-wetted treatments were at rates specified in the guidance above -2°C,
 - b. 65% below -2°C and above -5°C and
 - c. 54% at or below -5°C and above -10°C
4. Within each temperature band, it was not possible to investigate how accurately spread rates took account of road surface wetness due to the lack of information on road wetness within WRF1.
5. The facility to record more information in WRF1 for individual routes e.g. road wetness, temperature, would allow the treatments made to be more fully assessed.
6. Dry salting is frequently used for precautionary treatments in all the temperature bands specified in the guide, when pre-wetted salt would be the only recommended option from the treatment matrix.
7. Overall, the evidence from the review of WRF1 and feedback from Service Providers indicates that Service Providers generally understand the requirements and guidance notes in the treatment matrix guide.
8. Service providers indicated areas of the guidance where they would benefit from additional information and advice.
9. Feedback from Service Providers has indicated that better information to support use of the treatment guidance would help decision making. For example, over half the Service Providers responded that the road sensor data is not sufficiently accurate to assess road surface wetness.

Effectiveness of the spread rates

1. The review has shown the treatment matrix is working effectively. There is no obvious requirement for changes to the treatment matrix or significant changes in the associated guidance.
2. Recommendations have been made on additional guidance where appropriate for inclusion in the treatment matrix guide and areas where further work is considered necessary.
3. Areas where further guidance would benefit Service Providers are mainly related to conditions where the amount of moisture on the road surface at the time a treatment is carried out is significantly greater than that assumed in developing

the rates. These conditions have always been problematic and are not new issues arising from use of the reduced spread rates.

4. It is not always clear that spread rates or timing of treatments are optimised when repeat treatments are made in sustained freezing e.g. if the rates take account of changing temperature overnight or residual salt.
5. To inform the guidance on repeat treatments during sustained freezing to make most efficient use of salt, further work is required to better understand appropriate rates and timing for repeat treatments, in particular to account for:
 - a. Different temperature-time profiles after carrying out treatments
 - b. Changes in surface wetness during sustained freezing
 - c. Residual salt levels

Performance of spreaders

1. A method was identified by which the measured amount of salt and brine discharged during spreader turnouts could be compared with the 'target' amount, based on data reported from the Fleetstar system.
2. The information reported from Fleetstar has indicated there may be variation in the spreader performance however it cannot be assessed if the variation is within acceptable limits using the data available at present.
3. The data logging system is not currently specified to make an accurate assessment of the amounts of de-icer discharged.
4. Recommendations were made for how Fleetstar could be further developed for the purpose of monitoring spreading performance, for consideration under the current review of the data logging system being carried out as part of the Highways Agency winter review.

Effect of different salt types (e.g. imported salts)

1. Service Providers have indicated that no changes to spreader settings have been made when spreading different salt types, although some Areas carry out calibration checks. Calibration checks are always recommended by national guidance.
2. There is insufficient evidence to make firm conclusions on whether spreading the alternative salt types (used for the dry component of pre-wetted salt) is fully effective, but it was possible to comment on the trends in the salt distribution profiles based on factors such as the salt grading.
3. Conditions may exist where lanes are under salted if spreader settings are not optimised for the type of salt being spread.
4. The current analysis was based on 3 lane spreading and no detailed information is available on 2 lane spreading.
5. The results from trials with non-indigenous salt highlighted the importance of spreaders being calibrated for the particular type of salt being spread, so that the required amounts of salt are actually being spread to all the lanes.
6. Recommendations were made for calibration and visual assessment of the salt distribution.

Accident analysis

1. The Stats19 collision data for the strategic road network was reviewed and showed the total number of collisions, in all weather conditions and across the whole time period, has reduced over the period 2006-2011, which includes the introduction of reduced spread rates with the new winter fleet.
2. In total, there were 25% fewer collisions in the winter months during which pre-wetted salting was carried out at the reduced rates (Quarter 1 2010 and 2010/11 Winter) than in the winter months with dry salting (2006/07 and 2007/08 Winters). As an indication of the trend for decreasing collisions, the summers of 2009 and 2010 had 20% fewer collisions than the summers of 2006 and 2007.
3. On both motorways and A-roads there was a greater reduction in collisions in the winter compared to the summer. However, the use of the summer data as the control, to account for overall trends in collision rates, is not ideal as conditions will be very different in the summer to winter.
4. Analysis of the total number of collisions can provide some indication that there has been no significant increase in numbers of collisions but is of limited use for assessing the effectiveness of the new precautionary spread rates, as both the winter analysis periods include all treatments made i.e. both precautionary and treatments for snow and ice.
5. The analysis of the collisions which occurred on roads where the treatment was known from WRF1 indicated that, based on the data used, any difference in the collisions rates between the period of dry precautionary salting and pre-wetted salting with the current rates is likely to be due to the general trend in collision rates.
6. To provide sufficient numbers of collisions for comparison, it has been necessary to use a broad set of data. Collisions have been compared on days where precautionary treatments have been made, but analysis has not been carried out for particular spread rates, weather conditions or taken account of any local factors. The use of such a broad set of data has meant that fully isolating the effect of the new treatments has not been possible although a broad view on significant change (or not) can be made.
7. Feedback from Service Providers indicated particular conditions of concern, where there was anecdotal evidence for increased incidents. Recommendations have been made on additional guidance where appropriate.
8. It is considered that the data has provided an overall check that there are no significant issues with the current spread rates, it has not been possible to identify any particular conditions or spread rates that are not effective.

9 Acknowledgements

The work described in this report was carried out in the Infrastructure division of the Transport Research Laboratory. The authors are grateful to Caroline Philpott, Karen Starr, Stefan Wood and Sue Pimperton of Halcrow for advice and assistance on the provision of Fleetstar and WRF1 data and analysis of data provided. The authors are grateful to Barry Cleave who carried out the technical review and auditing of this report.

The assistance of Service Providers from the following Areas was much appreciated: Area 1, 3, 4, 5, 6, 8, 9, 10, 12, 13, 14, Area 2 DBFO, A1 D-D DBFO, A19 DBFO, A69 DBFO.

10 References

Cleave B V, Jordan R J, Evans M and McMahon W (2010) NWSRG Practical Guidance - Calibration. NWSRG

DfT. (2004). *Instructions for the completion of road accident reports*. Retrieved October 2011, from <http://www.dft.gov.uk/collisionreporting/Stats/stats20.pdf>

Jordan R and Evans M (2011). Proposed precautionary treatment rates for the Highways Agency's road network, *Published Project Report PPR459*, Wokingham, Berkshire: Transport Research Laboratory (TRL).

Appendix A Questionnaire responses

1. For what road and weather conditions do you consider the currently recommended spread rates are too low?	Area 1	Area 3	Area 4	Area 5	Area 6	Area 8	Area 9	Area 10	Area 12	Area 13	Area 14	Area 2 DBFO	A1 D-D DBFO	A19 DBFO	A69 DBFO
None				✓		✓	✓	✓	✓	✓	✓		✓	✓	
When forecast road surface temperatures are near to -2°C and -5°C											✓				
Freezing soon after rainfall					✓						✓	✓			✓
Heavy hoar frost	✓	✓	✓		✓						✓	✓			
In lightly trafficked areas											✓	*			

Comments to Question 1	
Area 3	A second application of salt should be applied when there is a prolonged/heavy hoar frost.
Area 4	If the sub-zero road conditions exceeds 11 hours.
Area 6	For RSTs between -0.5 and -2°C when road surfaces are forecast to be wet.
Area 12	Current spread rates seem about right.
Area 2 DBFO	*Lightly trafficked is difficult to determine and as a compounding factor, light traffic leaves roads cooler. We frequently see RST variances across a road of up to 2 degrees, but varying treatment rates across a carriageway will be challenging.
A69 DBFO	It depends whether the treatment has been carried out prior to the day in question.

2. For what road and weather conditions do you consider the recommended spread rates are too high?	Area 1	Area 3	Area 4	Area 5	Area 6	Area 8	Area 9	Area 10	Area 12	Area 13	Area 14	Area 2 DBFO	A1 D-D DBFO	A19 DBFO	A69 DBFO
None	✓	✓	✓	✓	*	✓	*	✓	✓	✓	✓	✓	✓	✓	✓
When forecast road surface temperatures are below -5°C and roads are damp											✓				

Comments to Question 2	
Area 6	*When heavy snow is falling/accumulating, spread rates are reduced from 20g successive to 10g successive. This allows the spreading vehicle to complete 2 full circuits of ploughing/treating the route before returning to the depot to re-load with salt. Once the snow has ceased & been cleared, spread rates can be increased to clear remaining compacted areas & prevent ice formation. The use of spot treating can save treating long stretches unnecessarily.
Area 9	*Can get into a 2 treatments a day rut, i.e. 14:00 and 01:00. In addition, long dry spells where the only risks are poor residual salt and very cold conditions.
Area 14	A combination of treatments was used to achieve recommended spread rates i.e. 2x8gms, with the first treatment early evening and additional treatment as temps drops below -5°C.

3. Under what road and weather conditions do you make TWO OR MORE follow-up PRECAUTIONARY treatments (excluding times when precipitation occurs after first treatment)?	Area 1	Area 3	Area 4	Area 5	Area 6	Area 8	Area 9	Area 10	Area 12	Area 13	Area 14	Area 2 DBFO	A1 D-D DBFO	A19 DBFO	A69 DBFO
Only when weather differs from what was forecast at time of spreading				✓				✓	✓	*	✓	*		*	✓
Always make treatment in the evening and before morning rush hour										*	✓	*		*	
Temperatures below zero from early evening through morning rush hour	✓	✓	✓		✓	✓	✓			*	✓	*		*	✓
Freezing soon after rainfall					✓			✓		*	✓	*	✓	*	✓
Heavy Hoar Frost		✓			✓	✓		✓	✓	*	✓	*		*	

Comments to Question 3	
Area 1	1) If there is a forecast amendment with RSTs in the next coldest band. 2) Generally if time below 0°C is >12hrs. As a general rule during these periods when it is dry, 1 treatment would be carried out prior to freezing & then another prior to morning rush i.e. 2 treatments total.
Area 3	It was assumed that this question should read two or more precautionary treatments. An unforecast rain event might require an additional treatment.
Area 6	When temperatures were below zero from early evening through morning rush hour and the roads were damp or wet.
Area 8	Where certain parts of the network have very low traffic flows at dawn on weekends and Bank Holidays.
Area 9	Tends to be rare, half a dozen or so times a season, typically 14:00 hours & 01:00 hours.
Area 12	Also sometimes to just cover early evening & early morning, so if a claim made, we can point to two treatments and done the best we could!
Area 13	*Two or more treatments are often carried out when you have an early evening frost & then either forecast precipitation or ice forming in the early hours of the following morning.
Area 14	In addition, a time element is applied to follow up treatments. If RST's are < 0°C for >12 hours i.e. RSTs < 0°C 1800 to 1000 (following 1st treatment), a 2nd treatment is carried out.

Area 2 DBFO	*Double treatments are applied in advance of snow or freezing rain & when required by the treatment matrix to do 2 x 15 g treatments. Additionally we 'double treat' as necessary to avoid failures under our Key Contract Indicator which would lead to performance failure deductions. This means that we need to have a treatment applied in the 15 hrs leading to any time when RSTs are sub zero.
A19 DBFO	*When period below zero exceeds 6 hours.

4. When making the decision on the spread rate, what information do you use TO ASSESS whether the road surface will be damp or wet?	Area 1	Area 3	Area 4	Area 5	Area 6	Area 8	Area 9	Area 10	Area 12	Area 13	Area 14	Area 2 DBFO	A1 D-D DBFO	A19 DBFO	A69 DBFO
Weather forecast – rainfall, humidity	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	*	✓	✓
Road sensors	✓	✓			✓	✓		✓		✓	✓	✓	*	✓	
Remote sensors		✓								✓	✓	✓	*		

Comments to Question 4	
Area 3	Any other intelligence that is available such as staff on the network, drainage issues and runoff risks.
Area 8	Also through contact with site staff travelling the network and use of the CCTV in the Control rooms.
Area 12	Information from ISUs on network of any run off areas, possible water pipe burst and road works that are using copious amounts of water etc.
Area 13	The decision matrix in Area 13 uses the forecast surface state from the forecast graphs provided as well as local knowledge of areas where run-off is a problem.
Area 14	The main driver for this area is the comments in the text in our forecast. Observations by drivers and ISU information is sometimes considered.
Area 2 DBFO	Also through our knowledge of the network and weather patterns over recent days/weeks. This would give us an indication of known wet spots/run offs and Thin Wearing Course drainage points.
A1 D-D DBFO	*Assessment is based on visual inspection from patrols and CCTV cameras, and from local knowledge of areas in shade and shelter.

5. When making the decision on the spread rate, WHAT problems do you encounter when assessing whether the road surface will be damp or wet?	Area 1	Area 3	Area 4	Area 5	Area 6	Area 8	Area 9	Area 10	Area 12	Area 13	Area 14	Area 2 DBFO	A1 D-D DBFO	A19 DBFO	A69 DBFO
Reliable weather information not available	✓	✓	✓	✓			*	✓	✓	✓	✓	*		✓	✓
Road sensor data not relevant	✓	✓		✓			*	✓	✓		✓	*			✓
Road sensor data not sufficiently accurate to tell if road is/will be wet or dry	✓	✓			✓	✓	*	✓	✓	✓	✓	*	✓		✓
Remote sensor data not relevant		✓			✓		*	✓			✓	*	✓		✓
Remote sensor data not sufficiently accurate to tell if road is/will be wet or dry		✓	✓		✓		*	✓	✓		✓	*	✓		✓

Comments to Question 5	
Area 8	When site staff are not travelling the network or when the views from the CCTV in the control rooms are not available.
Area 9	*None – we use the forecast data as well as the consultancy service via our forecast provider, MeteoGroup, which gives more confidence on water and moisture quantities.
Area 12	Road sensors are only a small spot on a route.
Area 13	Sometimes the road sensor will show that the road surface was damp after treating where as the second sensor on the site will show treated surface. This can sometimes lead the Duty Officer to request a second treatment.
Area 14	Sensor information does not give a full view of the condition of the whole route and is on a small spot on the network. Sensors are not generally used to assist with decision making.
Area 2 DBFO	*The weather stations do not provide sufficient coverage of the network. However the areas with CCTV can provide additional information. The sensor data can only report what is happening and not what is likely to happen, which is why the forecast is so important.

6. When making the decision on the spread rate, how do you assess residual salt levels?	Area 1	Area 3	Area 4	Area 5	Area 6	Area 8	Area 9	Area 10	Area 12	Area 13	Area 14	Area 2 DBFO	A1 D-D DBFO	A19 DBFO	A69 DBFO
Not at all	✓			✓		✓		✓	✓		✓				✓
Visually	✓			✓				✓	✓		✓		✓		✓
Road sensors	✓		✓	✓	✓		✓	✓	✓	✓	✓			✓	✓
Experience, taking into account treatments on successive days	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Assume follow-up treatments (see question 2) can be at reduced rate	✓							✓			✓		✓		

Comments to Question 6	
Area 1	Cutting back on treatments is only considered if treatments have been carried out on a number of consecutive days and there has been no precipitation/run off, humidity is low and no risk of hoar frost. ISUs/supervisors drive route and confirm all dry before making decision.
Area 9	Sensors are checked to calculate the freeze point – this gives an indication on the quantity of residual salt. Also, many years ago it was kind of accepted across the industry that 12 hours with no rain/snow or any type of precipitation was the longest to leave the road without re-treatment.
Area 12	If a treatment is required in "peak times" and humidity low/treatment undertaken early that morning, we will use "residual salt" on route to take treatment time past rush hour - Thus ensuring treatments down in required times as per SWP.
Area 14	Residual salt information is only taken into account to delay a treatments i.e. delay treatment outside peak traffic times.
Area 2 DBFO	Residual salt is only taken into account following multiple treatments over several dry days. It is never used in place of a treatment (as was historic practice) but more to opt for a reduced spread rate when close to the temperature band boundaries or to defer a treatment until after a rush hour.

7. How are the spread rates reduced when there is evidence of (sufficient) residual salt?	Area 1	Area 3	Area 4	Area 5	Area 6	Area 8	Area 9	Area 10	Area 12	Area 13	Area 14	Area 2 DBFO	A1 D-D DBFO	A19 DBFO	A69 DBFO
Not taken into account	✓		✓	✓	✓	✓	✓	✓	*	✓	✓	*			✓
Treatment not made	✓			✓				✓	*		✓	*		✓	✓
Spread rate reduced by a fixed amount	✓			✓				✓	*		✓	*	✓		✓
Spread rate reduced to that for a lower temperature band than forecast	✓	✓	✓	✓	✓	✓	✓	✓	*	✓	✓	*	✓	✓	✓

Comments to Question 7	
Area 1	Treatments would not be made if several days' treatments have been carried out and the road is visibly white with salt.
Area 3	This may be considered after successive treatments and where the temperature would only just fall into the next treatment band.
Area 4	Generally not taken into account due to local varying factors on any given route.
Area 6	Generally all decisions are made in accordance with the spread rates detailed in the treatment matrix. However, if there is high confidence of residual salt, the decision maker may consider using a lower spread rate where the conditions are on the boundary between 2 spread rates or would consider not treating at all on Amber/Green marginal nights.
Area 12	*Decision made sometimes that RST will NOT drop to its lowest value straight away. Therefore two treatment runs with one early evening and one early morning to put down required dosage and thus satisfy Treatment Matrix. This covers risk at both ends of treatment period.
Area 13	It depends on the forecast conditions as to whether or not the forecast spread rate can be reduced. We would not reduce the spread rate for forecast snow or freezing rain but have on occasion reduced it for forecast frost conditions.

Area 14	We would not use residual salt information not to carry out a treatment. Reduced spread rates are sometimes used to take into account residual salt. Reduced rates of spread are not fixed and any treatments that are applied are still in line with the treatment matrix.
Area 2 DBFO	*In response to the 4th bullet point answer – this is inconsistent as a spread rate would be reduced to that for a higher band. Following multiple treatments on dry days we may opt for the lower spread rate in cases where the forecast min RST is close to the band boundary.

8a. Do you increase the spread rates for certain types of thin surfacing?	Area 1	Area 3	Area 4	Area 5	Area 6	Area 8	Area 9	Area 10	Area 12	Area 13	Area 14	Area 2 DBFO	A1 D-D DBFO	A19 DBFO	A69 DBFO
New surfacing e.g. less than 6 months old	No	No	No	No	No	No	No	Yes							
8b. If yes, how are spread rates increased?	Area 1	Area 3	Area 4	Area 5	Area 6	Area 8	Area 9	Area 10	Area 12	Area 13	Area 14	Area 2 DBFO	A1 D-D DBFO	A19 DBFO	A69 DBFO
Use of blast button			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Spread rate increased by a fixed amount			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Spread rate increased for a lower temperature band than forecast											✓				

Comments to Question 8	
Area 1	Other than for 6 & 7 above, do not rely on residual salt on negative textured surfacing.
Area 6	We do not generally increase spread rates for different types of road surface.
Area 10	Use of treatment matrix within SWP would deem to have covered this for different types of surfacing.
Area 13	We do not increase spread rates for thin surfacing although we have experienced more problems throughout the winter season with thin surfacing materials. They were a problem during the freezing rain event of 09-02-12 and we have had ice patches forming in wheel tracks on newer surfaces.
Area 14	We have asked that further research is carried out in this area as there is possible funding available for HA research.

9. Where is the blast button used?	Area 1	Area 3	Area 4	Area 5	Area 6	Area 8	Area 9	Area 10	Area 12	Area 13	Area 14	Area 2 DBFO	A1 D-D DBFO	A19 DBFO	A69 DBFO
Cold spots	*		✓	*	✓		✓	✓	*	✓	*	*		*	✓
Wetter areas, e.g. some types/sections of thin surfacing, drainage issues, etc.	*	✓		*	✓	✓	✓	✓	*	✓	*	*		*	✓
Some bridges	*	✓	✓	*	✓	✓	✓	✓	*	✓	*	*	✓	*	✓
All bridges	*	✓	✓	*	✓	✓	✓	✓	*	✓	*	*	✓	*	✓

Comments to Question 9	
Area 1	*Areas where there is run off that cannot be stopped or diverted.
Area 4	And by local knowledge specific to the designated route.
Area 5	* Question not answered
Area 6	Also on bends, gradients and other known vulnerable areas.
Area 8	Drivers will record this in the treatment confirmation sheets.
Area 9	Includes vulnerable locations too. Locations where regular blast button use is made will be included in our 2012/2013 severe weather plan and marked on the new route cards.
Area 12	*Comment in question 10
Area 13	We have a loaded gritter patrol as a treatment option. This allows the drivers to spot treat using the blast button on any areas they deem hazardous throughout the patrol.
Area 14	*Blast buttons are not used in any situations as described above.
Area 2 DBFO	*The blast button is only used at junctions (typically on the single carriageways) where we are trying to force salt into areas where the gritter does not pass. For example, after leaving a roundabout a driver may 'blast' salt as he rejoins a single carriageway where we want traffic to 'carry salt' onto the wrong side of the splitter island.
A19 DBFO	*Through at-grade junctions.

10. Under what conditions is the blast button used at critical locations?	Area 1	Area 3	Area 4	Area 5	Area 6	Area 8	Area 9	Area 10	Area 12	Area 13	Area 14	Area 2 DBFO	A1 D-D DBFO	A19 DBFO	A69 DBFO
On every turnout	✓	*		*		*	*	✓	*	*	*	*	✓	✓	✓
Only when route is wet and critical locations are wetter than elsewhere	✓	*		*	✓	*	*	✓	*	*	*	*			✓
Only when route is wet and critical locations are colder than elsewhere	✓	*	✓	*		*	*	✓	*	*	*	*			✓
Whenever route is wet and critical locations are colder and wetter than elsewhere	✓	*	✓	*	✓	*	*	✓	*	*	*	*	✓	✓	✓

Comments to Question 10	
Area 3	*Areas where extraneous water on the carriageway e.g. seepage, minor drainage issues etc
Area 5	*Question not answered
Area 6	Often used on dry nights, following rainfall, to give extra protection to wet and seepage areas.
Area 8	*When drivers are briefed because of specific issues e.g. after roads works.
Area 9	*Drivers are encouraged to use their discretion and use the blast button on any areas they feel may be vulnerable over and above the known areas.
Area 12	*Blast button used when driving by junctions, especially on APTRs and some type laybys. Driver sometimes uses in snow/battle conditions and where "run off" areas of water cross carriageway.
Area 13	*We only use the blast button if called to an incident caused due to ice or when the driver deems necessary on loaded patrols.
Area 14	*All the route is treated with the same rate of spread.
Area 2 DBFO	*The blast button would be used when road conditions are dry but the driver encounters moisture passing across the carriageway, or at known TWC 'drain points' which have been identified in the SWP as vulnerable locations.
A1 D-D DBFO	Spread rate is always increased on elevated bridge sections regardless of wetness and coldness.

11. How do you monitor the amount of salt discharged?	Area 1	Area 3	Area 4	Area 5	Area 6	Area 8	Area 9	Area 10	Area 12	Area 13	Area 14	Area 2 DBFO	A1 D-D DBFO	A19 DBFO	A69 DBFO
Rely on automatic data logging	✓	✓	✓	✓		✓		✓	✓	✓	✓	✓	*	✓	*
Monitor on-board weights before spreader leave depot and when they return, with spreader stationary at the same fixed location for each measurement	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		*	✓	*

Comments to Question 11	
Area 1	Use of depot weighbridges at all but one depots – weights taken before and after salting.
Area 6	Operatives record both the onboard weighing figures and the salt and brine counters on the HA Winter Spreading Vehicles.
Area 8	By occasional spot checks on individual vehicles over an in-house weighbridge.
Area 12	Look at Driver Log sheets to also gauge salt used – Driver log sheet part of Aone + IBMS Process
Area 2 DBFO	We have no confidence in the on board weighing system and have no weighbridges.
A1 D-D DBFO	Rely on calibration of spreading equipment.
A69 DBFO	*None of the above

12. What types of salt do you use at your depots (excluding salt solely for brine production)?	Area 1	Area 3	Area 4	Area 5	Area 6	Area 8	Area 9	Area 10	Area 12	Area 13	Area 14	Area 2 DBFO	A1 D-D DBFO	A19 DBFO	A69 DBFO
6mm Thawrox	*	✓	✓	*		✓	✓	✓	✓	✓	✓	✓	✓	✓	*
6mm Cleveland Potash	*		✓	*	✓			✓	✓		✓		✓	✓	*
6mm Marine Salt		✓	✓		✓			✓	✓		✓	✓	✓	✓	
Other	✓	✓		✓	✓							✓			✓

Comments to Question 12	
Area 1	*6mm rock salt from Irish salt sales used.
Area 3	6mm marine salt
Area 5	*10mm Thawrox
Area 6	On 2 routes from the Kings Lynn depot we use 6mm Thawrox Plus (Safecote treated). The other 24 routes in Area 6 all use 6mm Cleveland Salt.
Area 9	We still have a quantity of marine salt left at some depots but all this years and late last year's stocks are now rock salt.
Area 2 DBFO	6mm marine salt
A69 DBFO	*10mm Ecothaw treated (Cleveland Potash), 10mm rock salt (Cleveland Potash) and 6mm rock salt (Salt Union).

13. Has it been necessary to adjust the amount of salt discharged when changing from one salt type to another?	Area 1	Area 3	Area 4	Area 5 (CE)	Area 6	Area 8	Area 9	Area 10	Area 12	Area 13	Area 14	Area 2 DBFO	A1 D-D DBFO	A19 DBFO	A69 DBFO
Yes/No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No

Comments to Question 13	
Area 6	We have undertaken check calibrations on the vehicles when different types of salt have arrived in the area.
Area 8	During salt shortages in previous years, checks of vehicle calibrations were undertaken.
Area 12	HA Romaquip Winter Vehicles have already been calibrated for change in salt – i.e. from 6mm dry to 6-8mm marine salt.

Appendix B Summary of treatments from WRF1

B.1 Summary of treatments made in December 2011

Table B1. Area A treatments in December 2011

Date	Treatment (g/m ²)	Time of treatment(s)	Pre-wet or dry salt	Temp (°C)	Weather hazard	Comments	Correlate with Treatment Matrix
01/12/2011	No Action	-	-	-2	Hoar Frost	Marginal RSTs at night, gritting planned for next morning.	
02/12/2011	8 and 8	04:00	Pre-wetted and dry	-2	Hoar Frost	All routes treated.	Yes
03/12/2011	No Action	-	-	2.5	Mild - No Frost	-	
04/12/2011	8 and 8	21:00	Pre-wetted and dry	-1	Ice and Hoar Frost/Mild - No Frost	Considerable variation across Area 2, several routes gritted because of risk of ice (1 route with dry salt).	Yes
05/12/2011	8 and 8	05:00 and 19:00	Pre-wetted and dry	-1	Hoar Frost and Ice	4 routes gritted with pre-wet at 05:00. 13 routes scheduled for gritting at 19:00 but subsequently increased to 21 routes following evening update.	Yes
06/12/2011	No Action	-	-	2.5	Mild - No Frost	-	
07/12/2011	8	19:00	Dry	0.5	Ice and Hoar Frost/Mild - No Frost	5 routes treated with dry gritting following evening update.	Yes (Ice forecast on several routes)
08/12/2011	8 and 8	21:00	Pre-wetted and dry	-0.5	Ice	12 routes treated with pre-wet and 9 routes treated with dry salt.	Yes
09/12/2011	15/9 and 16/10	15:00 and 20:00	Pre-wetted and dry	-4.5	Ice and Hoar Frost	Two phases of treatment at 15:00 and 20:00 with higher spread rates implemented at 15:00. 14 routes are gritted in the evening, which is less than previously planned due to drier conditions than originally forecasted.	Yes

10/12/2011	8 and 8	16:00	Pre-wetted and dry	0.5	Hoar Frost/Mild - No Frost	5 routes gritted with pre-wet and 8 routes gritted with dry salt.	
11/12/2011	8 and 8	22:00	Pre-wetted and dry	-0.5	Ice and Hoar Frost/Mild - No Frost	2 routes gritted with pre-wet and 8 routes gritted with dry salt.	Yes
12/12/2011	No Action	-	-	3	Mild - No Frost	-	
13/12/2011	8	19:00/21:00/ 00:00	Dry	-0.5	Hoar Frost/Rain	10 routes gritted with dry salt at a range of different times due to isolated rain showers.	Yes
14/12/2011	8/16	02:00, 14:30, 20:15	Dry	0	Hoar Frost/Rain	A number of routes treated with dry salt at different times throughout the day because of showers and continued low temps.	Yes (if surface moisture influenced decision)
15/12/2011	16	04:00	Dry	0	Hoar Frost/Rain	10 routes gritted with dry salt because of heavy rain shower and continued low temps.	Yes (if surface moisture influenced decision)
16/12/2011	8/15/16 and 8/16	03:40 and 20:00	Pre-wetted and dry	-2.5	Ice and Hoar Frost	4 routes gritted at 03:40 due to snow. All routes gritted in the evening with considerable variation in type of gritting and spread rates.	Yes
17/12/2011	8/15 and 8/16	15:00 and 20:00	Pre-wetted and dry	-3.5	Ice and Hoar Frost	Two phases of pre-wet and dry treatment at 15:00 and 20:00 with larger spread rates at 15:00.	Yes
18/12/2011	8/10 and 8/9	16:00	Pre-wetted and dry	-2.5	Hoar Frost and Ice	Most routes treated at 16:00 with a range of dry/pre-wetting salt and spread rates.	Yes
19/12/2011	No Action	-	-	1.5	Mild - No Frost	-	
20/12/2011	No Action	-	-	4	Mild - No Frost	-	
21/12/2011	No Action	-	-	4	Mild - No Frost	-	
22/12/2011	No Action	-	-	7	Mild - No Frost	-	
23/12/2011	8 and 8	20:00	Pre-wetted and dry	-1	Hoar Frost/Mild - No Frost	Most routes treated at 20:00 with pre-wet or dry salt.	Yes
24/12/2011	No Action	-	-	4	Mild - No Frost	-	
25/12/2011	No Action	-	-	8	Mild - No Frost	-	

26/12/2011	No Action	-	-	5	Mild - No Frost	-	
27/12/2011	No Action	-	-	5	Mild - No Frost	-	
28/12/2011	8 and 8	20:00	Pre-wetted and dry	0.5	Marginal/Mild - No Frost	Several routes gritted due to isolated showers and cold temps.	Yes (if surface moisture influenced decision)
29/12/2011	No Action	-	-	2	Mild - No Frost	-	
30/12/2011	No Action	-	-	6.5	Mild - No Frost	-	
31/12/2011	No Action	-	-	7.5	Mild - No Frost	-	

Table B2. Area B treatments in December 2011

Date	Treatment (g/m ²)	Time of treatment(s)	Pre-wet or dry salt	Temp (°C)	Weather hazard	Comments	Correlate with Treatment Matrix
01/12/2011	No Action	-	-	2	Rain	-	

02/12/2011	No Action	-	-	2.5	Rain	-	
03/12/2011	No Action	-	-	3	Mild - No Frost	-	
04/12/2011	8	21:00	Pre-wetted	0	Hoar Frost and Ice/Mild - No Frost	14 routes were treated.	Yes
05/12/2011	8	20:00	Pre-wetted	-0.5	Hoar Frost and Ice/Mild - No Frost	14 routes were treated.	Yes
06/12/2011	No Action	-	-	3	Mild - No Frost	-	
07/12/2011	No Action	-	-	0	Mild - No Frost/Hoar Frost and Ice	RST's marginal in places but expected to stay above zero.	
08/12/2011	8	22:00	Pre-wetted	0.5	Ice	All routes treated because Roadcast/thermal maps showed routes becoming marginal for extended period.	Yes (Ice forecast)
09/12/2011	9	19:00	Pre-wetted	-3	Hoar Frost and Ice	All routes treated.	Yes
10/12/2011	8	17:00	Pre-wetted	-1.5	Hoar Frost and Ice	All routes treated.	Yes
11/12/2011	No Action	-	-	0.5	Mild - No Frost	All routes monitored in the evening with view to morning treatment on 12/12.	
12/12/2011	8	04:00	Pre-wetted	0.5	Hoar Frost and Ice	All routes treated.	Yes (Ice forecast)
13/12/2011	No Action	-	-	1	Rain	-	
14/12/2011	No Action	-	-	0.5	Mild - No Frost	-	
15/12/2011	No Action	-	-	-0.5	Snow and Rain	All routes monitored in the evening with view to morning treatment on 16/12.	
16/12/2011	18/15 and 20/16	06:30 and 19:00	Pre-wetted and dry	-0.5	Rain and Snow/Ice and Sleet	All routes gritted at least twice. One route in the morning was treated with dry gritting. Three routes were treated with dry gritting in the evening due to unavailability of brine.	Yes (snow forecast)
17/12/2011	15 and 20	19:00	Pre-wetted and dry	-3	Ice	All routes treated with one route implemented with dry gritting.	Yes (Ice and wet snow forecast)

18/12/2011	8/15 and 20	09:00 and 17:00	Pre-wetted and dry	-3.2	Ice and Hoar Frost	Pre-wetted salt implemented at 09:00 for precautionary measures due to reports of ice on two routes. All routes treated in the evening with one route dry gritted.	Yes (assuming dry treatment on 1 route was due to snow lying on road)
19/12/2011	15 and 20	05:00	Pre-wetted and dry	-3.5	Ice and Hoar Frost	Due to length of time RST's were forecasted to be below zero, a secondary treatment of 15g is instructed (1 route has 20g of dry salt).	Yes (assuming dry treatment on 1 route was due to snow lying on road)
20/12/2011	No Action	-	-	2.5	Mild - No Frost	-	
21/12/2011	No Action	-	-	4.5	Mild - No Frost	-	
22/12/2011	No Action	-	-	6	Mild - No Frost	-	
23/12/2011	No Action	-	-	-0.5			
24/12/2011	8 and 8	03:00	Pre-wetted and dry	-0.5	Hoar Frost and Ice	RST's near or well below zero with ice in places. All routes treated with one route dry gritted.	Yes
25/12/2011	No Action	-	-	7	Mild - No Frost	-	
26/12/2011	No Action	-	-	6.5	Mild - No Frost	-	
27/12/2011	No Action	-	-	5	Mild - No Frost	-	
28/12/2011	No Action	-	-	1	Mild - No Frost	-	
29/12/2011	No Action	-	-	1	Mild - No Frost	Marginal but evening update showed no treatment required.	
30/12/2011	No Action	-	-	4.5	Mild - No Frost	-	
31/12/2011	No Action	-	-	8.5	Mild - No Frost	-	

Table B3. Area C treatments in December 2011

Date	Treatment (g/m ²)	Time of treatment(s)	Pre-wet or dry salt	Temp (°C)	Weather hazard	Comments	Correlate with Treatment Matrix
------	-------------------------------	----------------------	---------------------	-----------	----------------	----------	---------------------------------

01/12/2011	No Action	-	-	-0.5	Mild - No Frost/Hoar Frost	A drop in RSTs anticipated overnight so treatment planned for next morning.	
02/12/2011	8/9	03:00/04:00	Pre-wetted	-0.5	Hoar Frost/Mild - No Frost	Most routes treated at 03:00 or 04:00. One route is gritted with 9g of salt.	No
03/12/2011	No Action	-	-	0.5	Mild - No Frost	-	
04/12/2011	No Action	-	-	-2	Ice and Sleet	A drop in RSTs anticipated overnight so treatment planned for next morning.	
05/12/2011	8/15 and 8	00:30/02:00 and 19:00/20:00	Pre-wetted and dry	-2	Ice and Sleet/Ice and Hoar Frost	All routes gritted with pre-wet salt (8 or 15g) at 00:30 or 02:00. A second phase of treatment takes place in the evening with some routes treated with dry salt.	No
06/12/2011	8 and 8	03:00	Pre-wetted and dry	-2	Ice and Hoar Frost	All routes gritted in the morning with predominantly pre-wetted salt.	Yes
07/12/2011	8 and 8	22:00	Pre-wetted and dry	-1	Ice and Hoar Frost	Several routes gritted at 22:00 with both pre-wet and dry salt used.	Yes
08/12/2011	8 and 8	00:01/02:00/03:00/04:00	Pre-wetted and dry	-0.5	Ice and Rain	Precautionary treatments implemented across whole network at various times.	
09/12/2011	15 and 16	19:00/20:00	Pre-wetted and dry	-5	Ice and Hoar Frost	Precautionary treatments implemented across whole network at 19:00/20:00.	Yes
10/12/2011	8/9 and 8/10	04:00 and 18:00	Pre-wetted and dry	-2.5	Ice and Hoar Frost	Precautionary treatments implemented across whole network at 04:00 and 18:00.	Yes
11/12/2011	No Action	-	-	-1	Ice and Hoar Frost	A drop in RSTs anticipated overnight so treatment planned for next morning.	
12/12/2011	8 and 8	04:00	Pre-wetted and dry	-1	Ice and Hoar Frost	Gritting treatments implemented across whole network at 04:00.	

13/12/2011	No Action	-	-	-1	Hoar Frost and Ice	A drop in RSTs anticipated overnight so treatment planned for next morning.	
14/12/2011	8 and 8	00:01/02:00/ 04:00 and 21:00	Pre-wetted and dry	-1	Hoar Frost and Ice	Pre-wet treatment implemented on all routes at various times in the morning. All routes treated again at 21:00 with pre-wet or dry treatment.	Yes
15/12/2011	8 and 8	18:00	Pre-wetted and dry	-1	Hoar Frost and Ice	All routes treated at 18:00 with predominantly pre-wetted salt. Depots on stand-by for next morning due to forecast of snow.	Yes
16/12/2011	15 and 15/20	04:30/06:30 and 19:00/20:00/ 21:00	Pre-wetted and dry	-1	Sleet and Snow/Ice and Hoar Frost	Most routes treated with dry salt in the early morning due to snow. All routes then treated in the evening with dry or pre-wet salt.	Yes (light snow)
17/12/2011	9 and 9/10	04:00, 17:00/18:00/ 19:00 and 22:00	Pre-wetted and dry	-3.5	Hoar Frost and Ice	All routes treated in the early morning with predominantly dry gritting used. A second phase of treatment is completed between 17:00 and 19:00 with an additional run at 22:00 for some routes because of rain and sleet showers.	Yes
18/12/2011	9/15 and 9/10/15/16	04:00 and 17:00	Pre-wetted and dry	-4.5	Hoar Frost and Ice	All routes gritted at 04:00 and then at 17:00 with pre-wet and dry gritting used.	Yes
19/12/2011	15 and 15/16	01:00	Pre-wetted and dry	-5	Hoar Frost and Ice	Gritting treatment similar to that of 17:00 on the previous day completed.	Yes
20/12/2011	8 and 8	04:30	Pre-wetted and dry	-0.5	Hoar Frost/Mild - No Frost	Partial treatment of networks with dry or pre-wet gritting.	Yes
21/12/2011	No Action	-	-	3.5	Mild - No Frost	-	
22/12/2011	No Action	-	-	5	Mild - No Frost	-	

23/12/2011	No Action	-	-	-1	Ice and Hoar Frost	A drop in RSTs anticipated overnight so treatment planned for next morning.	
24/12/2011	8 and 8	02:30/03:00	Pre-wetted and dry	-1	Ice and Hoar Frost	All routes gritted with pre-wet or dry salt due to presence of ice.	Yes
25/12/2011	No Action	-	-	6.5	Mild - No Frost	-	
26/12/2011	No Action	-	-	7	Mild - No Frost	-	
27/12/2011	No Action	-	-	4	Mild - No Frost	-	
28/12/2011	No Action	-	-	1.5	Mild - No Frost	-	
29/12/2011	No Action	-	-	-1	Ice and Hoar Frost	A drop in RSTs anticipated overnight so treatment planned for next morning.	
30/12/2011	8 and 8	02:00/03:00	Pre-wetted and dry	-1	Ice and Hoar Frost	All routes gritted in the early morning with pre-wet or dry salt at 02:00 or 03:00.	Yes
31/12/2011	No Action	-	-	6.5	Mild - No Frost	-	

Table B4. Area D treatments in December 2011

Date	Treatment (g/m ²)	Time of treatment(s)	Pre-wet or dry salt	Temp (°C)	Weather hazard	Comments	Correlate with Treatment
------	-------------------------------	----------------------	---------------------	-----------	----------------	----------	--------------------------

							Matrix
01/12/2011	8/9 and 10	22:00	Pre-wetted and dry	-2.5	Hoar Frost	All routes were treated but three of them were completed with dry salt as pre-wetted salt was not available.	Yes
02/12/2011	No Action	-	-	2.5	Mild - No Frost	-	
03/12/2011	No Action	-	-	0	Mild - No Frost	-	
04/12/2011	8 and 8	20:00	Pre-wetted and dry	-2	Hoar Frost	Three routes were completed with dry salt treatment with the remainder being pre-wetted.	Yes
05/12/2011	9/10	14:30/15:00	Dry	-3	Hoar Frost	All routes treated with dry salt due to the risk of ice.	Yes
06/12/2011	9 and 9	04:30 and 06:30	Pre-wetted and dry	-3	Ice/Hoar Frost and Freezing Rain	Northern routes gritted at 04:30 due to showers. Dry gritting scheduled at 06:30 after another band of showers.	Yes
07/12/2011	No Action	-	-	-2	Marginal	Increased cloud cover caused RSTs to rise so no treatment required.	
08/12/2011	9 and 10	22:30	Pre-wetted and dry	-2.5	Ice	Salting carried out on all roads after evening rain had stopped. Most routes had pre-wetted treatment apart from 7 routes which were dry salted.	Yes
09/12/2011	18 and 18	15:00/16:00	Pre-wetted and dry	-6	Marginal	All routes treated because RSTs expected to fall with ice patches.	Yes
10/12/2011	8/18 and 8/18	00:30 and 16:00	Pre-wetted and dry	-6	Marginal/Hoar Frost and Ice	All routes gritted at 00:30. Two routes (1 dry/1 pre-wet) required treatment at 16:00.	Yes
11/12/2011	No Action	-	-	-0.5	Marginal	RSTs falling so treatment anticipated next morning.	
12/12/2011	8	01:00 and 04:00	Pre-wetted	-0.5	Hoar Frost and Ice/Marginal	Most routes were pre-wetted at 01:00 but an additional treatment was carried out on some routes at 04:00.	Yes

13/12/2011	9/10	18:30/23:00	Pre-wetted and dry	-3	Hoar Frost and Rain	All routes treated at 23:00 apart from one route, which was brought forward to 18:30.	Yes
14/12/2011	8	15:00/21:00	Pre-wetted	-2	Rain and Ice	5 routes were pre-wetted at 15:00 with the remainder being completed at 21:00.	Yes
15/12/2011	8	06:00 and 16:00	Pre-wetted	-0.7	Hoar Frost and Ice/Marginal	5 routes gritted at 06:00 because of falling temp and forecast of ice. 1 route is gritted at 16:00 due to Hoar Frost and Rain.	Yes
16/12/2011	15 and 16/20	01:00/03:15/04:00, 14:30 and 21:00	Pre-wetted and dry	-0.2	Snow and Hoar Frost	Several routes required dry salt treatment at different times in the morning because of snow. 4 more routes are treated with dry salt at 14:30 before all routes are treated at 21:00.	Yes (because of snow forecast)
17/12/2011	18 and 18	16:00	Pre-wetted and dry	-5.5	Hoar Frost and Ice	All routes treated at 16:00.	Yes
18/12/2011	18 and 18	03:00, 09:00, 15:00 and 00:00	Pre-wetted and dry	-5	Hoar Frost and Ice/Snow Showers/Ice and Freezing Rain	All routes treated with pre-wetted salt at 03:00 and 5 routes additionally treated at 09:00 due to snow showers. Two more phases of treatment on all routes was completed at 15:00 and 00:00.	Yes
19/12/2011	No Action	-	-	0.5	Marginal	-	-
20/12/2011	No Action	-	-	3	Mild - No Frost	-	-
21/12/2011	No Action	-	-	3	Mild - No Frost	-	-
22/12/2011	No Action	-	-	6	Mild - No Frost	-	-
23/12/2011	9 and 10	23:00	Pre-wetted and dry	-2	Hoar Frost and Rain	All routes gritted at 23:00	Yes
24/12/2011	No Action	-	-	2.5	Mild - No Frost	-	-
25/12/2011	No Action	-	-	7.5	Mild - No Frost	-	-
26/12/2011	No Action	-	-	5	Mild - No Frost	-	-
27/12/2011	No Action	-	-	5	Mild - No Frost	-	-
28/12/2011	No Action	-	-	0.5	Mild - No Frost	-	-

Treatment Matrix Review

29/12/2011	No Action	-	-	0	Mild - No Frost	-
30/12/2011	No Action	-	-	4	Mild - No Frost	-
31/12/2011	No Action	-	-	4.5	Mild - No Frost	-

Table B5. Area E treatments in December 2011

Date	Treatment (g/m ²)	Time of treatment(s)	Pre-wet or dry salt	Temp (°C)	Weather hazard	Comments	Correlate with Treatment
------	-------------------------------	----------------------	---------------------	-----------	----------------	----------	--------------------------

							Matrix
01/12/2011	8	14:00 and 22:00	Pre-wetted	-1.5	Hoar Frost and Mild - No Frost	17 routes pre-wetted in two phases of treatment at 14:00 and 22:00.	Yes
02/12/2011	No Action	-	-	3	Mild - No Frost	-	
03/12/2011	9	23:00	Pre-wetted	-0.4	Ice	5 routes required pre-wetted treatment.	No
04/12/2011	9 and 20	05:00 and 17:00	Pre-wetted and dry	-2.1	Ice and Snow Showers/Snow and Ice	1 route was treated with pre-wetted salt at 05:00. 7 routes were treated with 20g of dry salt because of snow.	Yes (forecast of snow)
05/12/2011	No Action	-	-	-	-	No information available	
06/12/2011	20	17:00	Dry	-0.9	Snow and Ice	7 routes were gritted with dry salt because of snow.	Yes (forecast of snow)
07/12/2011	9 and 9	04:00 and 18:00	Pre-wetted and dry	-2	Snow and Ice	8 routes were gritted with pre-wetted salt at 04:00. 7 routes were gritted with dry salt at 18:00 due to snow.	Yes
08/12/2011	No Action	-	-	-1.5	Strong winds	No treatment required although previous actions report was missing.	
09/12/2011	15 and 18	16:30/18:30 and 21:00	Pre-wetted and dry	-7	Ice and Hoar Frost/Snow and Ice	All routes were gritted in the afternoon (dry salt routes 16:30/pre-wetted routes 18:00). 2 routes were treated at 21:00 due to heavy rain during past treatment.	No
10/12/2011	No Action	-	-	0.2	Mild - No Frost and Rain	-	
11/12/2011	8	21:00	Pre-wetted	-0.6	Ice	7 routes were treated with pre-wetted salt at 21:00 due to ice.	Yes
12/12/2011	8	00:15	Pre-wetted	-1	Ice	2 routes were treated with pre-wetted salt at 00:15 due to ice.	Yes

13/12/2011	8	15:00/16:00	Pre-wetted	-1	Snow	9 routes were treated because of snow.	Yes
14/12/2011	8/15	17:00/18:00 and 20:30/21:00/22:00	Pre-wetted	-4	Ice	9 routes were treated in the late afternoon. 8 routes were treated at various times in the evening due to ice.	No
15/12/2011	15/16	17:00	Pre-wetted	-3.1	Ice and Snow Showers	7 routes were treated for ice.	Yes
16/12/2011	8 and 20	01:30 and 18:00	Pre-wetted and dry	-5.1	Ice and Snow Showers	1 route was treated with pre-wetted salt at 0:30. All routes were treated at 18:00 with dry salt because of snow.	No
17/12/2011	18 and 20	04:00, 09:00 and 16:00/18:00	Pre-wetted and dry	-8	Snow Showers and Ice/ Ice and Hoar Frost	Most routes were gritted at 04:00 due to snow showers. 2 further routes were treated with dry salt because of snow at 09:00. All routes were treated at either 16:00 or 18:00.	Yes
18/12/2011	18	16:00	Pre-wetted	-4.9	Ice	Most routes were treated at 16:00.	Yes
19/12/2011	No Action	-	-	-0.3	Marginal/Ice	RSTs dropping overnight so treatments anticipated for the next morning.	
20/12/2011	8	04:00	Pre-wetted	-0.3	Ice	7 routes treated for ice.	Yes
21/12/2011	No Action	-	-	5.9	Mild - No Frost	-	
22/12/2011	No Action	-	-	3.3	Mild - No Frost	-	
23/12/2011	8	20:15	Dry	-1.1	Ice and Hoar Frost/Mild - No Frost	12 routes treated for ice.	Yes
24/12/2011	No Action	-	-	4.1	Mild - No Frost	-	
25/12/2011	No Action	-	-	7.2	Mild - No Frost	-	
26/12/2011	No Action	-	-	6.2	Mild - No Frost	-	
27/12/2011	No Action	-	-	3.4	Mild - No Frost and Rain	-	
28/12/2011	No Action	-	-	0.9	Mild - No	No treatment required.	

					Frost/Marginal		
29/12/2011	8 and 8	17:00 and 00:00	Pre-wetted and dry	-1.3	Ice and Hoar Frost/Mild - No Frost	6 routes treated with dry salt at 17:00 and 3 routes treated with pre-wetted salt at Midnight.	Yes
30/12/2011	8	02:00	Dry	-1.5	Ice and Hoar Frost/Mild - No Frost	6 routes required dry salt treatment.	Yes
31/12/2011	No Action	-	-	4.4	Mild - No Frost	-	

Table B6. Area F treatments in December 2011

Date	Treatment (g/m ²)	Time of treatment(s)	Pre-wet or dry salt	Temp (°C)	Weather hazard	Comments	Correlate with Treatment Matrix
01/12/2011	8/9	20:00/22:00/00:00	Pre-wetted	-3	Hoar Frost and Ice	All routes treated due to dropping RSTs and ice patches.	Yes
02/12/2011	No Action	-	-	0.5	Marginal	Evening update showed no treatment required.	
03/12/2011	8/9	20:00	Pre-wetted	-2.5	Hoar Frost and Ice/Mild - No Frost	2 routes required gritting and more treatment planned for next morning.	Yes
04/12/2011	8 and 20	04:00 and 14:00/16:00	Pre-wetted and dry	-2.5	Hoar Frost and Ice/Ice and Snow Showers	5 routes required pre-wetted treatment at 04:00. All routes required dry salt gritting in the afternoon due to snow.	Yes (dry salting because of snow forecast)
05/12/2011	16/20	02:00 and 14:00	Dry	-5	Ice and Snow	All routes required two phases of dry salt treatment due to snow.	Yes
06/12/2011	16	02:00	Dry	-5	Snow Showers and Hoar Frost	All routes required gritting in the early morning due to snow and ice.	Yes
07/12/2011	9	02:00, 14:00 and 23:15	Pre-wetted	-2	Ice and Hoar Frost	Three phases of pre-wetted salt treatment with several of the routes requiring treatment on each phase.	Yes
08/12/2011	9	02:00	Pre-wetted	-2	Ice	2 routes required gritting due to ice.	Yes
09/12/2011	9 and 9/16	06:00 and 14:00	Pre-wetted and dry	-5.5	Hoar Frost/Snow and Ice	2 routes (1 pre-wetted and 1 dry) were treated at 06:00. All routes were treated at 14:00 due to snow.	No
10/12/2011	9 and 16	02:00, 13:00 and 16:30	Pre-wetted and dry	-5.5	Snow and Hoar Frost	All routes required gritting in the morning due to snow. Several routes were gritted with pre-wetted salt at 13:00 and 1 additional route at 16:30.	No
11/12/2011	9	22:00/23:00	Pre-wetted	-3	Hoar Frost and Ice	Most routes treated before Midnight.	Yes

12/12/2011	9	06:00	Pre-wetted	-3	Hoar Frost and Ice/Mild - No Frost	1 route required treatment at 06:00 but nothing needed for the rest of day.	Yes
13/12/2011	8/9 and 9	01:00, 03:00 and 14:00	Pre-wetted and dry	-1.5	Ice	Several routes required treatment at various different times of the day.	Yes
14/12/2011	9 and 9/20	01:00/02:00, 14:00 and 19:00/21:00	Pre-wetted and dry	-4.5	Hoar Frost/Snow and Ice	A range of different treatments for different routes were implemented throughout the day	Yes (dry salting because of snow forecast)
15/12/2011	9/18	02:00 and 18:00	Pre-wetted	-4.5	Ice and Hoar Frost	4 routes were treated at 02:00. All routes required treatment at 18:00 and higher spread rates due to ice.	Yes
16/12/2011	9 and 16	02:00 and 18:00	Pre-wetted and dry	-4.5	Snow and Ice	All routes were treated with pre-wetted salt at 02:00 and then dry salt at 18:00.	Yes
17/12/2011	15/18 and 16/18	02:00 and 15:00	Pre-wetted and dry	-4.5	Snow and Ice/Ice and Hoar Frost	All routes treated for snow at 02:00. Dry and pre-wetted treatment used on routes at 15:00.	Yes
18/12/2011	9 and 16	02:00 and 15:00	Pre-wetted and dry	-5.5	Snow and Ice/Ice and Hoar Frost	All routes treated with dry salt at 02:00 due to snow. All routes gritted again at 15:00 but some routes were pre-wetted.	No
19/12/2011	9 and 16	02:00 and 18:00	Pre-wetted and dry	-5	Snow and Ice	All routes treated at 02:00 with pre-wetted and dry salt implemented. Several routes were treated with dry salt at 18:00.	Yes
20/12/2011	10	01:00/02:00	Dry	-2.5	Hoar Frost and Ice	A few routes treated.	Yes
21/12/2011	No Action	-	-	3.5	Mild - No Frost	-	
22/12/2011	No Action	-	-	4	Mild - No Frost	-	
23/12/2011	9	18:00/19:00/22:00	Dry	-1.5	Ice	Several routes treated for ice.	No
24/12/2011	9	01:00	Dry	-1.5	Ice	4 routes treated for ice.	No
25/12/2011	No Action	-	-	5.5	Mild - No Frost	-	

Treatment Matrix Review

26/12/2011	No Action	-	-	6	Mild - No Frost	-	
27/12/2011	No Action	-	-	2.5	Mild - No Frost	-	
28/12/2011	8	00:00	Pre-wetted	-1	Hoar Frost and Ice/Mild - No Frost	4 routes required pre-wetted treatment for Ice.	Yes
29/12/2011	8 and 8/16	02:30, 16:00/21:00/23:00/00:00	Pre-wetted and dry	-2.5	Ice and Hoar Frost	1 route was pre-wetted at 02:30. Most routes were treated with dry salt at different times in the evening.	Yes
30/12/2011	16	01:00/02:00	Dry	-2.5	Ice and Hoar Frost	Several routes treated for ice at various times in the morning.	Yes
31/12/2011	No Action	-	-	2	Mild - No Frost	-	

B.2 Summary of treatments made in February 2012

Table B7. Area A treatments in February 2012

Date	Treatment (g/m ²)	Time of treatment(s)	Pre-wet or dry salt	Temp (°C)	Weather hazard	Comments	Correlate with Treatment Matrix
01/02/2012	15/18 and 16/18	04:00 and 14:30	Pre-wetted and dry salt	-7.5	Hoar Frost	Most routes were treated at 04:00 with a range of treatments implemented. All routes were treated at 14:30 with 18g of pre-wetted salt.	Yes
02/02/2012	18 and 18	04:00 and 19:00	Pre-wetted and dry salt	-9	Hoar Frost	All routes were treated at 04:00 with 18g of pre-wetted or dry salt. At 19:00, most routes were treated with dry salt, but two used pre-wetted salt.	Yes
03/02/2012	9/18 and 10/18	10:00 and 22:00	Pre-wetted and dry salt	-8.5	Hoar Frost and Ice	All routes were treated at 10:00 with predominantly dry salt used (2 routes of pre-wet). All routes were treated in the evening with 18g of pre-wetted salt.	Not entirely
04/02/2012	20	11:00	Dry salt	-8.5	Snow and sleet	All routes were gritted with 20g of dry salt due to snow and sleet.	Yes
05/02/2012	8 and 8	15:00	Pre-wetted and dry salt	-1.5	Hoar Frost and Ice	All routes were treated at 15:00. Two routes were pre-wetted and the remaining were dry salted.	Yes
06/02/2012	8 and 8	19:00	Pre-wetted and dry salt	-0.5	Ice	Most routes were treated due to ice on the roads. Pre-wetted salt was used on two routes and the remaining were dry salted.	Yes
07/02/2012	18 and 18	14:30	Pre-wetted and dry salt	-7	Ice and Hoar Frost	18g of pre-wetted or dry salt was used.	Yes

08/02/2012	9/15 and 10/16	04:00 and 18:45	Pre-wetted and dry salt	-5.5	Ice and Hoar Frost	A secondary treatment was required at 04:00 due to RSTs well below zero. A full treatment was implemented at 18:45 with predominantly 16g of dry salt used.	Yes
09/02/2012	20	15:00 and 19:00/20:00	Dry salt	-0.5	Snow and Ice	Most routes were treated with 20g of dry salt at 15:00. An additional treatment was required because of falling RSTs.	Yes
10/02/2012	16	11:30	Dry salt	-8.5	Hoar Frost and Ice	All routes were treated with 16g of dry salt.	No
11/02/2012	16 and 20	02:00, 14:00 and 00:00	Dry salt	-7.5	Ice and Freezing Rain	All routes were treated with 18g of dry salt at 02:00 and 14:00. 20g of dry salt was required for all routes at 00:00 because of the ongoing threat of ice formation.	Not entirely
12/02/2012	No Action	-	-	-0.5	Marginal	-	-
13/02/2012	8 and 8	20:00	Pre-wetted and dry salt	-0.5	Marginal	8g of pre-wetted or dry salt was implemented on some routes at 20:00.	Yes
14/02/2012	No Action	-	-	3	Mild - No Frost	-	-
15/02/2012	No Action	-	-	3	Mild - No Frost	-	-
16/02/2012	No Action	-	-	4	Mild - No Frost	-	-
17/02/2012	No Action	-	-	6.5	Mild - No Frost	-	-
18/02/2012	8/15 and 8/16	20:00	Pre-wetted and dry salt	-3.5	Ice	A range of different treatments was required at 20:00 due to ice.	Yes
19/02/2012	9 and 10	18:00	Pre-wetted and dry salt	-3.5	Hoar Frost and Ice	9g of pre-wetted salt and 10g of dry salt were used across all routes at 18:00.	Yes
20/02/2012	No Action	-	-	1.5	Mild - No Frost	-	-
21/02/2012	No Action	-	-	2.5	Mild - No Frost	-	-
22/02/2012	No Action	-	-	7.5	Mild - No Frost	-	-
23/02/2012	No Action	-	-	7.5	Mild - No Frost	-	-
24/02/2012	No Action	-	-	6.5	Mild - No Frost	-	-

Treatment Matrix Review

25/02/2012	8 and 8	22:00	Pre-wetted and dry salt	-2	Hoar Frost	Several routes required 8g of dry or pre-wetted salt at 22:00.	Yes
26/02/2012	No Action	-	-	5	Mild - No Frost	-	-
27/02/2012	No Action	-	-	6.5	Mild - No Frost	-	-
28/02/2012	No Action	-	-	6	Mild - No Frost	-	-
29/02/2012	No Action	-	-	4	Mild - No Frost	-	-

Table B8. Area B treatments in February 2012

Date	Treatment (g/m ²)	Time of treatment (s)	Pre-wet or dry salt	Temp (°C)	Weather hazard	Comments	Correlate with Treatment Matrix
01/02/2012	9 and 10	03:00 and 20:00	Pre-wetted and dry salt	-5	Ice and Snow Showers	All routes were treated with either 9g of pre-wetted salt/10g of dry salt. All routes were treated once more with predominantly pre-wetted salt used.	Yes
02/02/2012	No Action	-	-	-6.5	Snow Showers and Hoar Frost	Treatment scheduled for the next morning.	-
03/02/2012	9/18 and 20	02:00 and 20:00/22:00	Pre-wetted and dry salt	-6.5	Snow Showers and Ice	A range of treatments was carried out across all routes at 02:00. Most routes were treated with 18g of pre-wetted salt at 22:00, but one route was gritted with 20g of dry salt.	Not entirely
04/02/2012	15/18 and 16/20	03:00, 13:00 and 15:00	Pre-wetted and dry salt	-5	Snow Drifting	Most routes were treated at 03:00 with pre-wetted salt. Additional treatments of either 18g pre-wetted salt/20g of dry salt were required at 13:00 and 15:00 due to snow.	Yes
05/02/2012	No data available	-	-	-	-	-	-
06/02/2012	15 and 16	15:00	Pre-wetted and dry salt	-5	Ice and Hoar Frost	All routes were treated with either 15g of pre-wetted salt/16g of dry salt. Additional treatments of either 18g of pre-wet/20g of dry salt were implemented at 10:30.	Yes
07/02/2012	9/18 and 10/20	03:00, 15:00 and 00:00	Pre-wetted and dry salt	-5	Snow Showers and Ice	All routes were treated at 03:00 with either 15g of pre-wetted salt/16g of dry salt. Another set of treatments was required at 15:00 with smaller spread rates. At 00:00, 18g of pre-wetted salt/20g of dry salt was used.	Not entirely

08/02/2012	15 and 16/20	21:00	Pre-wetted and dry salt	-4	Ice and Hoar Frost	A range of treatments were required across all routes due to ice and hoar frost.	Yes
09/02/2012	15/18 and 16/20	15:00 and 19:30	Pre-wetted and dry salt	-7	Snow	At 15:00, 18g of pre-wetted salt/20g of dry salt was implemented across the area. An additional treatment of 18g pre-wetted salt was spread across all routes at 19:30.	Yes
10/02/2012	15/16 and 18/20	21:00 and 10:30	Pre-wetted and dry salt	-2	Ice and Hoar Frost	All routes were treated with either 15g of pre-wetted salt/16g of dry salt. Additional treatments of either 18g of pre-wet/20g of dry salt were implemented at 10:30.	Not entirely
11/02/2012	18 and 18/20	21:00	Pre-wetted and dry salt	-7.5	Ice and Hoar Frost	Most routes were treated with 18g of dry salt due to hoar frost and ice.	Yes
12/02/2012	8/18 and 8/10/15/18/20	05:00, 09:00 and 22:00	Pre-wetted and dry salt	-3.4	Snow and Ice	At 05:00, all routes were treated due to snow showers and ice. Most routes were re-treated at 09:00 with 15g of dry salt due to further snow showers. At 22:00, smaller spread rates were required.	Not entirely
13/02/2012	8 and 8	21:00	Pre-wetted and dry salt	0	Ice and Hoar Frost	8g of pre-wetted or dry salt was used on all routes at 21:00.	Yes
14/02/2012	No Action	-	-	2.5	Mild - No frost	-	-
15/02/2012	8 and 8	21:00	Pre-wetted and dry salt	1	Hoar Frost	Half of the routes needed 8g of either pre-wet or dry salt due to hoar frost.	Yes
16/02/2012	No Action	-	-	3	Mild - No frost	-	-
17/02/2012	No Action	-	-	6	Mild - No frost	-	-
18/02/2012	8 and 10	22:00	Pre-wetted and dry salt	-2	Ice and Rain	The majority of routes with the exception of one (10g dry) were treated with 8g of pre-wetted salt.	Not entirely
19/02/2012	9 and 10	19:00	Pre-wetted and dry salt	-3.5	Ice and Hoar Frost	The majority of routes with the exception of one (10g dry) were treated with 9g of pre-wetted salt.	Yes

Treatment Matrix Review

20/02/2012	No Action	-	-	1	Mild - No frost	-	-
21/02/2012	No Action	-	-	2.5	Mild - No frost	-	-
22/02/2012	No Action	-	-	6.5	Mild - No frost	-	-
23/02/2012	No Action	-	-	6.5	Mild - No frost	-	-
24/02/2012	No Action	-	-	6	Mild - No frost	-	-
25/02/2012	No Action	-	-	1	Mild - No frost	-	-
26/02/2012	No Action	-	-	3.5	Mild - No frost	-	-
27/02/2012	No Action	-	-	7	Mild - No frost	-	-
28/02/2012	No Action	-	-	7.5	Mild - No frost	-	-
29/02/2012	No Action	-	-	3	Mild - No frost	-	-

Table B9. Area C treatments in February 2012

Date	Treatment (g/m ²)	Time of treatment(s)	Pre-wet or dry salt	Temp (°C)	Weather hazard	Comments	Correlate with Treatment Matrix
01/02/2012	18 and 20	22:00	Pre-wetted and dry salt	-5	Snow Showers and Ice	3 routes were treated with 20g of dry salt and the remaining routes were all pre-wetted.	Yes
02/02/2012	18	19:00/22:00	Pre-wetted salt	-6.5	Snow and Ice	All routes were gritted with 18g of pre-wetted salt with 7 routes treated at 19:00 and the remainder at 22:00.	Yes
03/02/2012	18 and 20	19:00/22:00	Pre-wetted and dry salt	-6.5	Snow and Ice	Treatments took place at either 19:00 or 22:00 with either 18g pre-wetted salt/20g dry salt used.	Yes
04/02/2012	18 and 18/20	14:00 and 17:00/18:00	Pre-wetted and dry salt	-2.5	Snow and Snow Showers	All routes are treated with either 18g pre-wetted salt/20g dry salt. A repeat treatment was required because of snow and ice.	Yes
05/02/2012	15 and 16	17:00	Pre-wetted and dry salt	-3	Ice and Hoar Frost	All routes were gritted with either 15g of pre-wetted salt/16g dry salt.	Yes
06/02/2012	9/18 and 10/18/20	00:01 and 19:00	Pre-wetted and dry salt	-3	Ice and Hoar Frost	All routes were gritted in the early morning with a range of dry and pre-wetted salt treatments implemented. A full treatment was also run at 19:00 with higher spread rates.	Yes
07/02/2012	9/16/18 and 10/16/18	01:00/03:00 and 17:00	Pre-wetted and dry salt	-7	Ice and Snow Showers	A range of treatments were arranged at 01:00 because of heavy snow showers. This was followed in the afternoon by a treatment of either 18g pre-wetted salt/18g dry salt.	Yes

08/02/2012	9/15/18 and 9/10/15/18	02:00 and 20:00	Pre-wetted and dry salt	-3	Ice	A full line-up of treatment was run at 02:00 with 15g of pre-wetted/dry salt. Another treatment was implemented across the network at 20:00.	Yes
09/02/2012	18 and 10/18/20	16:00 and 19:30	Pre-wetted and dry salt	-5	Snow and Ice	A range of treatments were used across the whole area at 16:00. 10g of dry salt was then used across several routes at 19:00 due to snow.	Yes
10/02/2012	9/18 and 9/18/20	03:00/04:00 and 19:00	Pre-wetted and dry salt	-8	Ice and Hoar Frost	High spread rates were used of pre-wet and dry salt in the 03:00/04:00 treatment due to a possible band of showers of the North Sea.	Not entirely
11/02/2012	9 and 9	03:00 and 18:00	Pre-wetted and dry salt	-9	Ice and Hoar Frost	All routes were treated at 03:00 with either 9g of pre-wetted/dry salt. A repeat treatment of the same spread rate took place at 18:00.	No
12/02/2012	8/18 and 8/20	00:01/03:00 and 23:00	Pre-wetted and dry salt	-9	Ice and Freezing Rain	All routes were treated in the early morning with either pre-wetted or dry	Not entirely
13/02/2012	No Action	-	-	-2.8	Mild - No Frost	-	-
14/02/2012	8 and 8	00:01	Pre-wetted and dry salt	0.5	Hoar Frost and Ice	All routes were treated at 00:01 with either 8g of pre-wetted/dry salt.	Yes
15/02/2012	No Action	-	-	3	Mild - No Frost	-	-
16/02/2012	8	04:00	Dry	1	Ice	Three routes were treated with 8g of dry salt due to ice.	Yes
17/02/2012	No Action	-	-	4.5	Mild - No Frost	-	-
18/02/2012	8 and 8/18	23:00	Pre-wetted and dry salt	-3	Ice and Hoar Frost	The whole area was treated with both pre-wetted and dry salt used for the treatments.	No
19/02/2012	9 and 9/10	18:00	Pre-wetted and dry salt	-4.5	Ice and Hoar Frost	All routes were treated at 18:00 with either pre-wetted or dry salt.	Not entirely
20/02/2012	No Action	-	-	1.5	Mild - No Frost	-	-

Treatment Matrix Review

21/02/2012	No Action	-	-	2.5	Mild - No Frost	-	-
22/02/2012	No Action	-	-	6.5	Mild - No Frost	-	-
23/02/2012	No Action	-	-	6	Mild - No Frost	-	-
24/02/2012	No Action	-	-	1.5	Mild - No Frost	-	-
25/02/2012	No Action	-	-	0.5	Mild - No Frost/Marginal	-	-
26/02/2012	No Action	-	-	4	Mild - No Frost	-	-
27/02/2012	No Action	-	-	6	Mild - No Frost	-	-
28/02/2012	No Action	-	-	9.5	Mild - No Frost	-	-
29/02/2012	No Action	-	-	3.5	Mild - No Frost	-	-

Table B10. Area D treatments in February 2012

Date	Treatment (g/m ²)	Time of treatment (s)	Pre-wet or dry salt	Temp (°C)	Weather hazard	Comments	Correlate with Treatment Matrix
01/02/2012	18	14:00/01:00	Pre-wet & Dry	-8	Hoar Frost		Yes
02/02/2012	18	14:00/01:00	Pre-wet & Dry	-9.5	Hoar Frost	All Routes @ 14:00 Routes 6-7 14-21 41-44 18g Dry Routes 1-5 8-13 22-40 18g Wet All Routes @ 01:00 - Interim report to follow Routes 6-7 14-21 41-44 18g Dry Routes 1-5 8-13 22-40 18g Wet	Yes
03/02/2012	18	19:00	Pre-wet & Dry	-10	Hoar Frost	All Routes @ 19:00 18g WET (Routes 6, 6a, 7 18g DRY)	Yes
04/02/2012	18/20	11:00:00/20:30	Pre-wet & Dry	-9	Snow-Snow Showers/Snow -Sleet		Yes
05/02/2012	20/9-10	03:00:00/15:00	Dry/Pre-wet & Dry	-2	Snow-Sleet/Hoar Frost-Ice	All Routes @ 15:00 9g Pre-Wet (Except Routes 6, 6a, 7, 24-30 & 41-44 10G Dry)	Yes
06/02/2012	8	00:00:00/22:00	Pre-wet & Dry	-1.5	Hoar Frost-Ice	Routes 30 & 15 Out @ 22:00 8g Pre Wet - All other routes out @ 00:00 8g Pre Wet Except (Routes 6, 6a, 7,41,42,43,44 8g Dry)	Yes
07/02/2012	9-10/18	14:00/01:00/15:00/16:00	Pre-wet & Dry	-7	Hoar Frost-Snow/Hoar Frost-Ice	Route 22,23,31,32 will go out @ 15:00 9g Pre Wet - Route 29 will go out @ 14:00 10g Dry - Min RST -7 ACTION Route 22,23,31,32 will go out @ 16:00 9g Pre Wet Min RST -7 ACTION	18 or 20?
08/02/2012	9-10/18-20	14:00/00:00	Pre-wet & Dry	-7	Hoar Frost-Ice	All routes leaving depots @ 00:00 All Routes 20g Dry	Yes

09/02/2012	20	12:00:00/20:00	Dry	-1	Sleet-Snow	ALL ROUTES @ 20:00 - 20G DRY - TIMES SUBJECT TO CHANGE DEPENDENT ON LOCAL RAINFALL	Yes
10/02/2012	20/18	03:00:00/13:00 /00:00	Dry/Pre-wet & Dry	-1/-9	Snow-Ice/Ice	ALL ROUTES @ 13:00 18g PRE-WET (ROUTES 6, 6a, 7 41-44 18g DRY) POSSIBLE 2ND TREATMENT @ 23:00 - TO BE CONFIRMED ALL ROUTES 18g PRE-WET @ 00.00 (ROUTES 6, 6a & 7 18g DRY)	Yes/20?
11/02/2012	18	19:00	Pre-wet & Dry	-6.5	Ice	Gritting at 18g wet on all routes at 19:00 hrs, except routes 6, 6A, & 7 which will run 18g dry. Min RST: - 6.5 C, and monitor thereafter.	Yes/20?
12/02/2012	No action			1	Mild - No frost		-
13/02/2012	No action			1	Mild - No frost		-
14/02/2012	No action			2	Mild - No frost		-
15/02/2012	No action			2	Mild - No frost		-
16/02/2012	No action			1	Mild - No frost		-
17/02/2012	No action			4	Mild - No frost		-
18/02/2012	15	21:00	Pre-wet & Dry	-3	Hoar Frost-Ice	ALL ROUTES 15g PRE-WET @ 21:00 (ROUTES 6,6a & 7 15g DRY)	15 or 20?
19/02/2012	9-10	19:00	Pre-wet & Dry	-4.5	Ice-Hoar Frost	ROUTES 1-7, 34-37 10g DRY ALL OTHER ROUTES 9g PRE-WET @ 19:00	Yes
20/02/2012	No action			1.5	Mild - No frost		-
21/02/2012	No action			1.5	Mild - No frost		-
22/02/2012	No action			3	Mild - No frost		-
23/02/2012	No action			6	Mild - No frost		-
24/02/2012	No action			6.5	Mild - No frost		-
25/02/2012	8	01:00	Pre-wet & Dry	-1.5	Hoar Frost	Grit on all routes as per report	Yes
26/02/2012	8	01:30	Dry	-1.5	Hoar Frost	Route 6a should be 01:30 , rest are as per previous report	Yes
27/02/2012	No action			4	Mild - No frost		-
28/02/2012	No action			6.5	Mild - No frost		-

Table B11. Area E treatments in February 2012

Date	Treatment (g/m ²)	Time of treatment (s)	Pre-wet or dry salt	Temp (°C)	Weather hazard	Comments	Correlate with Treatment Matrix
01/02/2012	9 and 10	17:00	Pre-wetted and dry salt	-9.4	Hoar Frost	Most of the routes were treated with either 10g of dry salt/9g of pre-wetted salt.	No
02/02/2012	9	17:00	Pre-wetted salt	-7.4	Hoar Frost	Most routes were treated with 9g of pre-wetted salt at 17:00.	No
03/02/2012	8	16:30	Pre-wetted salt	-7	Hoar Frost	Most routes were treated with 18g of pre-wetted salt at 16:30.	No
04/02/2012	20	08:00	Dry salt	-2	Snow Showers and Freezing Rain	Most routes were treated with 20g of dry salt because of forecast snow and possibility of snow showers.	Yes
05/02/2012	15 and 20	04:30 and 18:00	Pre-wetted and dry salt	-5	Ice	Most routes were gritted with dry salt due to ice. Several routes were then treated again at 18:00 with pre-wetted salt.	Yes
06/02/2012	9/15	02:30 and 18:00	Pre-wetted salt	-4.8	Hoar Frost and Ice	Several routes were treated at 02:30 with 9g of pre-wetted salt. Most routes were also treated at 18:00 with 15g of pre-wetted salt.	Yes
07/02/2012	15/18	06:00 and 18:00/20:30	Pre-wetted salt	-6.6	Hoar Frost and Ice	Several routes were treated with 15g of pre-wetted salt in the morning. Most routes were then treated in the evening with 18g of pre-wetted salt.	Yes
08/02/2012	9	06:00	Pre-wetted salt	-7	Hoar Frost	Most routes were treated with pre-wetted salt at 06:00.	No
09/02/2012	18	00:30	Pre-wetted salt	-7	Freezing Rain and Ice	Several routes were treated with 18g of pre-wetted salt due to the risk of freezing rain and ice.	Yes

10/02/2012	8	17:00/19:00/23:00	Pre-wetted salt	-2.2	Ice	8g of pre-wetted salt was used at various times in the evening across most routes.	No
11/02/2012	8/18	17:30	Pre-wetted salt	-1.5	Ice	Pre-wetted salt was used on most routes at 17:30.	No
12/02/2012	No Action	-	-	-1.1	-	-	-
13/02/2012	No Action	-	-	-1	-	-	-
14/02/2012	No Action	-	-	0.1	Marginal	-	-
15/02/2012	No Action	-	-	0.5	Mild - No Frost	-	-
16/02/2012	No Action	-	-	-0.5	Mild - No Frost	-	-
17/02/2012	No Action	-	-	3.8	Mild - No Frost	-	-
18/02/2012	16	20:30	Dry salt	-5.7	Ice and Hoar Frost	The majority of routes were treated with 16g of dry salt due to wintry showers.	No
19/02/2012	9	20:30	Pre-wetted salt	-3.7	Hoar Frost	6 routes were treated with pre-wetted salt; meanwhile the others required no action.	-
20/02/2012	No Action	-	-	3.5	Mild - No Frost	-	-
21/02/2012	No Action	-	-	5.2	Mild - No Frost	-	-
22/02/2012	No Action	-	-	6.7	Mild - No Frost	-	-
23/02/2012	No Action	-	-	5.9	Mild - No Frost	-	-
24/02/2012	No Action	-	-	-1	Mild - No Frost	-	-
25/02/2012	No Action	-	-	3.3	Mild - No Frost	-	-
26/02/2012	No Action	-	-	3.4	Mild - No Frost	-	-
27/02/2012	No Action	-	-	6.1	Mild - No Frost	-	-
28/02/2012	No Action	-	-	5.5	Mild - No Frost	-	-
29/02/2012	No Action	-	-	4.5	Mild - No Frost	-	-

Table B12. Area F treatments in February 2012

Date	Treatment (g/m ²)	Time of treatment(s)	Pre-wet or dry salt	Temp (°C)	Weather hazard	Comments	Correlate with Treatment Matrix
01/02/2012	15 and 10/16	02:00 and 14:00/15:00	Pre-wetted and dry salt	-6.5	Hoar Frost and Ice	2 routes were gritted with dry salt at 02:00. All routes were then treated with either 10/16g of dry salt except for two, which used pre-wet salt.	Not entirely
02/02/2012	9/15	01:00/02:00 and 21:00/22:00	Pre-wetted salt	-6.5	Hoar Frost	All routes were treated with pre-wetted salt in the early morning. 4 routes were treated in the evening (2 with MgCl ₂).	Not entirely
03/02/2012	9/16	01:00 and 14:00/15:00	Pre-wetted salt	-7	Hoar Frost	Several routes were treated with pre-wetted salt in the morning. All routes were treated with pre-wetted salt in the afternoon (1 route used MgCl ₂).	No
04/02/2012	16	02:00	Pre-wetted salt	-7	Hoar Frost	All routes were treated in the early morning with 16g of pre-wetted salt.	No
05/02/2012	9/16	02:00 and 15:00	Pre-wetted salt	-4.5	Hoar Frost and Ice	All routes were treated with pre-wetted salt at 15:00.	Not entirely
06/02/2012	9/10	02:00, 14:00 and 18:30	Dry salt	-4.5	Hoar Frost and Ice	All routes were treated with 10g of dry salt at 02:00 and then repeated with 9g of dry salt at 14:00. 5 routes were gritted at 18:30 due to unexpected rain showers.	Not entirely
07/02/2012	9/16 and 9/15/16	01:00/02:00, 14:00 and 20:00	Pre-wetted and dry salt	-8	Hoar Frost and Ice	All routes were gritted with either 10/15g of dry salt and once more with 16g of either pre-wetted/dry salt in the afternoon. Two routes were additionally treated at 20:00.	Not entirely

08/02/2012	9/16	02:00 and 14:00	Dry salt	-5	Ice and Hoar Frost	All routes were treated with 16g of dry salt at 02:00. Further treatment with smaller spread rates was carried out at 14:00.	Yes
09/02/2012	16	14:00/18:00/20:00	Dry salt	-2	Snow and Ice	All routes were treated with 16g of dry salt at various times during the afternoon/evening with additional treatments required.	No
10/02/2012	9/16	03:00 and 14:00	Dry salt	-7	Ice and Hoar Frost	All routes were treated at 03:00 with 16g of dry salt. An additional treatment was required with smaller spread rates at 14:00.	No
11/02/2012	9/16	02:00 and 14:00/16:00/18:00	Dry salt	-3	Hoar Frost and Ice	At 02:00, all routes were treated with either 9g/16g of dry salt. An additional treatment of 9g dry salt was carried out in the evening.	Yes
12/02/2012	7 and 9/16	02:00 and 18:00	Pre-wetted and dry salt	-2	Hoar Frost and Ice	All routes were treated at 02:00 with either 9g/16g of dry salt. A further treatment with 7g of pre-wetted salt was required at 18:00.	No
13/02/2012	8 and 8	05:30 and 19:00	Pre-wetted and dry salt	-2	Ice and Hoar Frost	2 routes were gritted with dry salt at 05:30. Most routes were then treated with pre-wetted salt in the evening.	Yes
14/02/2012	8	01:00	Dry salt	1.5	Mild - No Frost	Three routes were gritted with dry salt at 01:00 due to heavy rain (-1°C at the time). No treatment was required during the day.	Yes
15/02/2012	8	23:00	Pre-wetted salt	0	Mild - No Frost	Three routes were treated with pre-wetted salt in the evening.	Yes
16/02/2012	No Action	-	-	0	Marginal	-	-
17/02/2012	8	02:30	Dry salt	1.5	Mild - No Frost	1 route was gritted with dry salt due to ice in the early morning.	Yes

18/02/2012	15 and 16	10:00, 18:00 and 21:00/22:00/23:00	Pre-wetted and dry salt	-5	Ice	2 routes were gritted with dry salt at 10:00 and 2 with pre-wetted salt at 18:00. All routes were then treated in the evening/next morning with higher spread rates.	Yes
19/02/2012	9 and 10	14:00	Pre-wetted and dry salt	-3	Hoar Frost	Two routes were treated with 10g of dry salt and the remaining with 9g of pre-wetted salt.	Yes
20/02/2012	9 and 10	02:00	Pre-wetted and dry salt	-3	Hoar Frost	Two routes were treated with 10g of dry salt and the remaining with 9g of pre-wetted salt.	Yes
21/02/2012	No Action	-	-	4.5	Mild - No Frost	-	-
22/02/2012	No Action	-	-	4.5	Mild - No Frost	-	-
23/02/2012	No Action	-	-	6	Mild - No Frost	-	-
24/02/2012	No Action	-	-	-1	Marginal	-	-
25/02/2012	8/9	02:00	Pre-wetted salt	1	Mild - No Frost	Most routes were treated with pre-wetted salt when temp. dipped below 0°C in the early morning.	Yes
26/02/2012	No Action	-	-	1	Mild - No Frost	-	-
27/02/2012	No Action	-	-	4	Mild - No Frost	-	-
28/02/2012	No Action	-	-	4.5	Mild - No Frost	-	-
29/02/2012	No Action	-	-	2.5	Mild - No Frost	-	-

Appendix C Contractual performance trials

In the trials, the amount of de-icer discharged over a distance of 2km was to be within $\pm 6\%$ of the target amount. The tests simulated spreading at 64km/h (i.e. the spreaders were stationary) at spread widths of 9, 11 and 13m.

The salt distribution profile was measured in dynamic tests when the spreaders were travelling at 64km/h with the spread width set to 13m. This setup was to replicate the spreading of a three lane motorway and hard shoulder. In order to determine the salt distribution, salt was collected from three test strips that extended across the test site and were from 10 to 14m apart. Each strip comprised 11 adjacent panels that were 2m long in the direction of travel. There were two 1.8m wide panels in each lane, two 1.5m wide panels in the hard shoulder (panels 2 and 3 in Strip 1) and one in the right margin (panel 13), and two 2m wide panels in the left and right verges (panels 1 and 11).

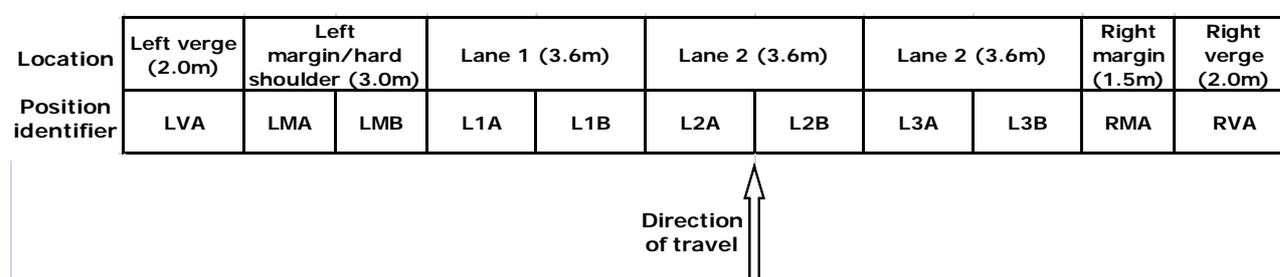


Figure 44. Positions of salt collection panels in the performance trials

The performance criteria to be satisfied in each dynamic test were as follows:

- The mass of de-icer collected from the main zone, margins and verges: $\leq \pm 10\%$ of the target amount.
- The mass of de-icer collected from one strip and the mean of the three strips: $\leq \pm 20\%$.
- The mass of de-icer collected from both verges: $\leq 5.0\%$ of total mass collected.
- The mean coverage for each lane: $\leq \pm 30\%$ of the nominal spread rate.
- The coverage in each panel in the main zone $\geq 50\%$ and $\leq 160\%$ of the nominal spread rate (for pre-wetted salt).
- The mean coverage in the left margin: $\geq 25\%$ of the nominal spread rate.

The pre-wetted salting and the dry salting trials were carried out with 6.3mm Thawrox, a de-icer that is commonly used by the Agency's Service Providers. The spreader settings controlling the salt distribution profile that satisfied the performance requirements were subsequently adopted across the fleet for spreading 6.3mm Thawrox. The spreader settings controlling the total amount of de-icer discharged were established by calibrating each spreader in turn.

Appendix D Spreader discharge tests in Area 8

Table D1 shows the amounts of salt and brine discharged in the discharge tests in Area 8 as measured by the weighbridge, the on-board weighing system, and the salt and brine counters. Greater variability was observed in the results from the on-board weighing system than in the weighbridge measurements.

Table D1. De-icer discharged in discharge tests in Area 8

Test No.	Vehicle speed (km/h)	Distance spread (m)	Weigh-bridge (kg)	On-board weighing system (kg)	Salt counter (kg)	Brine counter (l)	Salt and brine counters (kg)	Weigh-bridge counters (%)
1	40	2000	290	260	177	62	251	115
2	64	2000	290	320	178	62	252	115
3	40	2000	305	330	177	63	253	121
4	64	2000	300	280	176	62	250	120
1 + 3	40	4000	595	590	354	125	504	118
2 + 4	64	4000	590	600	354	124	503	117
1 to 4	-	8000	1185	1190	708	249	1007	118

Taking the total amounts of salt and brine discharged over the two discharge tests at each speed, the totals measured by the weighbridge were 595kg at 40km/h and 590kg at 64km/h. The totals measured by the on-board weighing system were 590kg and 600kg, respectively. Therefore, the weighbridge and the on-board weighing system confirm that the amounts of salt and brine discharged were not dependent on the speed of the spreader. Thus the over-spreading measured in the distribution runs at Aston Down was not because the runs were carried out at 40km/h rather than the normal speed of 64/km for spreading on motorways.

When spreading at 10g/m² over 2km with a 12.6m spread width, the total amount of de-icer discharged should be 252kg. The totals recorded by the salt and brine counters differed from 252kg by 2kg at worst. Averaged over the four discharge tests, the results show that approximately 18% more de-icer was discharged compared to that indicated on the salt and brine counters. Therefore, it would appear that the spreader used for the distribution runs and the road trials was over-spreading the target amount of de-icer by about 18% during the discharge tests in Area 8.

It was not clear how the over-spreading occurred and whether the amounts of salt and brine discharged exceeded the target amount by the same percentage. Table D2 shows how over-spreading the amounts of dry salt or brine affect the over-spreading in terms of the amount of salt per metre. If only the dry salt component is over-spread and the total amount of de-icer is over-spread by 26% (i.e. as was measured by the on-board weighing system in distribution Runs 3 and 4 with 6.3mm salt at Aston Down, the total amount of salt is over-spread by 34%. This percentage is comparable to the over-spreading that was calculated from the salt collected at Aston Down.

Table D2. Effect of over-spreading on the amount of salt discharged

Over-spreading by weight of de-icer (%)	Extra dry salt (% of target)	Extra brine (% of target)	Dry salt:brine mix proportions	Salt/m	Over-spreading by weight of salt (%)
0	0	0	70:30	96.5	0
18	26	0	74:26	119.2	23
18	0	60	59:41	101.5	5
26	37	0	77:23	129.8	34
26	0	87	56:44	104.7	8

Different 6.3mm salts with different moisture contents were used at Aston Down and in Area 8, and this may have had an effect on the discharge rate. If only the dry salt component was over-spread in the discharge tests, Table D2 indicates that the amount of salt was over-spread by 23%. This figure is in reasonable agreement with the amount of salt over-spread in distribution Runs 1 and 2 with 3mm salt. It appears, therefore, that it is unlikely that the brine component was over-spread significantly but the dry salt component was.

The salt counter was in agreement with the amount of salt discharged when the spreader was calibrated for each de-icer at a simulated speed of 64km/h. However, it was concluded that the salt counter was not consistent with the amount of de-icer discharged during the distribution runs. It should be noted that the authors have no evidence that other spreaders of the same type over-spread in the same way as was measured in the distribution runs and the discharge tests. The salt counters on the two spreaders used for the contractual performance trials conducted by Schmidt were shown to be accurate. The amount of salt discharged was within $\pm 5\%$ of the target in the performance trials. Service Providers have not reported more salt usage than expected.

Appendix E Example Fleetstar reports

HA Service Provider Summary Report Date: Wed 13/06/2012 17:15

Report start: Thu 01/03/2012 Report end: Sat 31/03/2012

Base (Collapse All)	Vehicle	Journey Start	Journey Mileage	Spread Mileage	Spread Time	Depot Out Time (hh:mm)	Depot In Time (hh:mm)	Run Time	Plough Mileage	Plough Time	Spot Count	Salt Used Tonnes	Brine Used Ltrs	Fuel Used Ltrs
- Area 9 - Bury Court			189.3	50.3	01:23			04:43	0	00:00	0	6.1	1530	98
	WS160-WP09 OOE - R09	18 Mar 201 21:08	77.1	18.7	00:30	21:09	23:13	02:04	0	00:00	0	1.5	539	40
	WS160-WP09 OOE - R09	26 Mar 201 09:18	23.5	9.3	00:16	09:31	10:05	00:35	0	00:00	0	1.8	0	11.5
	WS160-WP09 OOE - R09	29 Mar 201 10:46	12.9	0	00:00	10:49	11:11	00:22	0	00:00	0	0	5	7.5
	WS160-WP09 OOE - R09	31 Mar 201 18:37	75.8	22.3	00:35	18:38	20:19	01:42	0	00:00	0	2.8	986	39
TOTALS:			189.3	50.3	01:23			04:43	0	00:00	0	6.1	1530	98

Figure E1. Example 'Service Provider Summary Report'

Summary Gritting Report - WS160-WP09 OOE - R09 Date: Wed 13/06/2012 17:43

Fleet		Registration		Vehicle Type		Base		VIN			
Highways Agency		WS160-WP09 OOE - R09		Schmidt Gritter		Area 9 - Bury Court		WMAN38ZZ19Y235960			
Start (hh:mm)	End (hh:mm)	Gritting Duration (hh:mm:ss)	Gritting Distance (miles)	Ploughing Duration (hh:mm)	Ploughing Distance (miles)	Vehicle Weight Out (kg)	Vehicle Weight In (kg)	Fuel Usage (ltrs)	Depot Gate Out (hh:mm)	Depot Gate In (hh:mm)	Vehicle Mileage (miles)
Sunday 18 March 2012											
19:53:51	20:01:05	00:00:00	0	00:00:00	0			0	-	-	0.2
20:08:23	20:08:30	00:00:00	0	00:00:00	0				-	-	0
20:08:35	20:23:07	00:00:00	0	00:00:00	0			0.5	-	-	0.1
21:08:30	23:57:34	00:30:19	18.7	00:00:00	0	7700	5460	40	21:09	23:13	77.1

Figure E2. Example 'Gritting Summary Report'



Detailed Journey Report

Date: Wed 13/06/2012 17:49

Fleet		Registration		Vehicle type		Base		
Highways Agency		WS160-WP09 OOE - R09		Schmidt Gritter		Area 9 - Bury Court		
Time (hh:mm:ss)	Distance (miles)	Location	Action taken	Road	For (miles)	Average Speed (mph)	Dir.	Duration (hh:mm:ss)
Sunday 18 March 2012								
Driver Karen Storer authenticated in vehicle								
19:53:51 GMT	0.0	STRENSHAM WORCESTER(WORCESTERSHIRE)	Departed on				S	
19:53:54	0.0	STRENSHAM WORCESTER(WORCESTERSHIRE)	Continued on					
19:54:51	0.0	STRENSHAM WORCESTER(WORCESTERSHIRE)	Idled					00:03:18
19:58:09	0.0	0.5 miles S of STRENSHAM WORCESTER (WORCESTERSHIRE)	Continued on	-----	0.1		S	
19:58:18	0.1	0.6 miles S of STRENSHAM WORCESTER (WORCESTERSHIRE)	Idled	-----				00:00:26
19:58:44	0.1	0.5 miles S of STRENSHAM WORCESTER (WORCESTERSHIRE)	Continued on	-----	0.1		S	

Figure E3. Example 'Detailed Journey Report'



Detailed Gritting Report - WS160-WP09 OOE - R09

Date: Wed 13/06/2012 17:55

Fleet		Vehicle Type		Base		Report start		Report end	
Highways Agency		Schmidt Gritter		Area 9 - Bury Court		Thu 01/03/2012		Sat 31/03/2012	
Time Stamp (hh:mm)	Spreading (on/off)	Spread Rate (grms/mtrs)	Spread Width (mtrs)	Ploughing (on/off)	Pre-wet (%)	Road Surface Temperature	Location		
Sunday 18 March 2012									
19:53	Off	7	5.4	Off	30	6	STRENSHAM WORCESTER		
19:54	Off	10	5.4	Off	--	6	STRENSHAM WORCESTER		
19:55	Off	10	5.4	Off	--	6	STRENSHAM WORCESTER		
19:56	Off	10	5.4	Off	--	6	STRENSHAM WORCESTER		
19:57	Off	10	5.4	Off	--	6	STRENSHAM WORCESTER		
19:58	Off	10	5.4	Off	--	6	STRENSHAM WORCESTER		
19:59	Off	10	5.4	Off	--	6	STRENSHAM WORCESTER		
20:00	Off	--	0.0	Off	--	6			
20:08	Off	7	5.4	Off	30	6	STRENSHAM WORCESTER		
20:09	Off	7	5.4	Off	30	3	STRENSHAM WORCESTER		
20:10	Off	7	5.4	Off	30	6	STRENSHAM WORCESTER		

Figure E4. Example 'Detailed Gritting Report'



Vehicle Raw Extended Data Report

Date: Thu 14/06/2012 15:04

Fleet		Registration			Vehicle type			
Highways Agency		WS160-WP09 OOE - R09			Schmidt Gritter			
Date	Time	Road	Latitude	Longitude	Speed (mph)	Dir.	Status	Extended Data
Sun 18/03/2012	19:53:04 GMT	M5	52° 03' 22.728" N	002° 08' 34.638" W	0	SW	Stopped	0x454e31353433302d312e62696e70742e3000280029
Sun 18/03/2012	19:53:17	M5	52° 03' 22.728" N	002° 08' 34.638" W	0	N	Stopped	0x454e31353433302d312e62696e70742e30002801303b31303b323034343032343b303735303332373b353b0d0a334638430429
Sun 18/03/2012	19:53:17	M5	52° 03' 22.728" N	002° 08' 34.638" W	0	N	Stopped	0x454e31353433302d312e62696e70742e30002801313b31303b323034343032343b303735303332373b353b4e69646f3b53324233333031343b3b3b0d0a314530410429
Sun 18/03/2012	19:53:18	M5	52° 03' 22.728" N	002° 08' 34.638" W	0	N	Stopped	0x454e31353433302d312e62696e70742e30002801343b4e69646f3b5332423333031343b3b353b3230343430323333031343b3b353b323034343032343b303735303332373b3432333b3136343634363b303b3b3b3b36353533353b3235353b0d0a463742350429

Figure E5. Example 'Raw Extended Data Report'

Appendix F Comparison of Fleetstar data with manual records

In Area D, measurements are routinely made by the Service Provider of the amounts of salt discharged for each turnout, using the onboard weighing system. The measurements are carried out with the vehicle stationary before and after spreading. The weighing system measures the combined weight of the salt hopper and brine tanks and four measurements are made of the total load during each turnout:

- Before turnout – when brine tanks are full with the salt hopper empty (1)
- Before turnout – when brine tanks are full with hopper loaded with salt (2)
- After turnout – when brine tanks and hopper are part full after spreading (3)
- After turnout – when brine tanks are still part full and hopper has been emptied (4)

From these weights, the following parameters are calculated and recorded for each turnout:

- The total amount of de-icer spread: (1) – (2)
- The amount of brine spread: (4) – (1)
- The amount of salt spread: (2) – (1) – (3) + (4)

Based on these records, a comparison was made between

- The target amount, reported from Fleetstar, and the measured amounts of de-icer discharged taken from the manual records of the onboard weight measurements.
- The onboard weights taken from the moving spreaders, as reported on Fleetstar, and the measured amounts of de-icer discharged taken from the manual records of the onboard weight measurements.

The average and median ratios between the onboard measurement and target amounts of salt and brine discharged, and standard deviation of the ratio distributions for each Area, are shown in Table D1.

Figure F1 and Figure F2 show the distribution in the ratio calculated between the onboard weight measurement and target amount of de-icer discharged for all turnouts analysed in January and February 2012 respectively.

Table F1. Average and Median ratio between the onboard measurement and target amounts of salt and brine discharged

Area	Month	Average ratio	Standard deviation of distribution
D	January	1.11	0.23
D	February	1.10	0.26

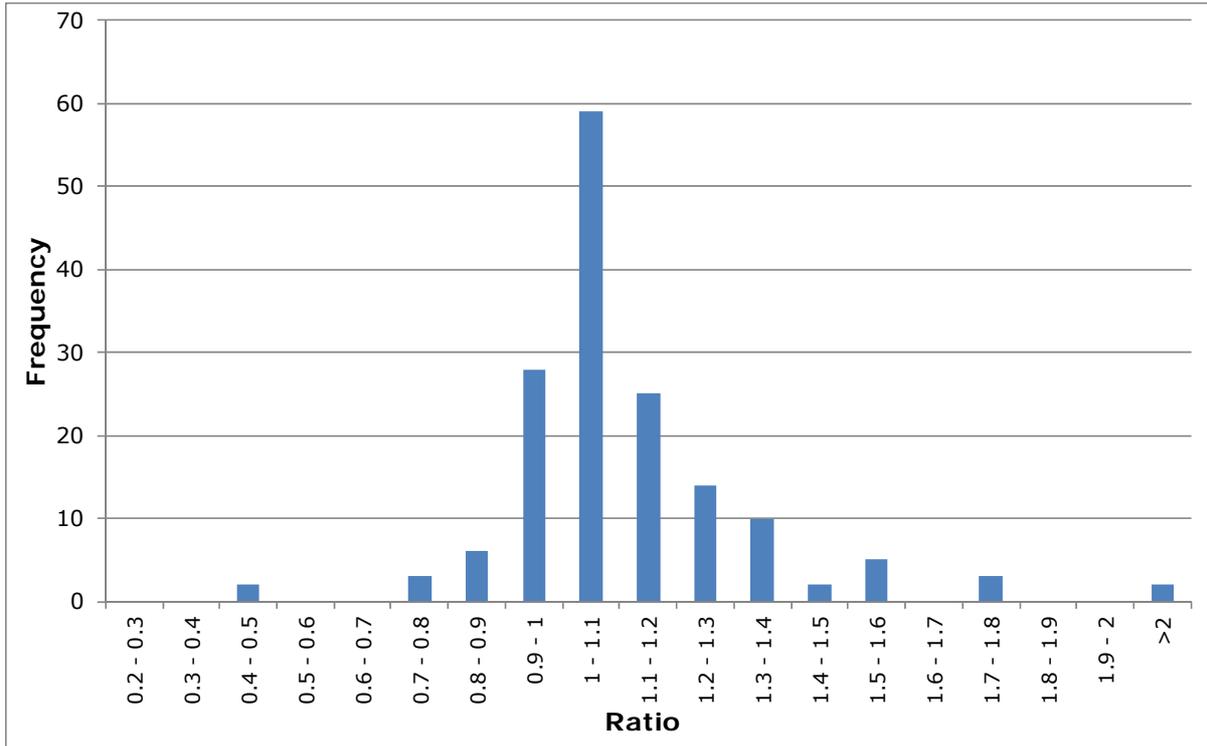


Figure F1. Frequency distribution of the ratio of onboard weight (Service Provide records) to target amount, for Area D in January 2012

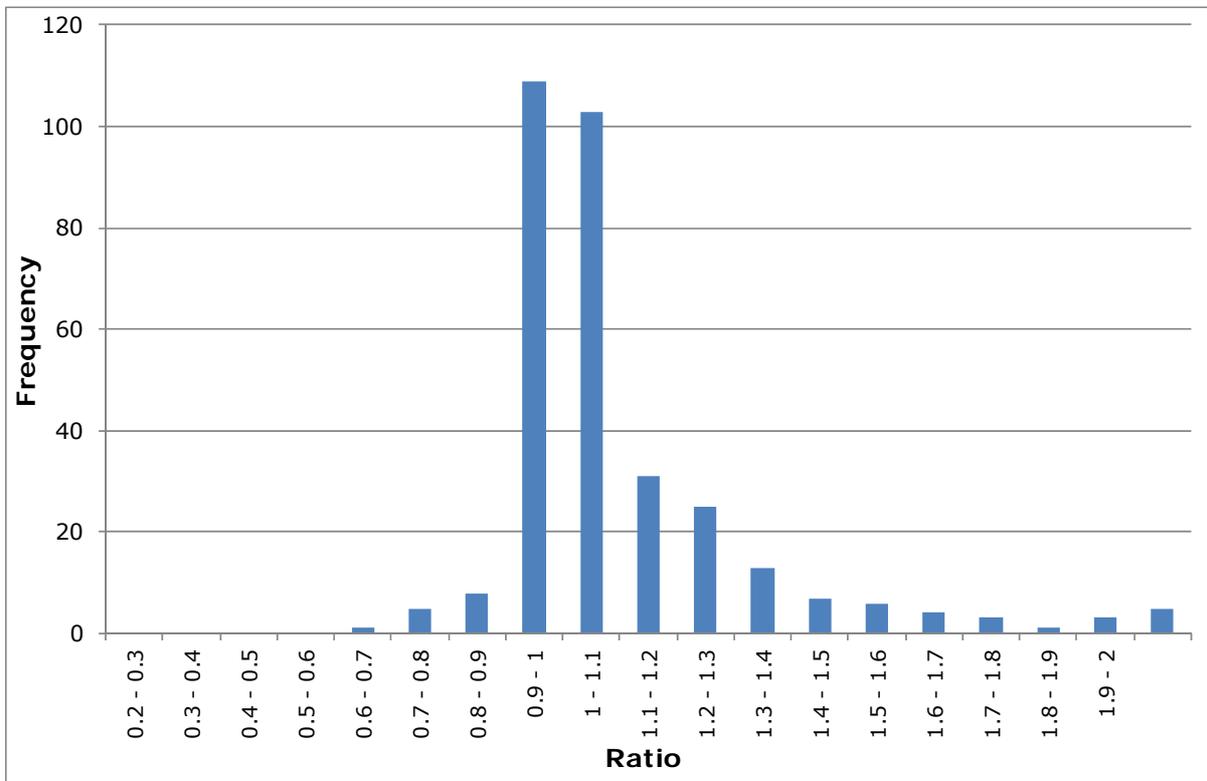


Figure F2. Frequency distribution of the ratio of onboard weight (Service Provide records) to target amount, for Area D in February 2012

The average and median ratios between the onboard weight measurements made by the Service Provider (Area D) and the onboard weight reported on Fleetstar, and standard deviation of the ratio distribution, are shown in Table F2. Figure F3 and Figure F4 show the distribution in the ratio in January and February 2012 respectively.

Table F2. Average and Median ratio between the onboard weight measurements made by the Service Provider and reported on Fleetstar

Area	Month	Average ratio	Standard deviation of distribution
D	January	1.03	0.15
D	February	1.03	0.21

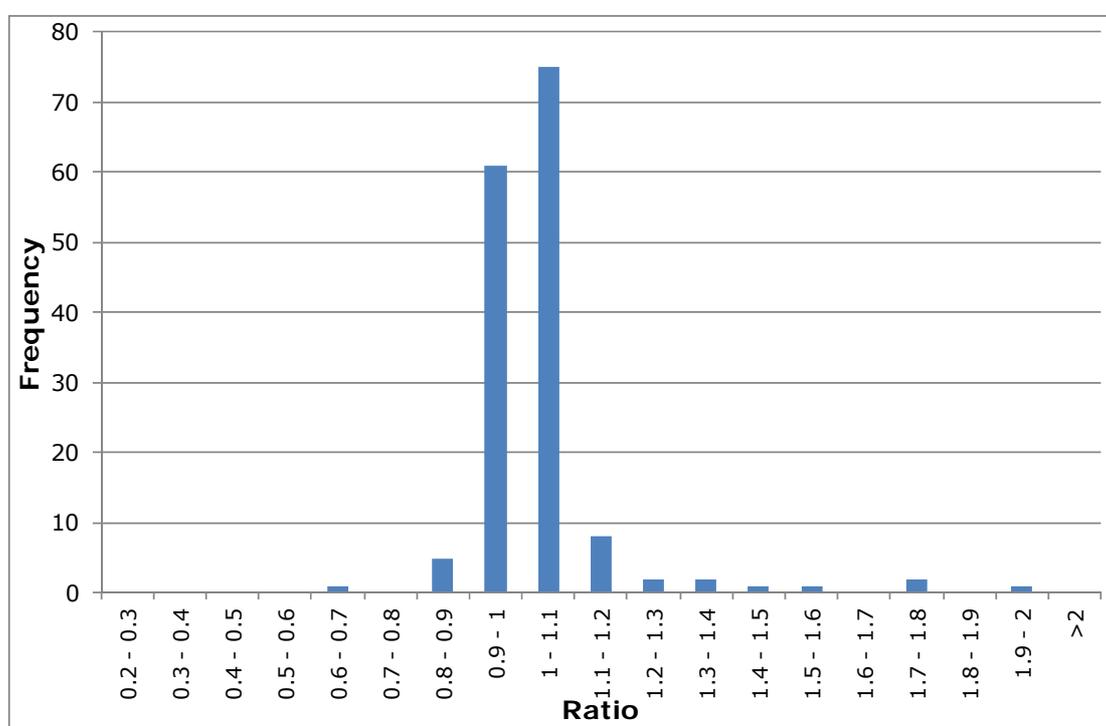


Figure F3. Frequency distribution of the ratio of onboard weight measurement by Service Provider and Fleetstar record, for Area D in January 2012

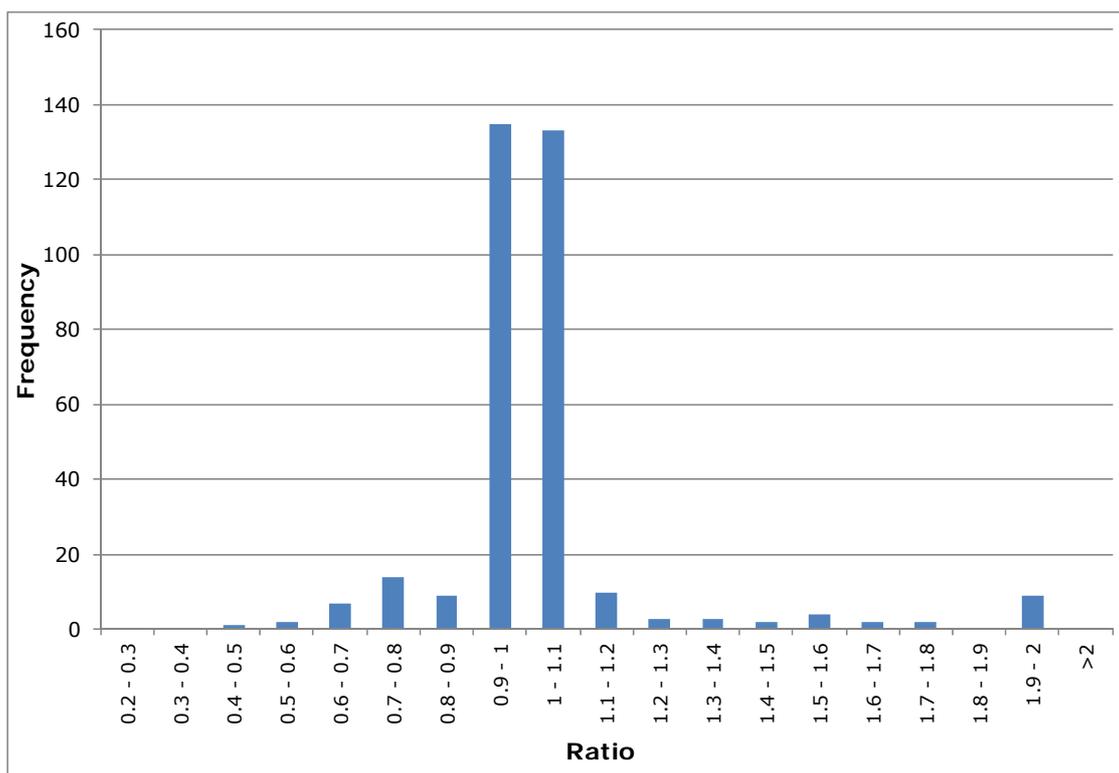


Figure F4. Frequency distribution of the ratio of onboard weight measurement by Service Provider and Fleetstar record, for Area D in February 2012

For both January and February, the average onboard weight as measured when the spreader was stationary was shown to be within 3% of the average value as reported on Fleetstar. However, there was some variation in the results. In January, the standard deviation of the ratio between the manual measurement and the value reported on Fleetstar was 15% of the mean value, in February the standard deviation was 20% of the mean.

In Area C, the counter readings from the spreader control panel are recorded for each turnout. These counter readings are based on the predicted amounts of salt and brine discharged, calculated based on the spreader settings and length of time for which spreading is carried out. The onboard weight is noted on the driver log sheet, for reference if any abnormal counter readings are recorded, but is not collated with the counter readings.

The counter readings are based on the same data used to report the amount of salt and brine discharged in the 'Service Provider Summary Report'. A comparison was made between the counter readings, as recorded by Area C in February 2012, and the readings as reported in the 'Service Provider Summary Report' for a sample of spreaders from Area C.

The average and median ratios between the counter readings made by the Service Provider and reported on Fleetstar, and standard deviation of the ratio distribution, are shown in Table F3. Figure F5 shows the frequency distribution of the ratio between the counter readings made by the Service Provider and reported on Fleetstar.

Table F3. Average and Median ratio between the counter readings made by the Service Provider and reported on Fleetstar

Area	Month	Average ratio	Standard deviation of distribution
C	February	1.07	0.27

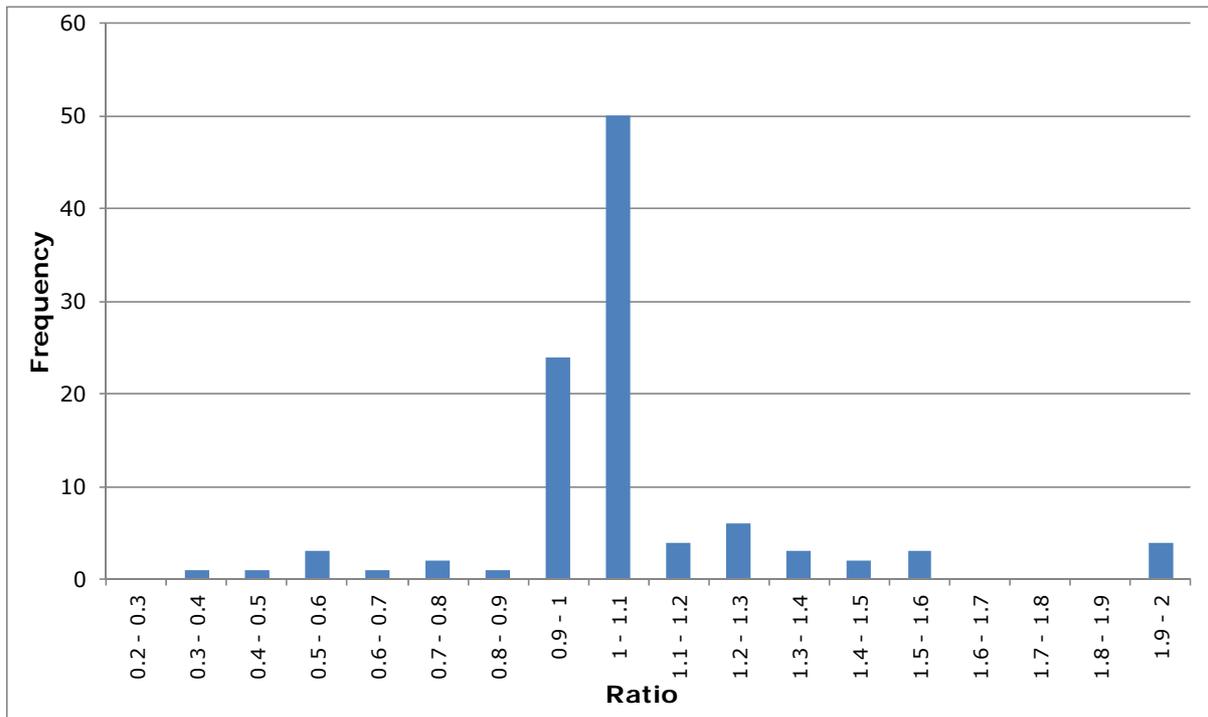


Figure F5. Frequency distribution of the ratio between the counter readings made by the Service Provider and reported on Fleetstar

The comparison showed that on average 7% more de-icer was measured, as recorded by the Service Provider as compared to Fleetstar. There was variation in the results, with the standard deviation of the measured ratios 25% of the mean value.

Appendix G Comparison of amount of de-icer discharged with target

Table G1. Average ratios between onboard weight and target amount, for Area 9 in January 2012

Spreader	Average ratio (Onboard weight/counters)			Average
	18g/m ²	8g/m ²	9g/m ²	
WS160	0.97	1.12	1.16	1.06
WS162	1.30		1.32	1.30
WS169	1.17			1.17
WS171	1.07	1.03		1.04
WS174	1.19	1.29		1.22
WS177	1.18			1.18
WS184	1.26	0.69	1.12	1.02
WS185	1.05	1.07	1.05	1.06
WS188	0.68	0.91	0.82	0.80
WS189	1.17	0.91		1.07
WS194	1.40	0.48	1.08	1.15
WS195	1.08	1.09		1.08
WS196				
WS197	0.98	0.94		0.97
WS205	1.09		1.58	1.17
WS211	0.95	0.96		0.96
WS214				
WS216	0.99	1.07	1.00	1.02
WS217	1.04	1.05	1.03	1.04
WS219		1.14	1.12	1.12
WS220	1.03	1.04	1.09	1.04
WS222	0.91	0.94		0.92
WS223	1.35	1.29	1.29	1.33
WS226	1.16	1.08	1.08	1.12
WS227	1.01	1.04		1.03
WS231				
WS236				
WS241	1.18			1.18
WS244	1.17	1.08	1.26	1.17
WS245				
WS251	1.02	1.30	1.59	1.21
WS252	1.12	1.17	1.16	1.15
WS257		1.02	1.25	1.11
WS260	0.89	1.18		1.04
WS270	1.06	1.02	1.14	1.06
WS275	1.00	0.76		0.92
WS279	0.99	0.96	1.06	0.99
WS280				
WS285	1.28	1.09	1.00	1.17
WS287				
WS289		1.04	0.91	0.94
Average	1.09	1.04	1.13	1.08

Table G2. Average ratios between onboard weight and target amount, for Area 9 in February 2012

Spreader	Average ratio (Onboard weight/counters)				Average
	15	18	8	9	
WS160	1.46	1.37	0.97	1.02	1.18
WS162	1.02	1.18		1.14	1.11
WS170		1.04		1.45	1.24
WS171	1.19	1.07	1.04	0.80	1.00
WS173					
WS174	1.20	1.25		1.49	1.32
WS175	1.01	1.17	0.99	1.04	1.08
WS177	1.08	1.44	1.01	1.00	1.12
WS178					
WS184	1.07	1.30	1.11	1.08	1.19
WS185		1.05	0.98	1.03	1.04
WS186					
WS188		0.93	0.98	0.89	0.93
WS189	0.87	1.09	0.92		1.01
WS194	1.57	1.10	1.05	1.12	1.13
WS195	1.09	1.07		1.06	1.06
WS196	1.48	1.34	0.99	1.10	1.28
WS197	0.97	1.03	1.08	0.96	1.02
WS205		0.95		0.99	0.96
WS207					
WS210					
WS211	0.97	0.91	1.01	0.95	0.94
WS214					
WS216	1.53	1.16	1.00	1.22	1.18
WS217	0.99	1.07	1.00	1.01	1.03
WS219	1.02	0.93	1.05	1.07	0.98
WS220	1.01	1.10		1.00	1.06
WS222	0.95	0.99		0.97	0.98
WS223	1.24	1.36	1.27	1.27	1.31
WS226	1.36	1.10	1.07		1.18
WS227	1.35	1.07		0.92	1.04
WS231					
WS237	0.99	1.13	1.02	0.98	1.08
WS241		1.13	1.07		1.11
WS244	1.10	1.12	1.10		1.11
WS245					
WS249		1.23		0.93	1.14
WS251	1.14	1.28	1.26	1.17	1.21
WS252		1.10		1.12	1.11
WS254		0.95	0.95	0.99	0.96
WS257		1.03	0.95	0.97	1.01
WS270	1.06	1.27	1.06	1.03	1.17
WS275		1.07			1.07
WS279	1.01	1.13		0.97	1.08
WS285	0.98	1.29	1.00	0.91	1.16
WS287					
WS300					
Average	1.14	1.12	1.04	1.04	1.09

Table G3. Average ratios between onboard weight and target amount, for Area 6 in February 2012

Spreader	Average ratio (Onboard weight/counters)				
	15g	18g	8g	9g	Average
WS001-WX08 MXM IP4	0.74	0.95	0.96	0.90	0.93
WS006-WX08 MWW RL2	0.67	0.88	0.64	0.84	0.82
WS011-WX08 WTM Res	1.06	0.97	1.11	0.97	0.99
WS018-WX08 WTY HA Re		0.97	1.06	1.14	1.01
WS023-WX08 WTV BH4		0.98	0.83	0.83	0.91
WS027-WX08 VOY NR3				0.86	0.86
WS033-WX08 WUO IP1		0.99	0.94	0.75	0.88
WS036-WX08 XKV RL1	0.59	0.87	0.91	0.93	0.85
WS037-WX08 WTW BH3		1.11	0.98	1.08	1.08
WS038-WX08 MWZ AR3	0.68	0.77	0.77	0.76	0.76
WS039-WX08 MVT NR4			0.68	0.72	0.71
WS058-WX08 VPR IP2		0.77	0.91	1.21	0.89
WS071-WX08 WUR NR1			0.73	0.73	0.73
WS072-WX08 WUP Res	1.08	1.08	0.81	1.06	1.02
WS075-WX08 VPN Res		0.74	0.76	0.99	0.79
WS076-WX08 VPO IP3	0.58	1.14	0.87		0.98
WS077-WX08 WTU Res				0.64	0.64
WS080-WX08 VPP BH2	1.08	0.91	1.01	0.83	0.92
WS085-WX08 XKY HA Re		1.04			1.04
WS095-WX08 XKM AR5	0.70	0.80	0.77	0.72	0.77
WS098-WX08 XKL PE1		0.71			0.71
WS106-WX08 VPF NR2		0.88		0.95	0.93
WS107-WX08 VPV AR1		0.85	0.90	0.97	0.91
WS108-WX08 WTN AR4	0.74	0.72	0.69	0.82	0.74
WS109-WX08 WTO BH5		0.89	1.06	0.99	0.98
Average	0.81	0.91	0.87	0.88	0.89

Table G4. Average ratios between onboard weight and target amount, for Area 12 in February 2012

Average of Ratio Row Labels	Average ratio (Onboard weight/counters)Labels				
	15g	18g	8g	9g	Average
WS306-GN09 KTG	0.40	0.34		0.41	0.41
WS307-GN09 KTJ					
WS308-GN09 KTK		0.50	0.48	0.66	0.61
WS309-GN09 KTL		0.92	0.73	0.73	0.76
WS310-GN09 KTO	0.57	0.57	0.56	0.70	0.67
WS312-GN09 OUS			0.48	0.53	0.51
WS313-GN09 OVA		0.73		0.78	0.77
WS314-GN09 OVC		0.78	0.61	0.60	0.64
WS315-GN09 OVB		0.86		1.12	1.07
WS317-GN09 OUY	0.72	0.87	0.59	0.83	0.80
WS318-GN09 OVF			0.91		0.91
WS319-GN09 OVD		0.92		0.55	0.73
WS321-GN09 OUX	0.86			1.16	1.14
WS323-GN09 OVE				0.77	0.77
WS324-GN09 OUU			0.78	0.55	0.60
WS325-GN09 OVJ				0.61	0.61
WS326-GN09 OVL			0.85	0.90	0.88
WS327-GN09 OVS				0.95	0.95
WS328-GN09 OVM			0.58	0.46	0.48
WS329-GN09 OVH				0.59	0.59
WS330-GN09 OVO	1.02		0.88	1.03	1.01
WS331-GN09 OVP	0.64		1.07	0.98	0.96
WS336-GN09 OUG	0.51		0.58	0.63	0.61
WS338-GN09 KUE		1.52	1.10	1.11	1.18
WS342-GN09 KUD				0.98	0.98
WS344-GN09 KUJ				1.04	1.04
Average	0.67	0.80	0.68	0.77	0.75

Appendix H STATS 19 Overview of winter collisions – circumstances and contributory factors

H.1 Severity

Table 19 shows the average collisions per quarter by severity in each of the periods and the percentage change between the two summer periods and the two winter periods.

Table 19: Average collisions per quarter by severity

Severity	Dry summer	Wet summer	Dry winter	Wet winter	% change summer	% change winter
Fatal	87	66	82	52	-24.6%	-36.4%
Serious	431	378	385	284	-12.3%	-26.1%
Slight	3,159	2,505	3,130	2,361	-20.7%	-24.5%
Total	3,677	2,948	3,596	2,698	-19.8%	-25.0%
% fatal or serious	14.1%	15.1%	13.0%	12.5%	-	-

The severity of collisions over the winter periods was slightly lower than those in the summer periods.

For all three severity levels, the reduction in collisions was greater over the winter period compared to over the summer periods. Fatal collisions also showed a greater reduction than the other severities in both summer and winter.

H.2 Road surface condition

The Stats19 collision data includes information about the road surface condition at the time of the collision.

Table 20: Average collisions per quarter by road surface condition

Road surface condition	Dry summer	Wet summer	Dry winter	Wet winter	% change summer	% change winter
Dry	2,922	2,443	2,011	1,428	-16.4%	-29.0%
Wet/damp	735	493	1502	972	-32.8%	-35.3%
Snow	1	0	20	80	-100.0%	296.7%
Frost/ice	2	1	44	204	-66.7%	364.4%
Flood	12	9	12	10	-29.2%	-18.4%
Total	3,677	2,948	3,596	2,698	-19.8%	-25.0%
% in frost/ice	0.0%	0.0%	1.2%	7.6%	-	-

Total includes unknown road surface condition

3.0% of collisions in the wet salting winter period were on snow-covered road surfaces and 7.6% were on frost or ice covered road surfaces compared with 0.6% and 1.2% respectively of collisions in the dry salting winter. This difference is likely to be partly due to the increased levels of frost and snow during the wet salting winter.

The severity of collisions on frost, icy or snowy road surfaces was slightly lower in the wet salting winter (13% of collisions involved a KSI) compared with the dry salting winter (14% of collisions involved a KSI).

H.3 Skidding

Table 21 shows the number of collisions per quarter in the four study periods.

Note that 'skidding' here includes jack-knifing and overturning.

Table 21: Average collisions per quarter by skidding collision type

Collision type	Dry summer	Wet summer	Dry winter	Wet winter	% change summer	% change winter
Collisions involving at least one vehicle skidding	1,599	1,159	1,534	1,102	-27.5%	-28.2%
Collisions involving no vehicles skidding	2,078	1,789	2,062	1,596	-13.9%	-22.6%
Total	3,677	2,948	3,596	2,698	-19.8%	-25.0%
% of collisions involving skidding	43.5%	39.3%	42.7%	40.8%	-	-

In each of the periods, between 39% and 43% of the collisions involved at least one vehicle skidding.

The collisions involving skidding showed greater reductions over the study periods than for non-skidding collisions. For skidding collisions, the percentage reductions were similar for both summer and winter, whereas the non-skidding collisions showed a greater reduction over winter than over summer.

The severity of collisions involving skidding was slightly higher in the wet salting winter (15.6% of collisions involved a KSI) compared with the dry salting winter (15.4% of collisions involved a KSI).

H.4 Slippery road due to weather as a contributory factor

Since 2005, Stats19 collision data has included contributory factor data. These give, in the opinion of the reporting police officer, what actions or failures contributed to the collision.

The factor 'slippery road (due to weather)' is one of the 77 factors. Stats20 guidance ((DfT, 2004)) states:

To be used where the weather has caused the road surface to become slippery. This will be, mainly, wet or icy roads but will also include roads which are slippery because of melting tarmac.

Note that the use of this factor may not be the result of extensive investigation, or measurements.

The table below shows the number of collisions where 'slippery road due to weather' was recorded as a contributory factor for each of the study periods.

Note that the analysis of contributory factors is limited to those collisions with factors recorded and collisions which are attended by a police officer. In each of the periods studied 86% of the collisions were attended by the police and had at least one contributory factor recorded.

Table 22: Average collisions per quarter with slippery road due to weather as a contributory factor

Collision type	Dry summer	Wet summer	Dry winter	Wet winter	% change summer	% change winter
Collisions with slippery road due to weather as a contributory factor	215	139	345	382	-35.4%	10.6%
Collisions without slippery road due to weather as a contributory factor	2,930	2,396	2,750	1,951	-18.2%	-29.1%
Total collisions with CFs recorded and attended by the police	3,145	2,535	3,095	2,333	-19.4%	-24.6%
% of collisions with slippery road due to weather as a contributory factor	6.8%	5.5%	11.2%	16.4%	-	-

16% of collisions in the wet salting winter period attended by the police had the contributory factor 'slippery road (due to weather)' recorded; this compares to 11% of collisions in the dry salting winter.

Collisions attended by the police where the contributory factor 'slippery road (due to weather)' was recorded reduced by 35% over the summer, but increased by 11% over the two winter periods studied. This difference is likely to be partly due to the increased levels of frost and snow during the wet salting winter. Collisions not involving this contributory factor decreased over both the summer and winter periods; with a bigger decrease during the winter (29% compared to 18%).

The severity of collisions attended by the police with the contributory factor 'slippery road (due to weather)' recorded was slightly higher in the wet salting winter (13% of collisions involved a KSI) compared with the dry salting winter (12% of collisions involved a KSI).

Appendix I Data available from WRF1

Data were available from WRF1, detailing on which days Service Providers treated the routes within their area.

Each area is split into gritting routes; a route can cover more than one road number, and a road number in an area can be split into more than one route.

WRF1 includes the following details:

- Route reference;
- Route description;
- Date and time of submitting report;
- Time of gritting*;
- Gritting*;
- Snow;
- Weather;
- Road condition;
- Road surface temperature.

**Meaning salting/anti-icing or de-icing treatments.*

WRF1 also gave details of whether the forecast temperature for the roads in each area was below 1°C, above 1°C or whether the day was classified as 'severe weather desk' in that area.

All of the reports for quarters 1 and 4 between 01/10/2006 and 31/03/2011 for all the areas were downloaded and collated, resulting in a database with 574,155 records.

There were 29,204 entries (5%) where the time and the type of treatment was not entered for each route on the report. For these cases, the treatment type and time was assumed to be the same as those on the first entry on the report, which was normally completed.

I.1 Types of treatments used

The details include the type of treatment and the spread rate. The type of treatment used was recorded as follows:

- Prec (precautionary dry)
- Pre-wet
- Dry
- Completed
- To be advised
- No action (and 'blank')
- Other treatments:
 - Cont
 - De-ice
 - Emeg
 - PA

The treatment type also gave the spread rate used, which varied from between 7 to 40 g/m².

Some of the records were entered as 'no treatment'. It was unclear when a record is entered as 'no treatment' and when no record was entered for a particular day or route.

Table 23 shows the proportion of days in each quarter and area where at least one treatment report was available.

Table 23: Percentage of total days in each quarter where treatment reports are available by Area

Area	% of total days reports available for						
	2006 Q4	2007 Q1	2007 Q4	2008 Q1	2010 Q1	2010 Q4	2011 Q1
1	97%	90%	98%	100%	99%	98%	99%
2	97%	96%	98%	100%	99%	99%	100%
3	66%	68%	78%	84%	93%	93%	100%
4	97%	98%	98%	100%	94%	93%	100%
5	98%	96%	98%	100%	100%	98%	100%
6	100%	98%	98%	100%	94%	92%	100%
7	100%	93%	98%	100%	99%	89%	100%
8	99%	97%	98%	100%	98%	97%	99%
9	100%	97%	99%	100%	99%	100%	100%
10	95%	94%	96%	98%	97%	97%	100%
11	100%	97%	98%	100%	-	-	-
12	98%	99%	98%	100%	100%	96%	100%
13	87%	88%	93%	92%	99%	97%	99%
14	98%	99%	98%	100%	96%	90%	100%
25	68%	71%	70%	68%	100%	100%	100%
26	88%	92%	98%	100%	100%	98%	100%
27	99%	96%	96%	99%	100%	100%	100%
28	97%	98%	98%	100%	100%	100%	100%
29	70%	77%	73%	75%	100%	98%	100%
30	95%	93%	96%	100%	100%	100%	100%
31	87%	96%	99%	100%	100%	98%	100%
32	97%	98%	95%	100%	100%	99%	100%
33	85%	90%	96%	100%	99%	100%	100%
34	88%	87%	96%	99%	-	-	-
35	98%	97%	100%	100%	100%	100%	100%
Total	92%	92%	94%	97%	99%	97%	100%

Note that area 11 and area 34 were not present in 2010

In most of the quarters in the majority of areas, reports were completed for at least 90% of days. Areas 3 and 29 showed slightly lower levels of data available.

Table 24 and Table 25 display the number of treated days by treatment type and area for the before and after period respectively. Note that the sum of treatment types does not equal the number of treated days. This is due to the fact that some areas are treated with multiple treatment types on the same day. For example, in a given area on a given day 'no treatment' could be recorded in the morning and 'dry' treatment could be applied the same evening. This would be recorded in two treatment types but only accounts for 1 treatment day.

Table 24: Number of treated days by treatment type and area (before period)

Area	Treatment type							Number of days with entries in database	Total days in period
	No treatment	Completed	Dry	Not used	Prec	Pre-wet	To Be Advised		
1	310	0	N/A	4	104	0	13	351	365
2	308	44	N/A	2	107	0	2	356	365
3	211	7	N/A	1	108	0	7	270	365
4	320	0	N/A	6	85	0	28	358	365
5	315	15	N/A	3	88	0	15	357	365
6	315	68	N/A	18	112	0	47	361	365
7	289	31	N/A	4	108	0	44	357	365
8	315	43	N/A	2	93	15	24	359	365
9	291	2	N/A	10	121	0	70	361	365
10	288	5	N/A	7	125	0	76	349	365
11	309	50	N/A	3	120	0	43	360	365
12	356	15	N/A	3	166	1	46	360	365
13	315	4	N/A	6	116	0	35	329	365
14	346	23	N/A	7	194	1	16	360	365
25	232	5	N/A	9	117	0	48	253	365
26	266	0	N/A	21	119	0	3	345	365
27	301	0	N/A	1	61	0	38	355	365
28	300	22	N/A	1	137	0	11	358	365
29	239	40	N/A	2	51	0	31	268	365
30	317	10	N/A	1	77	0	17	350	365
31	297	41	N/A	8	77	0	46	348	365
32	306	0	N/A	0	117	0	1	355	365
33	291	0	N/A	0	72	0	44	338	365
34	317	5	N/A	27	1	0	19	337	365
35	301	88	N/A	4	111	0	55	360	365

Table 25: Number of treated days by treatment type and Area (after period)

Area	Treatment type							Number of days with entries in database	Total days in period
	No treatment	Completed	Dry	Not used	Prec	Pre-wet	To Be Advised		
1	229	72	48	2	58	71	18	268	272
2	231	121	73	118	55	32	31	270	272
3	209	106	35	9	48	65	40	260	272
4	216	90	16	2	42	55	37	261	272
5	244	83	19	3	51	42	38	270	272
6	219	117	65	4	49	71	8	260	272
7	200	104	28	4	50	42	68	261	272
8	211	96	39	2	46	47	37	266	272
9	200	105	69	2	50	41	72	271	272
10	250	103	32	2	62	50	105	266	272
11	-	-	-	-	-	-	-	-	-
12	258	81	81	5	77	50	107	268	272
13	264	123	83	2	61	1	83	267	272
14	216	84	91	6	74	16	83	259	272
25	251	162	97	10	71	1	41	272	272
26	182	128	75	4	55	0	3	270	272
27	236	116	71	1	52	1	9	272	272
28	194	121	67	1	59	1	6	272	272
29	223	112	64	5	50	2	28	270	272
30	211	96	60	1	44	0	13	272	272
31	194	114	71	3	47	1	42	270	272
32	202	109	67	0	53	0	0	271	272
33	214	108	60	4	46	1	31	271	272
34	-	-	-	-	-	-	-	-	-
35	187	125	75	3	51	0	65	272	272

The most common entry for all of the areas was 'no treatment', although this was sometimes entered on the same day as another type of treatment. The different treatments used in each area will depend upon the weather conditions in that area.

Figure 45 shows the number of records in the database for each year and month in the study period by the type of treatment used. The different spreading rates are grouped together into six categories. It is believed that the 'pre-wet' and 'dry' options were only available in the 'after' period and the 'prec' (or precautionary) treatment option was only available in the 'before' period – to mean dry salting as this was standard at that time. 'Other gritting' includes the treatment types 'de-ice', 'pre-ice', 'cont', 'emeg', 'mult' and PA.

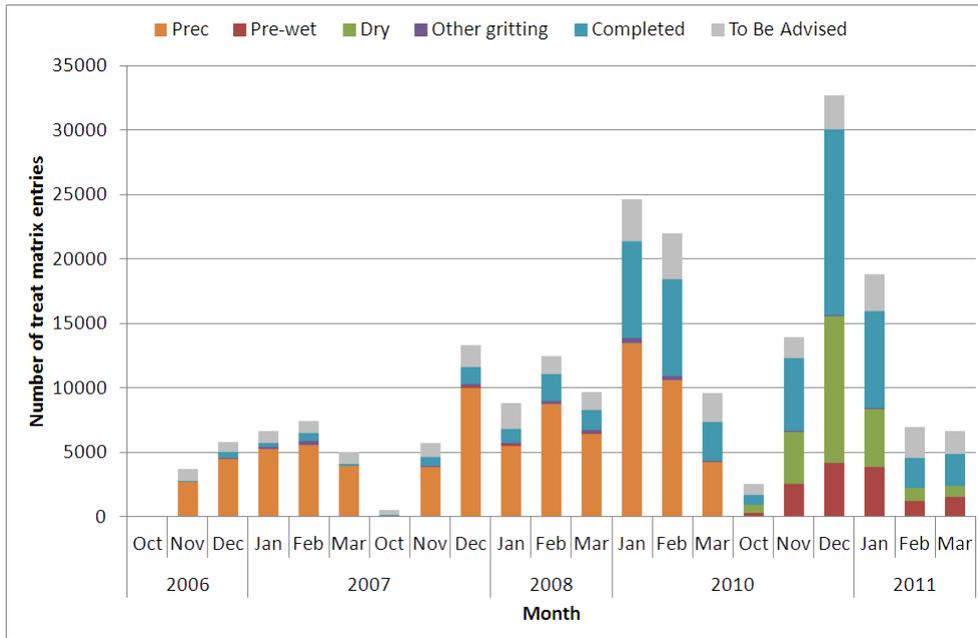


Figure 45: Number of records in WRF1 by month, year and treatment type

As can be seen in the chart, December 2010 had by far the most entries in WRF1. This month also had the highest proportion of ‘treatments’ recorded as completed (44%). It also shows that a significant amount of dry salting was carried out in 2010 and 2011.

Figure 46 shows the number of entries in WRF1 by hour and treatment type. The time entered is usually a single time for all routes within a report and will therefore not be the exact time that a route was treated.

Some routes had multiple entries on the same day, and not all routes had an entry for all days. January 20th 2007 had no entries for any routes.

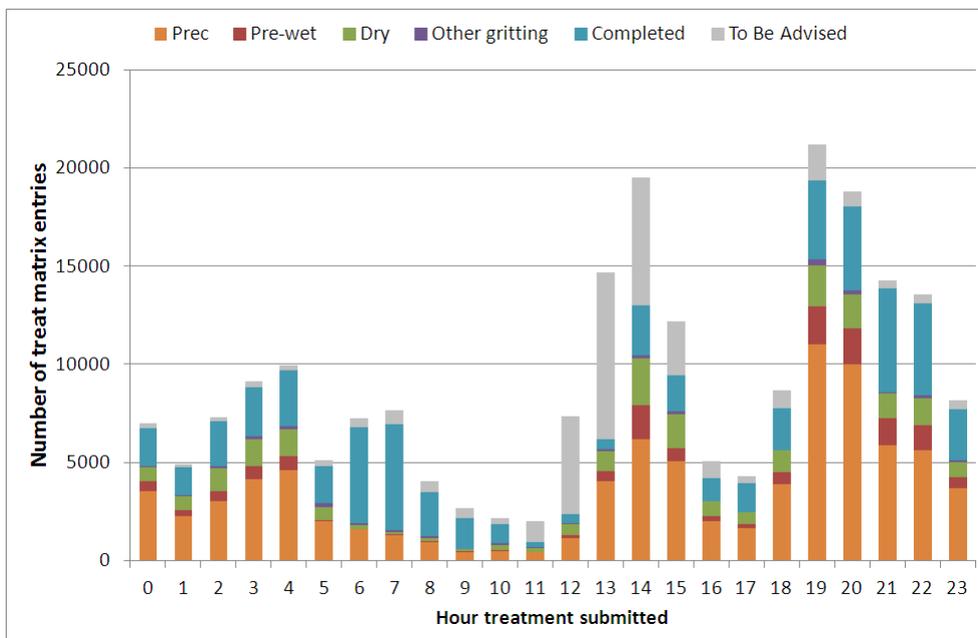


Figure 46: Number of records in WRF1 by hour and treatment type

Figure 46 shows that the treatment times with the most entries are 1-3pm and 7-10pm; 12 noon – 3pm is the period with the highest number of ‘to be advised’ entries.

Appendix J Categorisation of areas, roads and day by treatment type

Each route consists of parts of one or more roads within an Agency Area, and each road within an area consists of parts of multiple routes. Also, a number of routes were treated using more than one treatment type.

To reduce the number of days where a road within an area would have multiple treatment types the grouped categories as described in Section I.1 were used.

In order to match the collision data with the treatment matrix the number of days that each road within an area was treated in the same way was extracted and all collisions on these 'area road days' were assigned that treatment type.

Table 26 shows the maximum possible number of area road days (the number of the roads within each area multiplied by the number of calendar days in the study period) and how these 152,000 possibilities are represented in the database.

Table 26. Area Road Days by treatment availability

	All entries
Total number of area road days in study period	152,004¹
Number of area road days on routes where entire area was treated similarly	73,194
Number of area road days where treatment was mixed within the area but entire road within area was treated similarly	6,741
Number of area road days-days where the treatment was mixed on a road within an area	47,205
Number of area road days not present in database	24,864

53% of area road days had the same treatment type either across the whole area or on an entire road within an area. 16% of area road days did not have any entry in the database².

Consideration was given to using only the 53% (79,935) of area road-days with a single treatment across the area or area road in the analysis.

The treatments carried out on these route days are shown in Table 27 below.

¹ Doesn't include 20th Jan 2007

² Some roads had some days where some of the routes they are part of were treated and a record was present in the database but other routes they are part of are not represented in the database for that particular day, even when looking at the length of that road within a single area. It is not currently known whether this is due to route renaming/restructuring or a lack of information for part of the length of a road within an area on some days.

Table 27: Area road days with the same treatment type across the area or road by treatment type

Treatment type	Number of area road days
No treatment	70,311
Precautionary	8,090
Pre-wet	124
Dry (in the after period)	271
Completed	117
To be advised	962
Not used	60
Total	79,935

The number of road days where pre-wetted salting was used (on an entire road within an area) was 124.

These road sections and dates were matched with the Stats19 database, which showed that 25 collisions occurred on these roads within areas on these dates. This small number of collisions was not suitable for statistical analysis.

J.1 Roads with multiple treatments on a day

47,205 area road days had different treatment types on different parts of a road within an Area. Analysis showed that majority of roads had mixed treatments on at least one day. It was therefore not feasible to look up the grid references of each of the routes making up the roads within areas to use these to match with the collisions.

The treatments on each of the area road days where there were mixed treatments were analysed by route to assess whether there were multiple treatments used on the entire road within area or whether different routes on a road were treated differently. Table 28 shows the results.

Table 28: Area road days with mixed treatments

	Number of area road days
Total area road days with multiple treatment types	47,205
Area road days with single treatments on different routes on a road	478
Area road days with multiple treatments on entire roads	41,317
Area road days with multiple treatments on parts of roads	5,410

This showed that in the majority of cases, there were multiple treatment types used on the entire road within an area.

The treatment types included 'no treatment', 'to be advised' and 'completed'. The table below shows the number of area road days where only these categories were used, where there was one specific type of treatment (dry, not used, prec and pre-wet) in addition to these three categories, or whether there were multiple specified treatments.

Table 29: Area road days with mixed treatments by grouped treatment types

	Number of area road days
Total area road days with multiple treatment types	47,205
Area road days with only 'no treatment', 'to be advised' and 'completed'	12,102
Area road days with 'no treatment', 'to be advised' and 'completed' and single type of specified treatment	32,865
Area road days with multiple specified treatments	2,238

There were 12,102 area road days where 'no treatment', 'to be advised' and 'completed' were the only treatment types recorded.

Where 'no treatment', 'to be advised' or 'completed' were used on the same area road day as a single type of specified treatment (dry, not used, prec and pre-wet), the former group were ignored and the specified treatment was assumed to apply to the whole area road day. There were 32,865 area road days where this was the case.

The single type of specified treatments used on the 32,865 area road days is shown below.

Table 30: Area road days with 'no treatment', 'to be advised' and 'completed' and single type of specified treatment by specified treatment

Area road days with 'no treatment', 'to be advised' and 'completed' and single type of specified treatment	Number of area road days
Prec	21,988
Pre-wet	4,851
Dry	5,636
Not used	390
Total	32,865

The remaining 2,238 area road days were those where there multiple specified treatment types (dry, not used, prec and pre-wet) were used. Table 31 shows the combinations that were used.

Table 31: Area road days with multiple specified treatments by combinations used

Treatment combination	Number of area road days
Dry & Pre-wet	2,238
Not used & Prec	990
Dry & Not used	84
Dry & Not used & Pre-wet	63
Prec & Pre-wet	50
Not used & Prec & Pre-wet	3
Total	3,428

The most common combination was use of dry and pre-wet salt on the same area road day

J.2 Summary

The area road days available for collision analysis were therefore those shown in the table below.

The area road days where there were multiple specific treatments were not included since these made up a small proportion of the total area road days.

Table 32: Area road days available for collision analysis

Condition	Number of area road days
Number of area road days on routes where entire area was treated similarly	73,194
Number of area road days where treatment was mixed within the area but entire road within area was treated similarly	6,741
Area road days with only 'no treatment', 'to be advised' and 'completed'	12,102
Area road days with 'no treatment', 'to be advised' and 'completed' and single type of specified treatment	32,865
Total area road days in analysis	124,902

The type of treatment used on these days is shown in Table 33.

Table 33: Treatments used on area road days available for collision analysis

Treatment type	Number of area road days
No treatment	70,311
Prec	30,078
Pre-wet	4,975
Dry	5,907
Completed	117
To Be Advised	962
No treatment/completed/to be advised	12,102
Not used	450
Total	124,902

On inspection of these two datasets it was found that the lists of Areas in each dataset did not match exactly. For example, the A282 is considered a DBFO separate from the M25 for some years of the WRF1 data, whereas because the Areas are assigned to the collisions retrospectively, the A282 is considered part of the M25 DBFO for all of the years in the collision data.

This meant that some areas were combined and therefore some of the area road days were combined (total number of area road days decreases) and some of the area road days with a single treatment type (by any of the methods) became multi matches if, say, A282 sections on the M25 DBFO had a different gritting type to the A282 DBFO on the same day.

Also, Area 11 was dissolved and merged into nearby areas in 2008/9 amongst other area boundary changes. The WRF1 data are coded with the area that they were part of at the

time of the treatment, whereas the collisions are coded with the area they were part of in October 2009 (i.e. after Area 11 was part of other areas). This also means that the number of area road days with the possibility of collision data was reduced.

The updated area road days available for collision analysis were therefore those shown in the table below:

Table 34: Area road days available for collision analysis with comparable areas

Condition	Number of area road days
Number of area road days on routes where entire area was treated similarly	69,688
Number of area road days where treatment was mixed within the area but entire road within area was treated similarly	6,563
Area road days with only 'no treatment', 'to be advised' and 'completed'	11,598
Area road days with 'no treatment', 'to be advised' and 'completed' and single type of specified treatment	31,663
Total area road days in analysis	119,512

The treatments used on these days is shown in Table 35.

Table 35: Treatments used on area road days available for collision analysis with comparable areas

Treatment type	Number of area road days
No treatment	67,082
Prec	28,497
Pre-wet	4,972
Dry	5,872
Completed	117
To Be Advised	940
No treatment/completed/to be advised	11,598
Not used	434
Total	119,512

Appendix K STATS 19 comparison of dry and pre-wetted salting – circumstances and contributory factors

K.1 Severity

Table 36 shows the number of collisions in the before and after period with no treatment, in the before period with precautionary treatment and in the after period with pre-wet salt.

Note that the number of collisions depends on the length of road and the number of days that each treatment was used. However, the severity of the collisions, in terms of the percentage of collisions that were fatal or serious can be compared.

Table 36: Number of collisions by severity on area road days with different treatments

Number of collisions	Treatment		No treatment	
	Before (prec)	After (pre-wet)	Before	After
Fatal	82	17	179	72
Serious	426	78	863	349
Slight	3,210	652	7,220	2,906
Total	3,718	747	8,262	3,327
% KSI	13.7%	12.7%	12.6%	12.7%

The severity of collisions in the before period with precautionary salting was slightly higher (13.7% of collisions involved a KSI) compared with the after period where the pre-wet treatment was applied (12.7% of collisions involved a KSI).

K.2 Road surface condition

Table 37 shows the road surface condition recorded for the collisions in the study period.

Table 37: Number of collisions by road surface condition on area road days with different treatments

Road surface condition	Treatment		No treatment	
	Before (prec)	After (pre-wet)	Before	After
Dry	2,097	423	4,596	2,066
Wet/damp	1,440	222	3,590	1,237
Snow	43	6	6	0
Frost/ice	128	93	16	9
Flood	4	3	36	13
Total	3,718	747	8,262	3,327
% frost/ice	3.4%	12.4%	0.2%	0.3%

1.2% of collisions in the before period with precautionary treatment were on snow-covered road surfaces and 3.4% were on frost or ice covered road surfaces compared with 0.8% and 12.4% respectively of collisions in the after period with pre-wet salting applied. This difference is likely to be partly due to the increased levels of frost and snow during the after period.

K.3 Skidding

Table 38 shows the road surface condition recorded for the collisions in the study period.

Table 38: Number of collisions by skidding on area road days with different treatments

Collision type	Treatment		No treatment	
	Before (prec)	After (pre-wet)	Before	After
Collisions involving at least one vehicle skidding	1,579	536	3,514	2,014
Collisions involving no vehicles skidding	2,139	211	4,748	1,313
Total	3,718	747	8,262	3,327
% of collisions involving skidding	42.5%	71.8%	42.5%	60.5%

A higher proportion of collisions involved skidding in the after period than the before period. This may be due in part to increased levels of frost and ice during the after period.

K.4 Slippery road (due to weather as contributory factor)

Table 39 shows the number of collisions with slippery conditions recorded as a contributory factor.

Table 39: Number of collisions with slippery road as a contributory factor on area road days with different treatments

Collision type	Treatment		No treatment	
	Before (prec)	After (pre-wet)	Before	After
Collisions with slippery road due to weather as a contributory factor	319	436	805	1,418
Collisions without slippery road due to weather as a contributory factor	2,861	277	6,277	1,616
Total collisions with CFs recorded and attended by the police	3,180	713	7,082	3,034
% of collisions with slippery road due to weather as a contributory factor	10.0%	61.2%	11.4%	46.7%

In the after period with pre-wet salting 61% of collisions attended by the police had 'slippery road due to weather' recorded as a contributory factor. This compares to just 10% of collisions in the before period with precautionary treatment.