# Review of salting trials

by M G Evans, T Willway and A Runacres

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CLIENT PROJECT REPORT

**TRL Limited**

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# REVIEW OF NSSRG SALTING TRIALS

Version: Final

**by M G Evans, T Willway (TRL Limited) and A Runacres (Consultant)**

**Prepared for: Project Record:** **Phase II of the NSSRG Research Programme**

**Client:** **National Salt Spreading Research Group**
**(Chair: David Davies, Lincolnshire County Council)**



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## Executive summary

The National Salt Spreading Research Group (NSSRG) commissioned TRL Ltd in 2001 to undertake a programme of research into the performance of highway winter maintenance salt spreading equipment. The first phase of the programme mainly focussed on spreader performance under controlled conditions on the TRL research track in Berkshire, and was completed and reported in 2005. This phase included thirteen track based trials and five road trials being undertaken with the assistance and co-operation of members of the NSSRG, as well as Strategic Highway Research Program (SHRP) tests to determine the de-icing capabilities of eight de-icers. A ‘Best Practice’ guidance document for spreading salt was produced for the benefit of all NSSRG members.

Phase 2 of the programme was commissioned following the Phase 1 final report and has so far included the undertaking of a further two track trials and four road trials of spreading equipment, as well as investigations into the dissolution rates of five de-icers, the investigation into practices of winter maintenance of footways and cycleways across the country and laboratory trials of the effects of salt application on the skidding resistance of road surfaces.

Before and during the period of the NSSRG research programme, the Highways Agency separately commissioned TRL to carry out certain performance trials of winter maintenance techniques, equipment and materials, and kindly made some of the results of those trials available to the NSSRG.

It is clear from the above that a considerable amount of work has now been undertaken in this area, and that this has involved a significant level of financial investment by the highway authorities and practitioners comprising the NSSRG, as well as investment by way of time and equipment from other NSSRG members. As Phase 2 of the research programme is currently nearing completion, it is appropriate to undertake a review of the trials undertaken to date in order to draw together the overall findings of the work, to assist in determining the value of the NSSRG research to stakeholders, and to ensure that any lessons arising from the work can be learnt and incorporated into future trial methodologies. This ‘Review Report’ was therefore commissioned by the NSSRG in September 2007.

The overall aims of the NSSRG research programme include assisting highway authorities and practitioners with operational decisions concerning the choice, setup and performance of their winter maintenance salt spreading equipment. The main drivers behind the work include improving the cost effectiveness of UK highway winter maintenance operations and a desire to ameliorate the environmental impact of those operations by reducing the amount of salt spread on the roads without compromising safety.

Specific objectives of the NSSRG Phase 1 and 2 trial programme include:

- Researching spread rate and distribution patterns of dry (untreated) salt, pre-wetted salt and salt treated with agricultural based additives (treated salt), as well as brine only application, through dynamic performance testing.
- Determination and confirmation of whether specific distribution systems are capable of delivering the required performance standards, in terms of required coverage and rate of spread for different de-icers.
- The development and evaluation of techniques for the measurement of residual salt levels.
- Comparisons of the performance of different de-icer types in highway based field trials.
- Identifying optimum salt grade, purity and moisture content for dry and pre-wetted salt applications.
- Identifying optimum rates of spread for different salting techniques.

The trial programme to date has tested the spread rate and distribution patterns for a wide range of equipment types and materials in both track based and road based trials, and techniques for the measurement of residual salt levels and other test methods have been evaluated and developed. The objectives of the trials have focussed on assisting authorities in understanding the performance of

equipment and materials in the configurations and specifications as are either actually employed in 'live' salting operations or would potentially be employed in future 'live' operations. The variations in measured performance of the equipment and materials during the trials have been relatively large, and this may relate to the various equipment configurations and settings currently used by highway authorities, as well as to a number of other influencing variables that altered between the trials. This is considered to be an important finding but it has also reduced the potential for the trials to provide robust comparisons regarding the performance of different de-icers and equipment types, and the programme has therefore not yet resulted in the provision of advice regarding optimum salt grades and spread rates for different materials and equipment combinations.

The research to date has however successfully produced valuable results in the specific objective areas, as well as in other closely allied areas. These include the production of detailed performance reports for a considerable number of specific equipment and de-icer combinations, with the performance trials highlighting that:

1. As currently configured and operated by highway authorities, salt spreading equipment may be delivering less than the targeted salt spread rates within traffic lanes (trials have consistently demonstrated this effect).
2. As currently configured and operated by highway authorities, salt spreading equipment may be producing relatively inconsistent performance (repeat tests under similar environmental conditions have produced variations of up to 30 per cent of the target spread rate in the amount of salt collected from traffic lanes).
3. Current salt spreading equipment generates longitudinal and transverse variation in spread and these 'snaking effects' are of a similar magnitude whether dry, treated or pre-wetted salt is used.
4. Variations in the performance of different spreading equipment as currently configured and operated by highway authorities appear to be greater than variations resulting from the use of different available techniques and materials. For example, it is considered likely that current variations in the performance of the equipment configurations being operated by authorities across the country are larger than the variation in performance that an authority would achieve by changing from untreated to treated salt, or from dry salting to pre-wetted salting etc.
5. Before purchase, highway authorities should request that manufacturers demonstrate their equipment is capable of achieving the required distribution specification for the relevant de-icing material, technique and road network. The most appropriate settings to achieve the specification should be provided by manufacturers and carefully noted and utilised by authorities.
6. Salt spreading equipment requires settings to be specifically adjusted for the particular de-icer type, grading and moisture content being used. There is also evidence to suggest that performance checks are required for each specific spread rate and spread pattern being used.
7. Variations in stockpile moisture content will affect spreader performance. De-icing materials should therefore be stored in a controlled manner to minimise such variations and authorities should regularly check the moisture content of each stockpile. Where appropriate, equipment settings should be adjusted to account for the measured moisture content.
8. Relevant highway authority personnel such as salting vehicle drivers should be knowledgeable and receive specific training in the capability, performance, set-up and calibration of the spreading equipment systems they utilise. This is in addition to the standard NVQ requirements. Training may be most appropriately delivered by the equipment manufacturers.
9. Highway authorities should exercise caution when considering the reduction of salt spread rates to less than 10 $g/m^2$ and, before instigating such a reduction, should satisfy themselves that the spreading equipment and set-up they employ are delivering consistent and accurate spread patterns to the whole of the target area.
10. There is evidence that trafficking does not redistribute de-icing materials sufficiently to eliminate initial 'snaking effects', an important factor when considering the reduction of spread rates.

11. Residual salt levels reduce markedly during the initial 12 hours after distribution regardless of whether dry, treated or pre-wetted salting techniques are employed. Trial results indicate that as much as approximately one half of the initial material can be lost during this period on a heavily trafficked road during dry road conditions.
12. There is some evidence to suggest that salt loss due to trafficking during dry road conditions is reduced on negatively textured road surfaces, compared to that for positively textured road surfaces.
13. Whenever liquids are employed for de-icing purposes, distribution systems should be equipped with flow meters so that the rate of spread of the liquid onto the road can be monitored and checked during and after the operation. This is in addition to ensuring that the concentration of the liquid solution is correct prior to the commencement of the operation.

One of the main challenges when undertaking research in the winter maintenance field is the large number of parameters that affect the performance of de-icers, and the trials undertaken to date have highlighted the need for these variables to be controlled whenever possible, and recorded and monitored when this is not possible. The difficulty in controlling ‘real world’ variables leads to a need to take particular care when interpreting the results of individual trials and applying these to wider scenarios. The practicalities of planning and undertaking both road and track trials to take place within limited weather windows cannot be overstated.

Some of the individual NSSRG performance trials have involved different grades of salt, different spread widths and different spreader types for each de-icer. Trials of different spreaders have involved different de-icer types, grades, spread widths and moisture contents. Direct comparison between the results of different trials across and outwith the NSSRG research programme is only appropriate once all the influencing parameters have been properly accounted for. Therefore, it is recommended that highway authorities carefully consider the research supporting claims made regarding new techniques, equipment and materials and satisfy themselves that apparently positive results from the research are directly attributable to that product.

It is notable that the trials to date have tended to utilise different de-icing materials in specifications as generally employed by highway authorities in ‘live’ operations. This approach allows general comparisons to be made between the performance of the materials in those specifications. However, because these specifications often include a number of differences between the materials being tested, the effects of changing a single parameter such as grain size or whether the material has been pre-wetted or not is difficult to determine from the results of such trials. Therefore, it may be that future trials should include studying the performance differences that arise from changing individual parameters. Also, the trials to date have been designed to investigate only a limited number of parameters. Investigation of, for example, the specific effects of moisture content and grading of de-icer on distribution and residual salt levels, would require trials designed specifically for this purpose. In order to provide unbiased comparisons, the spreading equipment utilised in any such trial would require separate calibrations so that the distribution is optimised for each de-icer.

Improvements and developments in trial methodology have been notable features of the NSSRG research programme and, as is usual in applied research, some of the lessons in this regard have been relatively hard won. One important conclusion that can be drawn from the trials to date is that each future trial should be carefully designed around a single set of achievable objectives. Although it is sensible to take maximum advantage of trials and research that have been designed around the aims and objectives of an individual sponsoring authority, care must be taken so that the scope of the trial is not broadened to the extent that interpretation and application of the results is jeopardised.

In general terms, the NSSRG trial programme to date has been designed so that the spreading equipment has been tested in the set-up configuration that would normally be used by the highway authority operating the equipment. This would appear to constitute a logical approach when the trial is investigating the current performance of the equipment when being used in a ‘live’ situation. However, this approach may not determine the maximum potential of the equipment if, for example, the set-up configuration used by the authority does not represent that which is most appropriate for a particular technique, material or spread rate as recommended by the equipment manufacturer. It has been established that in a relatively large proportion of the trials, the spreading equipment may not have been optimally set up for the specific de-icer and/or spread rate/pattern being tested. It is considered that issues such as those experienced during the trials with calibration, incorrect equipment settings, de-icer condition and possible equipment malfunctioning may well therefore not be limited to these trials but that they may also be experienced during 'live' salting operations albeit that these may not be routinely identified.

Therefore, another lesson to be drawn from the trials to date is the importance of obtaining precise details regarding the calibration procedure and specific set-up configuration for the equipment being trialled. This would be in addition to undertaking checks on spreader performance through static discharge tests and, where possible, weighbridge measurements. Knowledge of this information would greatly assist in the provision of advice to NSSRG members regarding optimum equipment settings for individual de-icing materials and distribution patterns.

In addition to the overall findings discussed above, this review of the NSSRG trial programme to date has resulted in a number of specific recommendations being made regarding future trial methodologies, such that:

- A suitably qualified and experienced person should be present at each trial with specific responsibility for ensuring that the trial equipment is satisfactorily calibrated and configured and that de-icing materials are of the appropriate quality and composition.
- Whenever practicable, manufacturers of the trialled spreading equipment should be present at each trial. They should, at least, be specifically invited to attend each trial.
- The NSSRG trial checklist should be employed during all trials.
- Spreading equipment should be calibrated and appropriately configured for the specific de-icer being trialled and for each spread rate and spread width.
- Spreading equipment should be calibrated as close to the commencement of the trial as practicality allows with the de-icing material that is to be used in the trial.
- Spreading equipment performance and de-icer condition should be checked immediately prior to each trial.
- Spreading vehicles should be driven and operated by suitably experienced and qualified operators.
- The spread distribution should be checked visually during a pre-trial test run.
- Where practicable, static discharge tests should be performed on each day of a trial and reliable weighbridge measurements should be made during the trial to confirm that the spreading equipment is operating within acceptable limits. This process should include direct measurements of brine concentration and discharge during trials involving pure brine solutions and/or pre-wetted salting.
- All available information regarding the configuration of the spreading equipment during the trials should be recorded.
- Where possible, data from on-board monitoring equipment should be collected to assist in confirming the configuration and performance of spreading equipment.
- A detailed check list should be used to ensure all actions have been carried out for each trial.
- During performance trials, the area of surface from which results are taken should be the full target spread width, margin and verge, with the trial panels marked out accordingly.

Highway winter maintenance is a direct, safety related service that is generally viewed by the UK public as being of particular importance to their everyday activities. The service is now directly incorporated into legislation across Great Britain in a way which reflects this importance but which also provides the potential for highway authorities to face litigation when accidents arise on roads adversely affected by winter conditions. Changes in the way in which Police investigations of road traffic accidents are conducted and the introduction of Corporate Manslaughter legislation later this year are also bringing highway maintenance and other road services into sharp focus. When these factors are coupled with the costs of carrying out highway winter maintenance operations, the purchase price of equipment and materials, the potential detrimental environmental side-effects of the over-use of de-icing materials and the variable nature of the UK weather and climate, it can be seen that properly managed independent research into the efficacy of highway winter maintenance operations and the performance of de-icer application systems, techniques and materials is of particular importance to the nation as a whole. Specific individual organisations undertake their own programmes of research in this field. However, the NSSRG holds a unique position in comprising member authorities from across the whole of the country, as well as representatives from a wide cross-section of manufacturers and suppliers. The NSSRG research programme is therefore considered to be of particular importance to highway winter maintenance activities across the UK and its findings are already proving extremely valuable in shaping the future of this highly important field.

Recommendations for the future direction of the NSSRG research programme that have arisen from this review report include building upon the work undertaken to date, reasserting the emphasis of providing practical guidance, using the existing knowledge and expertise of NSSRG members to best advantage, maximising the potential for specific issue ‘quick wins’ and addressing the all important issues of safe salting.

# 1 Introduction

The National Salt Spreading Research Group (NSSRG) commissioned TRL Ltd in 2001 to undertake a programme of research into the performance of highway winter maintenance salt spreading equipment. The first phase of the programme mainly focussed on spreader performance under controlled conditions on the TRL research track in Berkshire, and was completed and reported in 2005. This phase included thirteen track based trials and five road trials being undertaken with the assistance and co-operation of members of the NSSRG, as well as Strategic Highway Research Program (SHRP) tests to determine the de-icing capabilities of eight de-icers. A 'Best Practice' guidance document for spreading salt was produced for the benefit of all NSSRG members.

Phase 2 of the programme was commissioned following receipt of the Phase 1 final report and has so far included the undertaking of a further two track trials and four road trials of spreading equipment, as well as investigations into the dissolution rates of five de-icers, the winter maintenance of footways and cycleways across the country and laboratory trials of the effects of salt application on the skidding resistance of road surfaces.

Before and during the period of the NSSRG research programme, the Highways Agency separately commissioned TRL to carry out certain performance trials of winter maintenance techniques, equipment and materials, and kindly made some of the results of those trials available to the NSSRG.

The overall aims of the NSSRG research programme include assisting highway authorities with operational decisions concerning the choice, setup and performance of their winter maintenance salt spreading equipment. The main drivers behind the work include improving the cost effectiveness of UK highway winter maintenance operations and a desire to ameliorate the environmental impact of those operations by reducing the amount of salt spread on the roads without compromising safety.

Specific objectives of the NSSRG Phase 1 and 2 trial programme to date include:

- Researching spread rate and distribution patterns of dry (untreated) salt, pre-wetted salt and salt treated with agricultural based additives (treated salt), as well as brine only application, through dynamic performance testing.
- Determination and confirmation of whether specific distribution systems are capable of delivering the required performance standards, in terms of required coverage and rate of spread for different de-icers.
- The development and evaluation of techniques for the measurement of residual salt levels.
- Comparisons of the performance of different de-icer types in highway based field trials.
- Identifying optimum salt grade, purity and moisture content for dry and pre-wetted salt applications.
- Identifying optimum rates of spread for different salting techniques.

A trial methodology was developed by TRL during Phase 1 of the NSSRG research programme in accordance with BS 1622 (BSI 1989) so as to allow the performance of spreader and de-icer combinations to be assessed with regard to variations in hopper load, spread rate and spread symmetry. The results from the track trials were then used to plan and carry out trials on the road, which were generally designed to corroborate, or otherwise, the trial results in 'real world' situations and also to investigate the effects of trafficking and other factors.

There are a large number of parameters which affect the distribution and performance of de-icers on the carriageway, only a proportion of which can be controlled by those undertaking a trial or 'live' operation.

Ideally, when investigating the effects of any one parameter under trial conditions, the others would be held constant, or at least the number of variables would be minimised. This would require detailed specification of parameters such as de-icer type and grading, as well as careful monitoring and, if possible, processes to compensate for those variables, such as de-icer moisture content, humidity and wind speed, which cannot be so carefully controlled.

Whilst the overall aims and objectives of the trials were established by NSSRG, individual trials tended to be undertaken in response to members of the Group (from local authorities or industry) volunteering their equipment, de-icers and/or road networks. Whilst this approach is fully understandable and the generosity of sponsoring organisations has been laudable, one of the results is that many of the individual trials have involved the variation of a relatively large number of parameters, which have also differed between the trials. The trial methodology has also developed with time, as experience has been gained, and the combination of all of these factors has led to difficulties with the interpretation of trial results and in their application to a wider context.

Therefore, in September 2007, TRL was commissioned by the NSSRG to undertake a review of the trials completed to date, to extract the maximum value from the results and ensure all the lessons that can be learned from the previous work can be incorporated into future trial methodologies. The various tasks of the review consisted of the following:

- Identification of the key elements of the methodology used for each performance and road trial (Section 2)
- Summary of trials completed to date (Section 3)
- Identification of correlations between trial results (Section 4 – spreading performance, Section 5 trafficking effects)
- Assessment of trial methodology with regard to lessons that can be drawn from the trials undertaken to date and how this knowledge can best be applied to future trials (Section 6).
- Discussion (Section 7)
- Conclusions and recommendations for future trials (Section 8)

It is expected that the NSSRG and those individual organisations that have funded and taken part in the trials to date will be able to utilise this Review Report to help shape the future of the NSSRG research programme and to assist them in assessing the value of the work to their organisation.

# 2 Trial methodologies

## 2.1 Track based performance trials

Performance trials were carried out on the test track at TRL using a methodology developed by TRL and based on the procedure in BS 1622 (BSI, 1989). The test methodology is described in the NSSRG Phase 1 Final Report (Burtwell et al, 2004) and the key points are summarised here.

It should be noted that the objectives of the trials have focussed on assisting authorities in understanding the performance of equipment and materials in the configurations and specifications as are either actually employed in 'live' salting operations or would potentially be employed in future 'live' operations. Spreading equipment used during the trials was provided by individual sponsoring authorities that had a particular interest in findings relating to that equipment, and those authorities generally determined the equipment settings and the specification of de-icing products to be employed in each trial. By this method, the results obtained from the trials have directly addressed the requirements of the sponsoring authorities and it has considered that this approach would also provide useful information to the wider NSSRG membership.

Static discharge tests were not carried out on site during the trials on the understanding by those managing the trials that the equipment providers had ensured that the spreaders had been appropriately calibrated for the types of de-icer being tested.

For each de-icer type, the method in most cases involved a total of 8 test runs at 50km/h as shown in Table 1. The exceptions to this included the trial of brine spreading, using the Epoke Combi Sirius S4502, where only asymmetric spreading was investigated and repeat tests were made for each spread rate. Similarly, only asymmetric spreading was investigated for the Giletta spreader and repeat measurements were made for each spread rate and hopper load combination. Trials of the modified Schmidt spreader were carried out only with the hopper one third full.

**Table 1. Permutations for salt spreading**

| Test Run No. | Spreader | | |
|---|---|---|---|
| | Spread rate ($g/m^2$) | Hopper | Distribution |
| 1 | 10 | Full | Asymmetric |
| 2 | 20 | Full | Asymmetric |
| 3 | 10 | Full | Symmetric |
| 4 | 20 | Full | Symmetric |
| 5 | 10 | 10 per cent Full | Asymmetric |
| 6 | 20 | 10 per cent Full | Asymmetric |
| 7 | 10 | 10 per cent Full | Symmetric |
| 8 | 20 | 10 per cent Full | Symmetric |

Collection of the de-icer was from 3 strips spaced 50m apart. The total width of each strip was 15m and de-icer was collected from eight $1m^2$ panels across the strip. One panel was placed in each of the zones, as specified in BS1622 and shown in Figure 1. BS1622 does not specify a 3-lane layout, therefore the 2-lane layout was modified as shown in Figure 2.

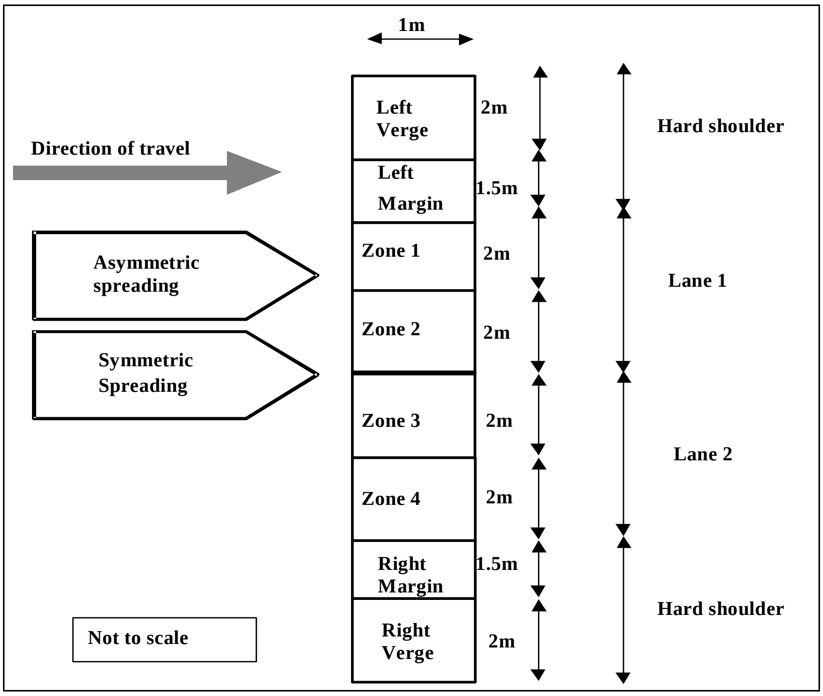


**Figure 1. Schematic layout of the markings for a single strip for 2-lane spreading according to BS 1622 (BSI, 1989)**

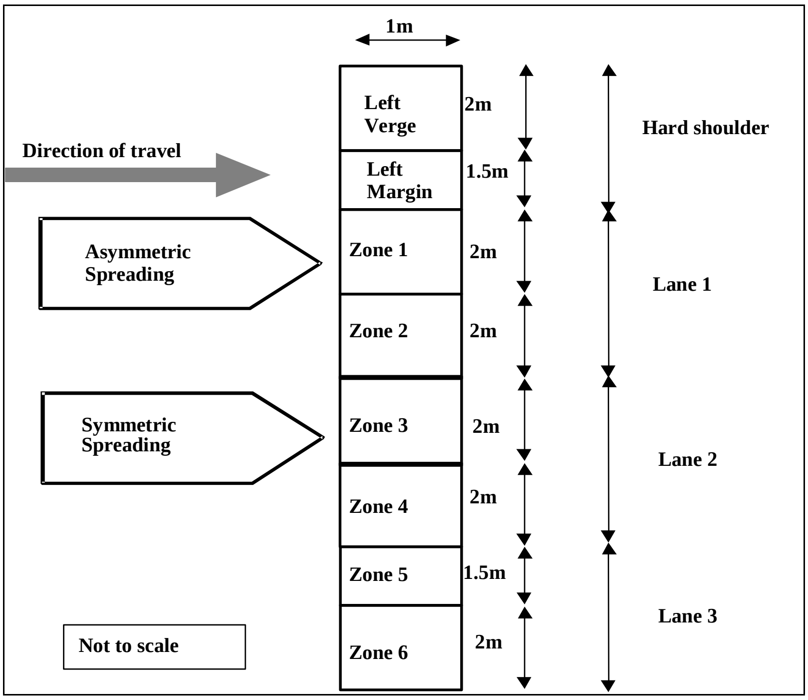


**Figure 2. Schematic layout of the markings for a single strip for 3-lane spreading**

As well as measuring the de-icer in the target area, it was possible to assess the level of wastage outside of the target area. De-icer was only collected from one panel within each zone, with the spread rate measured within this panel taken to be representative of the zone as a whole. The above setup therefore collected only about half of the salt from lanes 1 and 2.

In order to increase the area from which the salt was collected, the above methodology was developed for the most recent trial of the Unibody. The width of lanes 1 and 2 was reduced from 8m to the spread width, and the total width of the strips was reduced from 15m to the spread width plus 7m. The panels used were 1.2m wide rather than 1m, and the number of panels within lanes 1 and 2 was increased to 5. The positions of the zones and quadrates are given in Table 2 for a spread width of 7m.

**Table 2. Panel details for Unibody trial**

| Panel name | Zone width (m) (start and end position from left verge (m)) | Panel width (m) (start and end position from left verge (m)) |
|---|---|---|
| Left verge | 2.0 (0.0 – 2.0) | 1.2 (0.4 – 1.6) |
| Left margin | 1.5 (2.0 – 3.5) | 1.2 (2.0 – 3.2) |
| Zone 1 – Lane 1 | 7.0 (3.5 – 10.5) (5 quadrates) | 1.2 (3.5 – 4.7) |
| Zone 2 – Lane 1 | | 1.2 (4.95 – 6.15) |
| Zone 3 – Lanes 1/2 | | 1.2 (6.4 – 7.6) |
| Zone 4 - Lane 2 | | 1.2 (7.85 – 9.05) |
| Zone 5 – Lane 2 | | 1.2 (9.3 – 10.5) |
| Right margin | 1.5 (10.5 – 12.0) | 1.2 (10.8 – 12.0) |
| Right verge | 2.0 (12.0 - 14.0) | 1.2 (12.4 – 13.6) |

### 2.2 Road trials

Trials were carried out on the road in order to corroborate the results obtained from the track trials and to investigate the effects of trafficking. The detailed methodologies adopted were dependent on the specific aims and location of each trial and were derived using the experience gained from the track trials, the main generic points being that:

- De-icer was collected from 3 or 4 test strips, spaced up to 100m apart
- The majority of de-icer spread within the lanes was collected (which necessitated a closer spacing between panels than the track trials)
- In most trials one spread rate, hopper load and spread symmetry were used
- It was not feasible to determine quantitatively wastage beyond the carriageway to the verge and margin, although polythene sheets were placed in the verge when space permitted.
- Static discharge tests and trial runs were performed before some trials
- The effect of trafficking on residual salt levels was measured in most trials

# 3 Summary of completed trials

Table 3 summarises the track based performance trials and Table 4 summarises the road trials carried out to date.

**Table 3. Summary of TRL performance trials carried out during Phase 1 and Phase 2**

| Spreader type | Grade of salt used | Moisture content (%) | Type of salting | Number of lanes (target spread width, m) |
|---|---|---|---|---|
| HA pre-wetted trial | 10mm rock | 4.7 | Dry | 2-lanes |
| | 6.3mm, rock (Salt Union) | 4.6 | Pre-wetted | |
| Econ 6m$^3$ Permanently mounted bulk spreader – 1995 model on Mercedes Benz Chassis | 10mm, rock (Salt Union) | 1.0 | Dry | 2-lanes (6.0) |
| Econ 6m$^3$ Low Throw Permanently mounted bulk spreader – 1999 model on Mercedes Benz Atego Chassis | 10mm, rock (Salt Union) | 3.0 | Dry | 2-lanes (6.0) |
| Epoke Sirius SH3590 | 3mm, rock (Salinity from Germany) | N/A | Pre-wetted | 3-lanes (9.0) |
| | 6.3mm, rock (Salinity from Germany) | 1.2 | Dry | 2-lanes (7.0) |
| Schmidt Stratos B90-42-VALN5Z | 6.3mm, rock (Salt Union) | 2.4 | Dry | 3-lanes + hard shoulder (13.0) |
| | | | Pre-wetted | |
| Econ 6m$^3$ Zero C Mk 4 Pre wet Permanently mounted bulk spreader – 2002 model on Leyland DAF Chassis | 6.3mm, rock (Salt Union) | 1.59 | Dry | 2-lanes (6.0) |
| | 3mm, rock (Salinity from Germany) | 1.72 | Pre-wetted | |
| Epoke Sirius SH3500 | 6.3mm, rock (Salinity from Germany) | 5.41 | Pre-wetted | 2-lanes (7.0) |
| Epoke Combi Sirius S4502 | Brine only | - | Brine | 2-lanes (7.0) |

<table>
<tr><th>Spreader type</th><th>Grade of salt used</th><th>Moisture content (%)</th><th>Type of salting</th><th>Number of lanes (target spread width, m)</th></tr>
<tr><td rowspan="2">Modified Schmidt Stratos B90-42-VALN5Z</td><td rowspan="2">6.3mm, rock (Salt Union)</td><td rowspan="2">1.93</td><td>Dry</td><td rowspan="2">3-lanes + hard shoulder (12.0)</td></tr>
<tr><td>Pre-wetted</td></tr>
<tr><td>Giletta 80501D 9.6 cu m dedicated spreader mounted on Mercedes 331AK 6x6 chassis</td><td>6.3mm, rock (Moroccan Bröste)</td><td>6.42</td><td>Dry</td><td>2-lanes (6.0)</td></tr>
<tr><td>Epoke Sirius SH3500 (Repeat)</td><td>3mm, rock (Salinity from Germany)</td><td>1.70</td><td>Pre-wetted</td><td>2-lanes (6.0)</td></tr>
<tr><td>Econ Unibody</td><td>6.3mm, rock (Salt Union)</td><td>1.3</td><td>Dry</td><td>2-lanes (7.0)</td></tr>
</table>

**Table 4. Summary of road trials carried out during Phase 1 and Phase 2**

<table>
<tr><th>Authority</th><th>Spreader type</th><th>Grade of salt used</th><th>Moisture content (%)</th><th>Type of salting</th><th>Number of lanes (target spread width, m)</th><th>Aim of trial</th></tr>
<tr><td rowspan="2">HA pre-wet</td><td rowspan="2">Various</td><td>10mm rock</td><td>3.7</td><td>Dry</td><td rowspan="2">3-lanes</td><td rowspan="2">Comparison of distribution and effects of trafficking for dry and pre-wetted salt</td></tr>
<tr><td>6.3mm, rock (Salt Union)</td><td>4.2</td><td>Pre-wetted</td></tr>
<tr><td>Surrey CC</td><td>Econ Zero C Mk 4</td><td>3mm, rock (Salinity from Germany)</td><td>1.94</td><td>Pre-wetted</td><td>2-lanes (7.0)</td><td rowspan="3">Distribution and effects of trafficking for pre-wetted salt</td></tr>
<tr><td>Lincolnshire CC</td><td>Epoke Sirius SH3500</td><td>6.3mm, rock (Salinity from Germany)</td><td>2.93</td><td>Pre-wetted</td><td>2-lanes (7.0)</td></tr>
<tr><td>Hampshire CC</td><td>Epoke Sirius SW3501 (2003 model)</td><td>6.3mm, rock (Salt Union)</td><td>1.29</td><td>Pre-wetted</td><td>2-lanes (5.0)</td></tr>
</table>

| Authority | Spreader type | Grade of salt used | Moisture content (%) | Type of salting | Number of lanes (target spread width, m) | Aim of trial |
|---|---|---|---|---|---|---|
| Welsh Assembly Government | Modified Schmidt | 6.3mm, rock | 2.74 | Dry | 3-lanes + hard shoulder | Comparison of distribution and effects of trafficking for brine, dry untreated and treated salt and pre-wetted salt |
| | | 6.3mm, Safecote treated rock salt | 3.27 | | | |
| | | 6.3mm, rock | 2.74 | Pre-wetted with brine | | |
| | | | | Pre-wetted with brine and Safecote mix | | |
| Scottish Executive A9 | Giletta 80501D | 6.3mm, rock (Moroccan Bröste) | 3.94 | Dry | 2-lanes (6.0) | Comparison of distribution and effects of trafficking for dry and treated salt |
| | | 6.3mm, Safecote treated Moroccan Bröste | 5.46 | | | |
| Lincolnshire CC | Epoke Combi Sirius S4502 | Brine only | - | Brine | 2-lanes (7.0) | Distribution and effects of trafficking for brine spreading |
| Highways Agency M62 | Foden 4000 | 6.3mm, rock (Salt Union) | 1.60-2.43 | Dry | 3-lanes + hard shoulder (13.0) | Comparison of distribution of dry and treated salt on thin surfacing |
| | | 6.3mm, Safecote treated rock salt (Salt Union) | 2.19-2.56 | Treated | | |
| Staffordshire CC, East Sussex CC, Scottish Executive A460 | Econ Zero C | 6.3mm, rock (Salt Union) | 3.3 (Trial 1) 4.7 (Trial 2) 5.7 (Trial 3) | Dry | 2-lanes (8.0) | Comparison of distribution and effects of trafficking for dry, treated and pre-wetted salt |
| | | 6.3mm, Safecote treated rock salt (Salt Union) | 3.2 (Trial 1) 4.6 (Trial 3) | Dry | | |
| | | 6.3mm, rock (Salt Union) | 4.7 (Trial2) | Pre-wetted | | |

# 4 Review of spreading performance

It is clear that, although the results of each trial relate to a specific combination of trial parameters and conclusions can be drawn regarding the distribution for each spreader de-icer combination under the conditions tested, there may also be wider benefits to be obtained if the results of different trials are compared against each other. Individual trial results have already been reported in detail and separately, but this report has included a review of these results in order to identify the main correlations that exist across the various test results relating to the effect of different parameters on distribution and spreader performance.

## 4.1 Spreader performance

Conclusions were drawn in the Phase 1 Final Report and the individual trial reports regarding the performance of each spreader de-icer combination under the conditions prevailing during the trial period.

In terms of the overall performance of the different spreaders, the results from both the track and road trials generally showed uneven distribution between the lanes and longitudinal variation, or snaking, in the de-icer distribution profile.

In many of the trials the total amount of de-icer discharged was less than the target amount and the amount spread within the lanes was also less than the target amount in nearly all of the trials. During trials involving the spreading over three lanes, the amount of de-icer spread in lane 3 was consistently less than the amount spread in each of the other lanes; a factor which must be taken into account when determining the target spread rate.

It should be noted that the target amount in the trials was assumed to equal the product of the spread width set on the spreader, the spread rate, and the area of the panels which were within the spread width and from which salt was recovered.

BS 1622 assesses the performance of spreaders somewhat differently. For performance tests as defined in Appendix A, a calculated total is defined as the product of the area of the panels in the main zone (the traffic lanes) plus the margins and verges (see Figure 1), and the spread rate. The total mass of salt collected from the main zone, margins and verges must be within 10 per cent of the calculated total, and the mass of salt collected from the verges must be less than 1 per cent of the total collected. These requirements would suggest that the spread rate should fall from near the target spread rate to effectively zero across the relatively narrow width of the margins. However, current spreader technology is not able to achieve this level of precision in placing de-icer, and therefore spreaders configured to satisfy the requirements of Appendix A of BS 1622 generally tend to overspread considerably in the main zone.

For the above reason, basing the target amount on the spread width was considered to be preferable to the BS1622 method for the performance trials conducted by TRL.

### *4.1.1 Accuracy and repeatability of spreader distribution.*

Unfortunately and due to time and cost constraints, the majority of trials involved only one test of the spreader for each combination of trial parameters. However, there was an opportunity for repeat testing during the performance trials on the Giletta spreader, where only asymmetric spreading with dry salt was investigated. Repeat testing was also carried out for some of the combinations of de-icer and spreader set-up during the M62 road trials and of treated and untreated salt during the A460 road trials. A comparison is therefore made here of the ‘repeat’ results from these trials in order to provide an approximate indication of the confidence levels that may be applied to all of the trial results.

For the Giletta performance trial, tests were carried out of asymmetric spreading with dry salt at rates of 10g/m² and 20g/m², with the hopper both full and 10 per cent full. Table 5 shows the percentage of the target spread rate achieved in the lanes for each test, test 1 and test 2 referring to the repeat tests carried out under the same conditions. Table 6 shows the difference between the results for test 1 and test 2 expressed as a percentage of the target spread rate.

**Table 5. Spread rates achieved in Giletta performance trials**

| Type of salting | Percentage of target spread rate (%) | | | | | |
|---|---|---|---|---|---|---|
| | Hopper full | | | Hopper 10 per cent full | | |
| | Lane 1 | Lane 2 | Average of lanes | Lane 1 | Lane 2 | Average of lanes |
| 10g/m² Test 1 | 27 | 119 | 73 | 41 | 129 | 85 |
| 10g/m² Test 2 | 44 | 61 | 52 | 61 | 92 | 77 |
| 20g/m² Test 1 | 31 | 68 | 49 | 33 | 88 | 60 |
| 20g/m² Test 2 | 58 | 195 | 126 | 42 | 114 | 78 |

**Table 6. Comparison between results for Giletta performance trials**

| Type of salting | Difference between test 1 and test 2 as percentage of target spread rate (%) | | | | | |
|---|---|---|---|---|---|---|
| | Hopper full | | | Hopper 10 per cent full | | |
| | Lane 1 | Lane 2 | Average of lanes | Lane 1 | Lane 2 | Average of lanes |
| Dry 10g/m² | 17 | -58 | -21 | 20 | -37 | -8 |
| Dry 20g/m² | 27 | 127 | 77 | 9 | 26 | 18 |

For the M62 road trials, repeat tests were carried out on symmetric spreading at a rate of 20g/m² with a 10 per cent full hopper, for both dry and treated salt. Table 7 shows the percentage of the target spread rate achieved in the lanes for each test. Table 8 shows the difference between the results for test 1 and test 2 expressed as a percentage of the target spread rate.

**Table 7. Spread rates achieved in M62 road trials**

| Type of salting | Percentage of target spread rate (%) | | | |
|---|---|---|---|---|
| | Lane 1 | Lane 2 | Lane 3 | Average of lanes |
| Dry Test1 | 73 | 74 | 95 | 76 |
| Dry Test2 | 132 | 85 | 150 | 110 |
| Treated Test 1 | 103 | 85 | 126 | 100 |
| Treated Test 2 | 127 | 93 | 153 | 118 |

**Table 8. Comparison between results for M62 road trials**

| Type of salting | Difference between test 1 and test 2 as percentage of target spread rate (%) | | | |
|---|---|---|---|---|
| | Lane 1 | Lane 2 | Lane 3 | Average of lanes |
| Dry | -59 | -11 | -55 | -34 |
| Treated | -24 | -7 | -27 | -18 |

For the A460 road trials, repeat tests were carried out of asymmetric spreading at a rate of 20g/m² with a full hopper, for both dry treated and untreated salt. Table 9 shows the percentage of the target spread rate achieved in the lanes for each test. Table 10 shows the difference between the results for test 1 and test 2 expressed as a percentage of the target spread rate. The untreated salt spread in Trial No. 1 used a different spreader to the other trials and is not included in the comparison.

**Table 9. Spread rates achieved in A460 trials**

| Type of salting | Percentage of target spread rate (%) | | | | | |
|---|---|---|---|---|---|---|
| | Untreated | | | Treated | | |
| | Lane 1 | Lane 2 | Average of lanes | Lane 1 | Lane 2 | Average of lanes |
| 20g/m² Test 1 | 70 | 89 | 79 | *27* | *120* | *73* |
| 20g/m² Test 2 | 38 | 118 | 78 | 33 | 87 | 60 |

**Table 10. Comparison between results for A460 road trials**

| Type of salting | Difference between test 1 and test 2 as percentage of target spread rate (%) | | | | | |
|---|---|---|---|---|---|---|
| | Untreated | | | Treated | | |
| | Lane 1 | Lane 2 | Average of lanes | Lane 1 | Lane 2 | Average of lanes |
| 20g/m² | 32 | -29 | 1 | -6 | 33 | 13 |

For the Giletta trials, the average difference in the salt measured within the lanes was 31 per cent of the target spread rate (varying between 8 and 77 per cent) for the trials under the same conditions. For the M62 trials the variation was 18 and 34 per cent for the treated and dry salt respectively. However, the A460 trials produced variations of 13 and 1 per cent for the treated and untreated salt respectively. When comparing individual lanes, these differences could be over 100 per cent of the target spread rate and were not always consistent between the two lanes, i.e. one lane could show an increase while the other showed a decrease in the relative amount of de-icer. It should perhaps be noted that the moisture content of the salt used in the Giletta trials was high, at around 6 per cent, and it is considered that this may have affected the distributions recorded during this trial. However, the salt had been emptied and reloaded before the trial in an attempt to minimise consolidation and this appeared to be successful at the time of the trial. Therefore, moisture content may not fully explain the variation discussed above. The M62 trials involved the salt being collected from 4 strips, which should be an improvement over a methodology employing 3 strips, and the spreader was also only loaded immediately prior to the trial to minimise consolidation.

It is clear from the results that the variation in spreader performance between trials under similar conditions can be highly significant.

It should be noted that the results discussed here relate to just three spreaders, performing under the individual trial conditions. However, the results appear to indicate that differences in measured spread rates within the target area of up to 10 per cent of the target spread rate would not be unusual and that this could be 30 per cent or more when distributions are compared across individual traffic lanes within the target area.

### *4.1.2 Comparison of road and performance trial results*

A comparison has been made between the results obtained during the track and road trials with the same spreader de-icer combinations. Tables 11 and 12 show the trial parameters and spread rates achieved in the lanes respectively in order to compare the distribution for the track and road trials, taking the left hand side of lane 1 as the common reference point. Lane 1 and lane 2 shown in Figure 3 to Figure 5 refer to the road trial layout and it should be noted that the spread width was not always the same for the two trials. It should also be noted that, for the track trials, the total width of lane 1 and lane 2 was taken to be the spread width used for that trial. For the road trials, the lanes refer to the actual road and the lane width did not always exactly match the spread width.

**Table 11. Summary of trial parameters for track and road trials**

| Spreader type | Type of salting | Spread width (m) | | Total lane width (m) | | Moisture content (%) | |
|---|---|---|---|---|---|---|---|
| | | Track trial | Road trial | Track trial | Road trial | Track trial | Road trial |
| Econ Zero C | 3mm Pre-wetted | 6 | 7 | 6 | 7.3 | 1.72 | 1.94 |
| Epoke Sirius SH3500* | 6.3mm Pre-wetted | 7 | 7 | 7 | 7.3 | 5.41 | 2.93 |
| Giletta 80501 | 6.3mm Dry | 6 | 6 | 6 | 6 | 6.42 | 3.94 |

* Spinner speed was set as for 3mm salt in both track and road trials

**Table 12. Percentage of target spread rate achieved across the lanes**

| Spreader type | Percentage of target spread rate (%) | | | | | |
|---|---|---|---|---|---|---|
| | Track trial (full hopper) | | | Road trial | | |
| | Lane 1 | Lane 2 | Average of lanes | Lane 1 | Lane 2 | Average of lanes |
| Econ Zero C | 72 | 85 | 79 | 53 | 149 | 101 |
| Epoke Sirius SH3500* | 30 | 31 | 31 | 38 | 77 | 57 |
| Giletta 80501 | 35 | 90 | 58 | 27 | 28 | 28 |

* Spinner speed was set as for 3mm salt in both track and road trial

Comparison of the results between track and road trials shows significant variations in performance. There were differences in the distribution profile across the carriageway and variations between the trials of up to 50 per cent of the target spread rate measured within the lanes. While there were some differences in salt moisture content and target spread width across the different trials, the variation shown by the results is considered likely to be greater than that which could be attributed to these variables alone. It is also possible that modifications were made to the spreading equipment following the track trials and before the road trials, but TRL have no information regarding this issue at present. The track and road trials on a Econ Zero C spreader were with different spreaders.

There was possible consolidation of the salt in the hopper of the Epoke Sirius SH3500 during the journey to TRL, which could explain the under salting measured during the track trial. The spinner speed during both the track and road trial was set incorrectly for 3mm salt and was therefore too high for the 6.3mm salt used in these trials, causing considerable wastage to the nearside and offside verges. During the Giletta road trial, clumping of the salt was observed along the road, with more salt spread in some areas than others. From observations, it would appear that the salt collection was made in areas where the spread rate was lower, possibly explaining the lower spread rates measured during this trial than in the track trial. The moisture content was high for the road trial, but even higher for the track trial, and the high wastage to the offside verge in the track trial was attributed to the high moisture content.

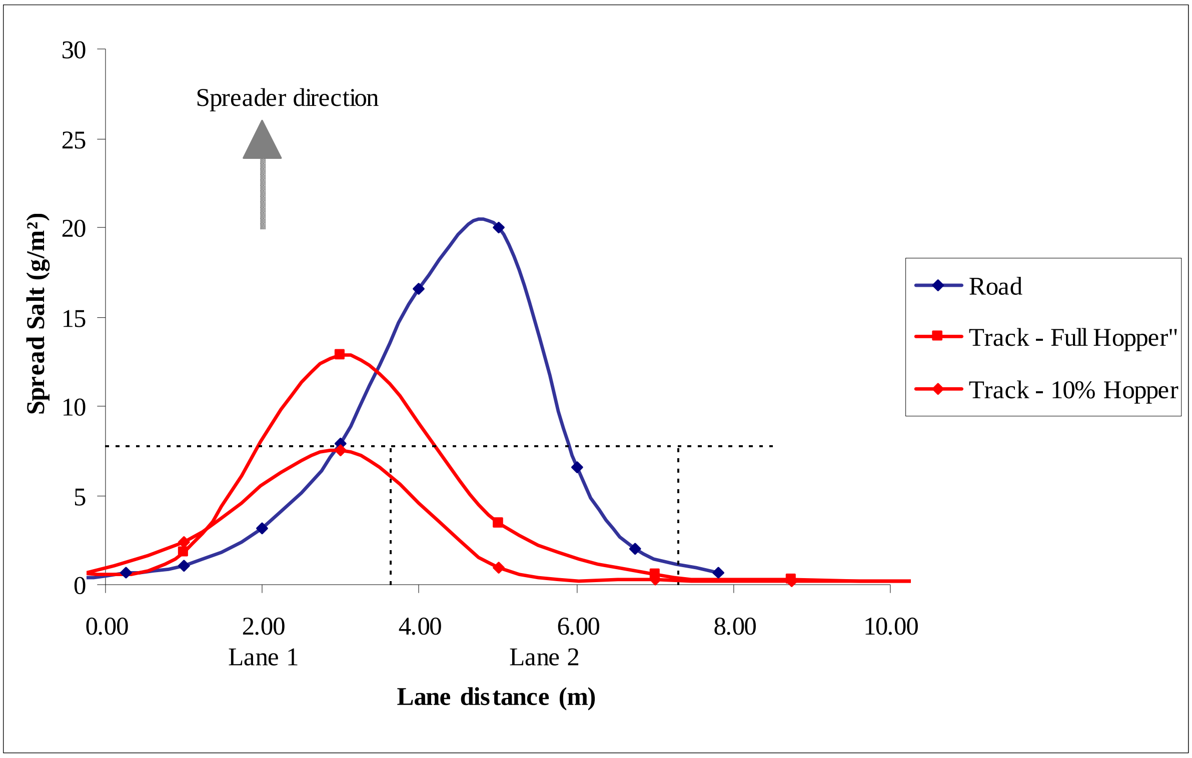


**Figure 3. Comparison of track and road trial de-icer distribution for Econ Zero C spreading 3mm pre-wetted salt**

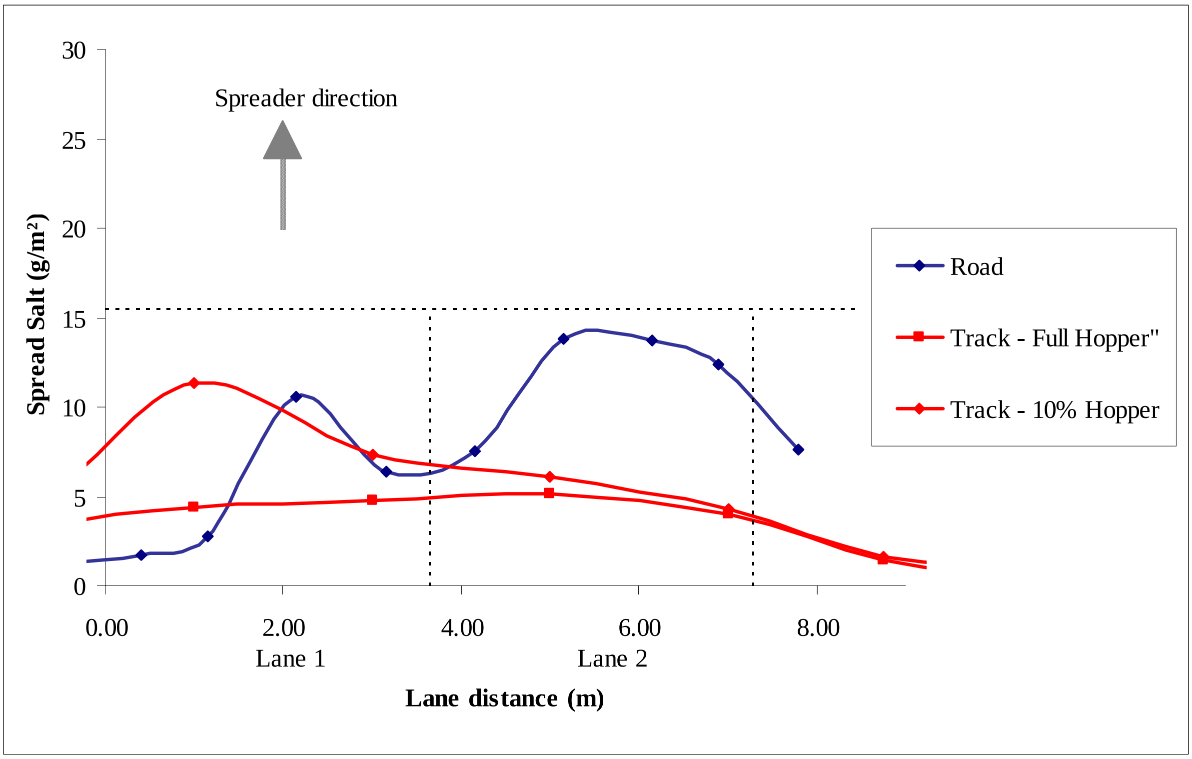


**Figure 4. Comparison of track and road trial de-icer distribution for Epoke Sirius SH3500 spreading 6.3mm pre-wetted salt**

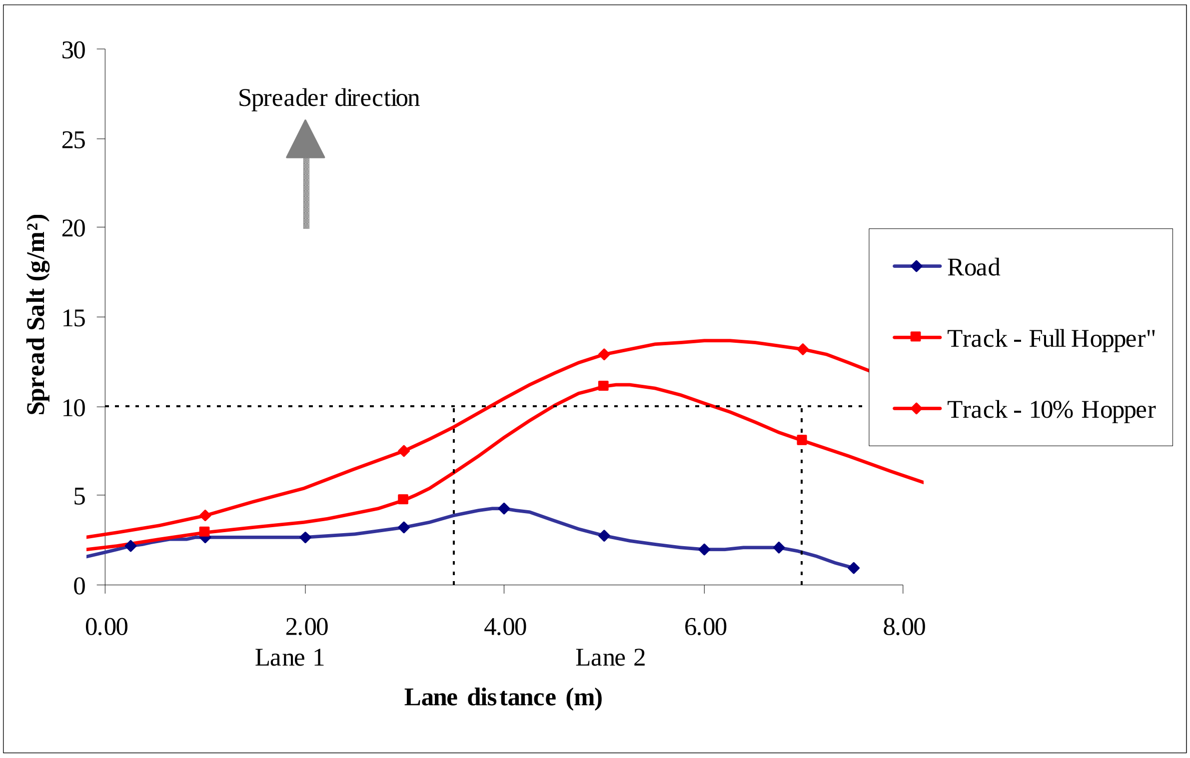


**Figure 5. Comparison of track and road trial de-icer distribution for Giletta 80501D spreading 6.3mm dry salt**

### 4.2 Hopper load

For each spread rate and symmetry setting, track trials were carried out with the hopper full and with a hopper that was only 10 per cent full. Road trials were also carried out on the M62 where the effect of hopper load could be investigated.

Table E1 in Appendix E provides the detailed results of the hopper load comparisons. The results are expressed as a percentage of the target spread rate and show the difference in the amount of salt discharged between the two hopper loads, when the other factors were unchanged,. It is considered that the effect should only be considered significant when the difference is greater than 10 per cent of the target spread rate. A negative value, highlighted in green in the table, indicates that less salt was discharged when the hopper was full than when 10 per cent full. A positive value, highlighted in red, shows that more salt was discharged when the hopper was full.

As can be seen from the results, in most cases more salt was discharged when the hopper was less full. On average, for all the trial results, the difference in the amount discharged was equivalent to 15 per cent of the target amount, and the difference in the salt delivered to the target area was equivalent to 8 per cent of the target spread rate.

### 4.3 Symmetry of application

In nearly all cases, the performance trials involved both symmetric and asymmetric spreading. A comparison has therefore been made of the total salt discharged, the spread rate in the target area and the wastage outside this area for the different spread symmetries.

The detailed results of these comparisons are shown in Tables E2, E3 and E4 in Appendix E. Table E2 shows the difference in the total amounts of salt discharged for asymmetric and symmetric spreading as a percentage of the target amount. Table E3 shows the difference in the spread rates for each lane and the target area as a whole. A negative value, highlighted in green in the table, indicates a higher spread rate for symmetric spreading. A positive value, highlighted in red, indicates a higher spread rate for asymmetric spreading.

Table E4 shows the difference in the measured wastage outside the target area, expressed as the percentage of the total amount of salt discharged. A negative value, highlighted in green in the table, indicates a higher wastage for symmetric spreading. A positive value, highlighted in red, indicates a higher wastage for asymmetric spreading.

The results from this comparison indicate that the total amount of salt discharged during most of the trials was measured to be lower for asymmetric than for symmetric spreading. On average the difference in the amount discharged was equivalent to 27 per cent of the target amount lower for asymmetric spreading and the difference in the salt delivered to the target area was equivalent to 6 per cent of the target spread rate lower for asymmetric. Consequently, in most trials there was greater wastage for symmetric spreading compared with asymmetric spreading, with the average difference for all the trials equal to 11 per cent of the total amount of salt discharged.

Whilst this suggests that the total amount of salt discharged and wastage are dependent on the mode symmetry, the difference in the total amount of salt discharged is more likely to be due to variability in spreader performance between trials. This is because the belt speed and gate height of the spreader for a specific target spread width and rate should not be dependent on the symmetry.

## 4.4 Spread rate

For each hopper load and spread symmetry, track trials were carried out with spread rates of 10g/m² and 20g/m². Road trials were also carried out on the M62 where the effect of varying the spread rate was investigated. Table E5 shows the difference in the amount of salt discharged at the different spread rates in the above trials, expressed as a percentage of the target spread rate. Table E6 and E7 show the difference in the spread rates in each lane and the target area as a whole, expressed as a percentage of the target spread rate, when spreading asymmetrically and symmetrically respectively. A negative value, highlighted in green in the table, indicates a higher spread rate, relative to the target rate, when spreading at 20 g/m². A positive value, highlighted in red, indicates a higher spread rate relative to the target at 10 g/m². Table E8 and Table E9 show the difference in the measured wastage outside the target area, expressed as the percentage of the total amount of salt discharged.

Nearly all trials resulted in less salt being delivered to the target area than the target amount and this was regardless of the target spread rate. However, there was a noticeable difference in the accuracy of the spread rate achieved compared to target, with the trial equipment tending to deliver a more accurate spread rate when salting at 10 g/m² than at 20 g/m². Across all of the above trials, the average amount of salt distributed to the target area at a spread rate of 10 g/m² was 89% of the target spread rate (8.9 g/m²) and the average amount of salt distributed to the target area at a spread rate of 20 g/m² was 75% of the target spread rate (15 g/m²). This result would seem to indicate the need for calibration of the spreader at all the different spread rates.

## 4.5 Spreader settings

As discussed earlier in this report, the trials undertaken to date have involved the spreading equipment being set up by the local authority and to the settings that the authority would normally utilise. As such there has not been any specific investigation into the effects of varying spreader settings whilst keeping other parameters constant.

It has been assumed by those managing the trials that the spreading equipment was calibrated for the type of salt being tested. However, only limited data is available concerning the specific equipment settings for each of the trials. The effect of altering spreader settings is clearly significant to distribution and performance, but it is considered highly likely that the specific effects will vary with de-icer specification.

One example of the effect that spreader settings can have is that, during a track trial using Epoke Sirius SH3500 equipment and pre-wetted 6.3mm rock salt, the spinner speed was inappropriately set for 3mm salt. The spinner speed was therefore set too high for the trialled material and this resulted in the 6.3mm salt being thrown further from the spreader than it should have been, a low average spread rate within the target area and high wastage.

A repeat trial was carried out at a later date using 3mm pre-wetted salt, which was therefore a material that was matched to the spinner speed. Tables 13 and 14 below show the average amounts of salt measured in each lane for each trial, spreading asymmetrically, and Figure 6 and Figure 7 show the distribution profiles, averaged for both hopper loads at each spread rate. It can be seen that much more salt was delivered to the target area in the repeat trial with less wastage.

While this is an extreme case of the effects of incorrect equipment settings, it serves to illustrate the importance of correctly setting the spreading equipment for the specific de-icer being spread.

The large variation across the results obtained from the track and road trials would tend to suggest that differences in spreader configurations are leading to significant variations in the amount of salt being distributed to the target area, as well as wastage.

**Table 13. Percentage of target amount for 6.3mm salt**

| Type of salting | Percentage of target spread rate (%) | | | | | |
|---|---|---|---|---|---|---|
| | Hopper full | | | Hopper 10% full | | |
| | Lane 1 | Lane 2 | Average | Lane 1 | Lane 2 | Average |
| Pre-wetted ($10g/m^2$) | 39 | 37 | 38 | 70 | 45 | 58 |
| Pre-wetted ($20g/m^2$) | 30 | 31 | 31 | 62 | 37 | 50 |

**Table 14 Percentage of target amount for 3mm salt**

| Type of salting | Percentage of target spread rate (%) | | | | | |
|---|---|---|---|---|---|---|
| | Hopper full | | | Hopper 10% full | | |
| | Lane 1 | Lane 2 | Average | Lane 1 | Lane 2 | Average |
| Pre-wetted ($10g/m^2$) | 110 | 67 | 89 | 92 | 144 | 118 |
| Pre-wetted ($20g/m^2$) | 134 | 123 | 129 | 114 | 122 | 118 |

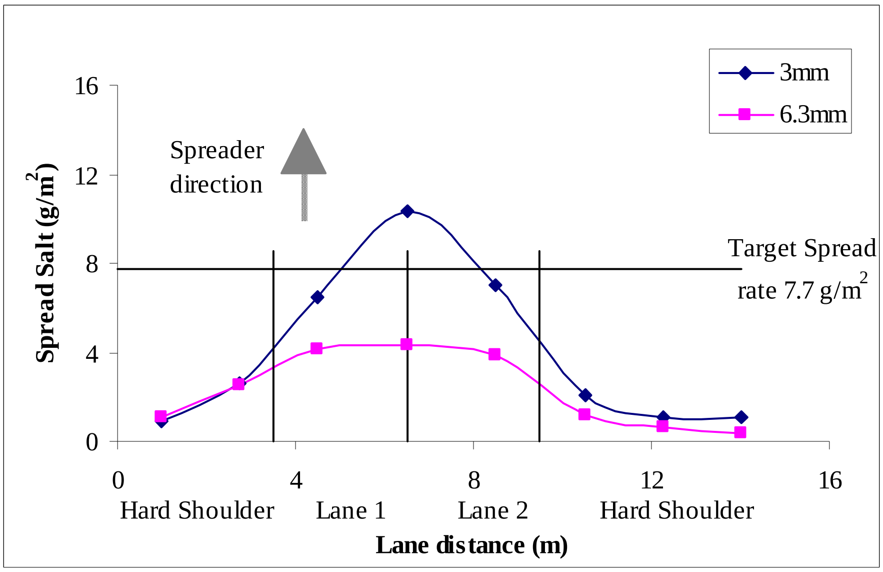


**Figure 6. Comparison of distribution for spreading at 10g/m² with 3mm and 6.3mm salt**

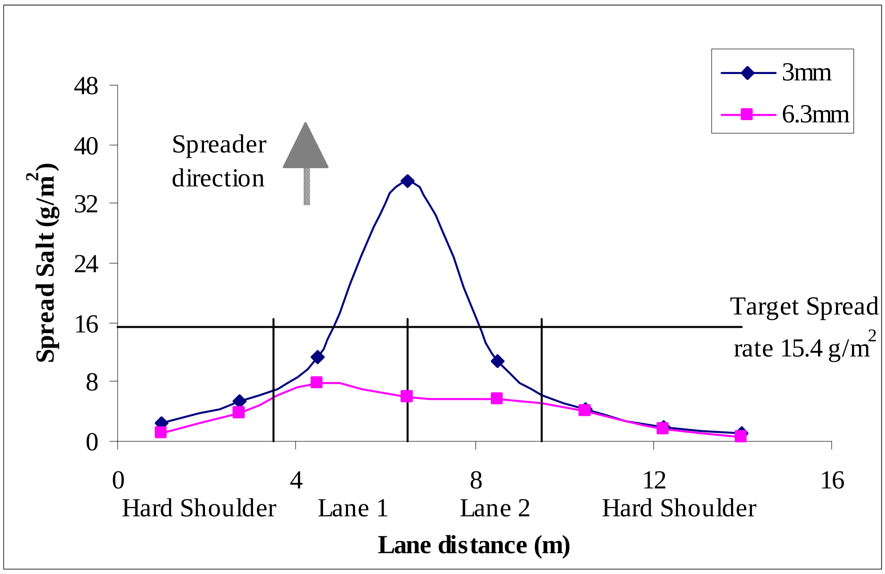


**Figure 7. Comparison of distribution for spreading at 20g/m² with 3mm and 6.3mm salt**

## 4.6 De-icer type

The simplest method to investigate the effects of de-icer type on spread distribution is to compare the results from trials where different de-icers were spread by the same equipment under similar conditions. In order to ensure that trials fairly represent each de-icer, the spreading equipment should be specifically configured before each test, utilising in each case the settings that would be used by an authority when spreading the de-icer in a 'live' operation.

Track trials of both dry and pre-wetted salt were carried out for the NSSRG with a number of spreader types. However and unfortunately, the majority of trials involved different salt types, grading and moisture content, and/or different spread patterns etc. Therefore, the results are not easily compared across these trials. Performance trials for the Highways Agency compared pre-wetted and dry salt spreading. However, the equipment types used for spreading each de-icer were different, and the dry salt components of each de-icer were a different grade.

Having stated the above, track trials were carried out using dry and pre-wetted salt using a Schmidt Stratos machine, enabling a direct comparison between the spreading of dry and pre-wetted salt. Repeat trials were also carried out at a later date with the same spreader, but with the direction of the spinner reversed..

Road trials were carried out on the A48(M) comparing the performance of 4 de-icer types: dry treated; dry untreated; pre-wetted with brine; and pre-wetted with a brine and treatment mix. Unfortunately, issues relating to the recovery of the salt from the road with this trial led to complications in comparing the results.

Road trials were carried out for the Highways Agency on the M6 that compared the performance of dry and pre-wetted salt. However, as for the equivalent track trials, different spreaders were used for the different de-icers and the dry salt used for each de-icer was of a different grade. The salt was also only recovered from the middle lane of the motorway.

Notwithstanding the above, road trials on the M62 and A9 have allowed comparison of dry treated and untreated salt, and trials on the A460 in Staffordshire compared dry untreated, dry treated and pre-wetted salt.

#### *4.6.1 Comparison between trials*

The total quantities of salt discharged during the Schmidt performance trials and the M62, A9 and A460 road trial, expressed as a percentage of the target amount, are shown in Table A1 in Appendix A. The amounts of salt discharged for pre-wetted spreading relative to the amounts discharged for dry salt spreading are shown in Table A2 and for dry treated salt relative to dry untreated salt in Table A3.

A comparison of the average salt distribution profiles for the different de-icer types for the Schmidt and the Modified Schmidt performance trials, the A460, M62 and A9 road trials are shown in Appendix B.

The overall spread rates achieved in the target area as a percentage of the target spread rate and the spread rate within each lane is shown for asymmetric spreading in Table C1, Appendix C, and in Table C2 for symmetric spreading. The ratio of the salt spread rates for pre-wetted/treated salting relative to dry salt spreading are shown in Table 15 and Table 16 for asymmetric and symmetric spreading, respectively.

It should be noted that the target amounts of pre-wetted salt were lower than those for dry salt due to the brine content, e.g. 10g of pre-wetted de-icer contains about 7.7g of salt.

The average ratio between the total salt discharged for each de-icer type and also between the spread rates in the target area for the different spreader and de-icer types are summarised in Table 17 and Table 18 for asymmetric and symmetric spreading, respectively.

As a measure of the longitudinal variation in the salt distribution, the range in the spread rate achieved in the lanes between the strips was expressed as a percentage of the average spread rate for the strips. For example, if the spread rates in strips 1 to 3 of a trial were 45, 50 and 55 per cent of the target spread rate, the range would be equal to 10 per cent of the target rate and the average spread rate would be 50 per cent of the target. The range expressed as a percentage of the average rate would be equal to: 100x10/50 = 20 per cent.

The range in spread rates measured in the Schmidt and the Modified Schmidt performance trials, the A460 road trials and the M62 road trials are shown in Table D1 to Table D3. Table 19 shows the average results for each spreader and de-icer type.

**Table 15 Ratio of salt spread rates achieved in target area for asymmetric spreading (pre-wetted or treated relative to dry)**

| Spreader type | Type of salting | Ratio of amount of salt | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Hopper full | | | | | Hopper 10 per cent full | | | | |
| | | HS | Lane 1 | Lane 2 | Lane 3 | Avg. of lanes | HS | Lane 1 | Lane 2 | Lane 3 | Avg. of lanes |
| Schmidt | Pre-wet/dry (10g/m$^2$) | | 0.66 | 0.91 | 0.77 | 0.77 | | 0.63 | 0.88 | 0.71 | 0.74 |
| | Pre-wet/dry (20g/m$^2$) | | 0.49 | 0.85 | 1.16 | 0.74 | | 0.77 | 0.88 | 1.49 | 0.96 |
| Modified Schmidt | Pre-wet/dry (10g/m$^2$) | | 0.71 | 0.42 | 0.35 | 0.54 | N/A | | | | |
| | Pre-wet/dry (20g/m$^2$) | | 0.67 | 0.72 | 0.56 | 0.67 | | | | | |
| Econ Zero C A460 road trials | Pre-wet/dry (Trial 2) | | 0.28 | 1.40 | | 0.91 | | | | | |
| | Treated/dry (Trial 3) | | 0.87 | 0.74 | | 0.77 | | | | | |
| Giletta A9 road trials | Treated/dry | | 0.93 | 1.71 | | 1.29 | | | | | |

**Table 16 Ratio of spread rates achieved in target area for symmetric spreading**

| Spreader type | Type of salting | Ratio of amount of salt | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Hopper full | | | | | Hopper 10 per cent full | | | | |
| | | HS | Lane 1 | Lane 2 | Lane 3 | Avg. of lanes | HS | Lane 1 | Lane 2 | Lane 3 | Avg. of lanes |
| Schmidt | Pre-wet/dry (10g/m$^2$) | | 0.79 | 1.40 | 1.49 | 1.16 | | 1.04 | 0.90 | 0.85 | 0.95 |
| | Pre-wet/dry (20g/m$^2$) | | 0.79 | 1.15 | 1.85 | 1.09 | | 0.91 | 0.94 | 1.61 | 1.06 |
| Modified Schmidt | Pre-wet/dry (10g/m$^2$) | | 1.29 | 0.78 | 0.77 | 0.91 | N/A | | | | |
| | Pre-wet/dry (20g/m$^2$) | | 0.71 | 0.58 | 0.51 | 0.60 | | | | | |
| Foden 4000 M62 road trials | Treated/dry (10g/m$^2$) | | 1.18 | 1.40 | 2.58 | 1.71 | N/A | | | | |
| | Treated/dry (20g/m$^2$) | | N/A | | | | | 1.12 | 1.12 | 1.14 | 1.13 |

**Table 17 Average ratio between pre-wetted/treated and dry untreated spread rates for asymmetric spreading**

| Spreader | Ratio of salt types | Average ratio between salt spread rates in target area | Average ratio between total amounts of salt discharged |
|---|---|---|---|
| Schmidt | Pre-wet/dry | 0.80 | 0.74 |
| Modified Schmidt | Pre-wet/dry | 0.61 | 0.58 |
| Econ Zero C | Treated/dry | 0.77 | 0.76 |
| Econ Zero C | Pre-wet/dry | 0.91 | 0.93 |
| Giletta | Treated/dry | 1.29 | 1.3 |

**Table 18 Average ratio between pre-wetted/treated and dry untreated spread rates for symmetric spreading**

| Spreader | Ratio of salt types | Average ratio between salt spread rates in target area | Average ratio between total amounts of salt discharged |
|---|---|---|---|
| Schmidt | Pre-wet/dry | 1.07 | 0.99 |
| Modified Schmidt | Pre-wet/dry | 0.76 | 0.78 |
| Foden 4000 | Treated/dry | 1.42 | N/A |

**Table 19. Range in spread rate measured within lanes for each strip**

| Spreader | Range as % of average spread rate | | | Ratio between de-icer types |
|---|---|---|---|---|
| | Dry | Pre-wetted | Treated | |
| Schmidt | 24 | 53 | - | 0.45 |
| Modified Schmidt | 36 | 34 | - | 1.06 |
| Econ Zero C | 28 | 33 | - | 0.85 |
| Econ Zero C | 19 | - | 33 | 0.58 |
| Foden 4000 | 62 | - | 49 | 1.27 |

#### *4.6.2 Comparison of pre-wet/dry salt distribution - Schmidt and modified Schmidt performance trial*

Detailed and specific information concerning the equipment settings used during the comparative trials of the Schmidt and modified Schmidt spreader is not available to TRL. Therefore, it is not clear to the authors of this report how the settings changed between the tests involving the dry and pre-wetted salt in terms of spinner speeds, chute settings etc.

During the trials of the unmodified Schmidt spreader, the ratio of salt collected in the lanes for pre-wetted salting relative to dry salting was slightly greater than the ratio of the total amount of salt discharged (shown in Tables 17 and 18). This would possibly indicate that a greater proportion of pre-wet salt was spread within the target area than dry salt. This was the case for both symmetric and asymmetric spreading. However, during the trial involving the modified Schmidt spreader, where the direction of the spinner was reversed, there was no clear difference between the ratios.

With regard to the distribution profiles, the Schmidt asymmetric spreading results (shown in Appendix B) indicated that the peak of the distribution was further to the offside (right of the spreader) when pre-wetted salting compared to dry salting. However, once again, this effect was less evident in the modified Schmidt results.

A significant degree of snaking was evident in the results of these trials, and there was no indication that, when compared with dry salt, snaking was reduced when pre-wetted salt was being applied (Table 19).

#### *4.6.3 Comparison of treated and untreated salt distribution - A9 road trials*

At the time that they were undertaken, it appeared to those managing the A9 road trials that the spreading equipment was being utilised with the same settings, regardless of whether treated or untreated salt was being spread. Therefore, the results of this trial should allow a direct comparison to be made between the distributions arising from use of the two materials.

However, although approximately 30 per cent more salt was measured within the lanes when spreading treated rather than untreated salt, the total amount of salt discharged was also greater for the treated salt by the same proportion (Table 17). It would therefore appear that the proportion of total salt distributed that was reaching the target area in these trials was similar for both materials.

Having stated the above, observations made on site during the trials indicated that the salt was being spread unevenly by the equipment, with some areas being more heavily salted than others. Therefore, it is considered that the measured distribution on the road may not accurately reflect the distribution achieved by the equipment (as this would depend upon whether or not the test panels received average distributions).

#### *4.6.4 Comparison of treated and untreated salt distribution - M62 road trials*

During the M62 road trials, the same equipment settings were used when spreading both the treated and the untreated salt. Therefore, it is considered that the results of these trials should allow direct comparisons to be made between the spread distributions of the two materials.

The measured distribution across the carriageway was similar for both the treated and untreated salt. However, a significant level of longitudinal ‘snaking’ was evident in the results and this was generally slightly worse in the case of the untreated salt.

#### *4.6.5 Comparison of pre-wet, treated and untreated salt distribution – A460 road trials*

During the A460 road trials the same spreader settings were used for the treated and untreated salt. It is understood that the only change effected for the pre-wetted salt operation other than the addition of brine was a reduction in the gate height.

The peak of the salt distribution in all of the A460 trials was generally in Lane 2 (the offside lane with respect to the salting vehicle) with significantly more salt being spread in Lane 2 than Lane 1. Generally, the peak tended to be nearer to the carriageway centreline for the untreated salt. The peak for the pre-wetted salt was furthest from the spreader. Although the wind may have been a contributory factor in one of the trials, it is considered that this cannot fully account for the measured differences. It is therefore assumed that these results were mainly caused by the different materials being spread.

The amount of salt spread in Lane 2 ranged from 87 to 162 per cent of the target amount for that lane and that in Lane 1 ranged from 25 to 70 per cent of the target amount for that lane, but the amount in the nearside of Lane 1 was significantly less than in the offside. The amount of salt spread to approximately 25 per cent of the target width was less than 25 per cent of the target rate.

There is some considerable doubt regarding the accuracy of the weighbridge measurements that featured in these trials and it has been concluded that these were subject to a random error of up to 50 kg due to an unknown mechanism.

The amount of brine discharged during the pre-wetted trials was not measured by the spreading equipment, and because of the error in the weighbridge measurements discussed above, it cannot be confirmed that the mix proportions of the dry salt and brine components of the pre-wetted salt were those targeted. In one of the trials, the weighbridge measurements suggested that the mix proportions for the pre-wetted salt were 95 per cent dry salt : 5 per cent brine by weight. However, the weighbridge results for the test run made in accordance with Appendix C of BS 1622 suggested that the mix proportions of the pre-wetted salt were 82 per cent dry salt : 18 per cent brine by weight.

In addition, the salt concentration of a sample of the brine utilised in the trial was found to be only approximately 1 per cent, which is well below the target figure of 26 per cent.

#### *4.6.6 Summary*

It is considered that the limited number of NSSRG and other TRL trials undertaken to date, specifically designed to investigate the influence of de-icer type on distribution, have not highlighted any significant differences between the distribution patterns that can be achieved by pre-wetted salting or treated dry salt, compared to those that can be achieved for untreated dry salt. However, it should be noted that this may be a result of any such differences being ‘masked’ by the relatively large distribution variations that have been demonstrated by the equipment used in the trials when spreading the same de-icer type. Comparison of the performance of the different de-icer types will only strictly be valid when the spreader performance has been optimised and calibrated for the particular de-icer being spread. For the trials, it is clear that the spreader performance was not always optimised.

### 4.7 De-icer moisture content

The trials undertaken by the NSSRG to date have not specifically been designed to investigate the effects of de-icer moisture content on spreader performance and a lack of repeat trials using de-icers with the same moisture content (and the relatively large variation that has existed, which ranged from 1 per cent to 6.4 per cent), has not allowed any proper assessment of whether effects arising from de-icer moisture content vary with equipment type and, if so, to what degree.

Results for the Giletta spreader, where the salt moisture content was highest, at around 6 per cent, showed significant wastage to the offside verge and margin. It is possible that this may have been a result of the high moisture content as the increased moisture levels, and subsequently increased mass, could have caused the salt grains to have been thrown further from the spreader than usual. However, without comparison with trials using a lower moisture content, it is impossible to discount the possibility that this distribution was simply a result of the spreader settings utilised.

During the A9 trials with a Giletta spreader, significant levels of clumping and uneven spread rates were identified. It is considered likely that this was caused by the relatively high moisture content of the de-icing material being used.

# 5 Review of trafficking effects

Road trials have been carried out on the A9, A460, A48, A33, A331 and A52 to investigate, amongst other issues, the effects of trafficking on residual salt levels.

The trials to date have all been carried out in dry conditions with similar levels of humidity and, with the exception of the trials on the A460 and A48, which were carried out on sections of road with negatively textured thin surfaces, the trials have been carried out on sections of road with positively textured hot rolled asphalt (HRA) surfaces.

Trials were carried out on the A33, A331 and A52 to investigate the effect of trafficking on pre-wetted salt only, whilst trials on the A9, A460 and A48 compared different de-icers.

## 5.1 Effect of traffic

Tables F1 to F6 in Appendix F show the average percentage salt loss for each trial with respect to time of trafficking. Figure 8 compares the percentage loss with level of trafficking for all the road trials, averaged over the lanes. It can be seen from Figure 8 that the effect of trafficking varied significantly across the trials and it is difficult to draw many robust comparisons. However, it is clear from the results to date that trafficking has a relatively large influence on residual salt levels, with levels reducing markedly during the initial 12 hours after distribution regardless of whether dry, treated or pre-wetted salt is used. Trial results indicate that as much as approximately one half of the initial material can be lost during this period on a heavily trafficked (around 5000 cars) road in dry road conditions.

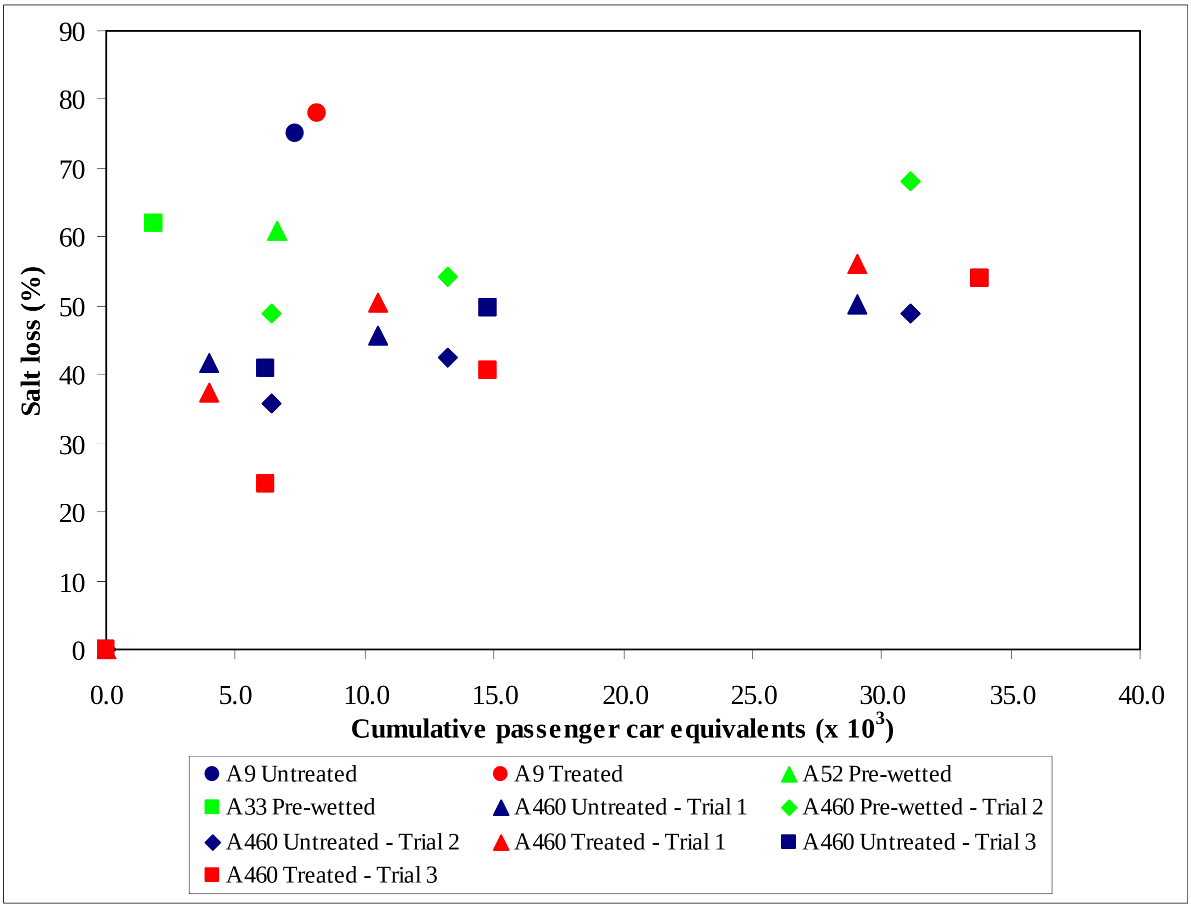


**Figure 8. Percentage salt loss for road trials**

When considering the effect of traffic on residual salt levels it is important to account for the degree of longitudinal snaking in the salt distribution before and after trafficking. Table 20 shows the range in the residual salt level measured within the traffic lanes for each test strip after various periods of trafficking, expressed as a percentage of the average level for all the test strips. This provides an indication of the degree of longitudinal variability evident in the results of each trial.

**Table 20. Range in residual salt measured within lanes for each strip**

| Road trial | De-icer type | Range as % of average residual salt | | | | |
|---|---|---|---|---|---|---|
| | | Approximate hours of trafficking | | | | |
| | | **0** | **1** | **12** | **20** | **36** |
| A33 | Pre-wetted | 28 | 32 | | 68 | |
| A331 | Pre-wetted | 47 | 11 | - | - | - |
| A52 | Pre-wetted | 28 | 24 | - | 18 | - |
| A9 | Dry untreated | 26 | 75 | - | 127 | - |
| | Dry treated | 65 | 106 | - | 107 | - |
| A460 | Dry –Trial 1 | 9 | - | 59 | 10 | 22 |
| | Treated – Trial 1 | 14 | - | 39 | 69 | 3 |
| | Dry – Trial 2 | 28 | - | 22 | 24 | 34 |
| | Pre-wetted - Trial 2 | 33 | - | 6 | 9 | 7 |
| | Dry –Trial 3 | 29 | - | 9 | 21 | 6 |
| | Treated – Trial 3 | 52 | - | 11 | 17 | 7 |

It has previously been assumed that trafficking will smooth out the salt distribution both along and across the carriageway and therefore that longitudinal snaking is not an important issue for normal salting operations. However, the results of the NSSRG trials to date suggest that the longitudinal redistribution of the residual salt by traffic does not occur to the degree that was previously believed and therefore longitudinal snaking during spreading operations may be a significant factor in determining the overall performance of a spreading operation. It could therefore also be an important consideration for operational decisions regarding the appropriate rate of spread for an operation.

### 5.2 Effect of de-icer

Overall, the results from all the trials to date where different de-icers were tested together have not identified any significant effect of de-icer type on the salt distribution after trafficking.

For the A9 trial similar losses were measured for both the treated and untreated salt after 18 hours trafficking, with the treated salt showing a lower loss after 1 hour. However, snaking was evident in the results for the treated salt, resulting in uncertainty in the measured spread rates and the difference measured in the losses would not appear to be statistically significant.

The A460 trials were also designed to assess the effects of trafficking on the residual salt levels arising from the spreading of the different materials. Overall, similar losses were measured within the lanes for each de-icer over the 48 hour duration of each trial (approximately 36 hours of trafficking), with the most significant decrease in the residual salt level occurring during the first 12 hours after spreading, with a maximum loss in Lanes 1 and 2 of 49 per cent of the salt before trafficking. The maximum percentage loss in Lanes 1 and 2 was 54 per cent after 24 hours and 68 per cent after 48 hours.

In order to make a valid comparison between the effects of trafficking on the different de-icer types, it is necessary to compare results obtained under conditions as similar as possible with regard to initial levels of salt, levels of traffic and climatic conditions. As discussed in Section 4.6.5, the distribution was not optimised for each de-icer during the A460 trials, with the position of the peak of the salt distribution ranging from the centre of the carriageway to the centre of lane 2. An alternative comparison for this trial would therefore be of the salt loss from lane 2, for those cases where the initial level of salt in the lane and trial conditions were as similar as possible for each de-icer, rather than both lanes together. However, this will still not be a fully accurate comparison as the position of the peak of the distribution determines how much salt moves from lane to lane. With little salt in lane 1 with the pre-wetted salt, there would have been less salt moving from lane 1 to lane 2 than for the other de-icers.

Table 21 shows a comparison of residual salt in lane 2 for the untreated salt in Trial 3, the pre-wetted salt in Trial 2 and the treated salt in Trial 1 and Trial 3. The salt loss, expressed as a percentage of the salt spread, is shown in Table 22.

**Table 21. Residual salt measured within lane 2 for each de-icer type**

| Time after spread (hrs) | Salt (g/m²) | | | |
|---|---|---|---|---|
| | Untreated (Trial 3) | Pre-wetted (Trial 2) | Treated (Trial 1) | Treated (Trial 3) |
| 0 | 23.6 | 24.9 | 24 | 17.4 |
| 12 | 13 | 12 | 13.4 | 10.8 |
| 24 | 11 | 10.8 | 10.2 | 8.2 |
| 48 | 10.4 | 7.2 | 8.8 | 6.6 |

**Table 22. Percentage loss within lane 2 for each de-icer type**

| Time after spread (hrs) | % Loss | | | |
|---|---|---|---|---|
| | Untreated | Pre-wetted | Treated (Trial 1) | Treated (Trial 3) |
| 12 | 45 | 52 | 45 | 38 |
| 24 | 53 | 57 | 57 | 53 |
| 48 | 56 | 71 | 63 | 62 |

As will be discussed in Section 6.2.1, there is an uncertainty of around 5 per cent in the salt collected from each strip resulting from the salt collection method used. The effect of longitudinal snaking will also create some uncertainty, with significant longitudinal variations in the salt distribution evident before and, for some of the trials, after trafficking. This would indicate that trafficking may not always ‘even out’ initial longitudinal variations. As shown in Table 20, there was significant snaking measured before trafficking for the pre-wetted salt in Trial 2 and the treated salt in Trial 3, potentially leading to inaccuracy in the measured losses. Table 23 shows the potential range of salt loss from lane 2 for the above trials, assuming a 5 per cent uncertainty in the salt collected on each occasion.

**Table 23. Percentage loss within lane 2 for each de-icer type (assuming 5 per cent uncertainty)**

| Time after spread (hrs) | % Loss | | | |
|---|---|---|---|---|
| | Untreated | Pre-wetted | Treated (Trial 1) | Treated (Trial 3) |
| 12 | 39 – 50 | 47 – 56 | 38 - 49 | 31 – 44 |
| 24 | 49 – 58 | 52 – 61 | 53 - 62 | 48 – 57 |
| 48 | 51 - 60 | 68.0 – 74 | 59 - 67 | 58 – 66 |

Comparing the results, in nearly all cases any difference between the salt loss for the different de-icer types was less than the range of uncertainty in the measurements. Climatic conditions and trafficking were very similar during the course of all three trials and would not be expected to produce significant variations between results.

The effect of treating or pre-wetting the salt would be expected to be most evident in the first hours after spreading. The increase in the pre-wetted salt loss between 24 and 48 hours relative to the other de-icer types is therefore unexpected and could be a result of uncertainty in the measured residual salt due to snaking in the distribution along the carriageway, although Table 20 shoes minimal snaking at these times.

When drawing conclusions from these results, it must be acknowledged that weighbridge measurements indicated that only a small amount of brine was discharged during the pre-wetted spreading, 5 per cent by weight of the total amount of de-icer. As discussed in Section 4.6.5, there were concerns regarding the accuracy of the weighbridge measurements during the trials and, taking into account other discrepancies between the weighbridge measurements and amounts of salt collected, it was concluded in the final Staffordshire trial report that inaccuracy in the weighbridge measurements was the most likely cause of the low brine discharge measurement. The distribution was also distinctly different for the untreated and pre-wetted salt suggesting they were different de-icers. However, uncertainty will remain that the pre-wetted spreading was carried out correctly. It is possible that insufficient brine may have been added to the dry salt during spreading, reducing the effect of the pre-wetting.

Assuming that the spreaders operated correctly during the trials, in particular with relation to the pre-wetting, there are possible explanations for the similarity in de-icer performance. With regard to the trial methodology, a key point to note is that spreading was carried out under a road closure, allowing the salt to settle on the carriageway and dissolution to occur for several hours before trafficking commenced. During normal spreading operations, the effects of passing vehicles would be expected to be more disruptive to the salt distribution, in particular that of the finer particles in the first hours after spreading. In this situation, the suppression of the fines as a result of pre-wetting or treating the salt would be expected to result in lower salt loss and a more even distribution of the salt along the carriageway. Spreading under live traffic would therefore be expected to produce more variation in de-icer performance.

Another key factor is likely to be the effect of the de-icer particle size variation. During the course of the NSSRG research, measurements have been made of the particle size distribution and moisture content for a number of different salt samples, in particular Thawrox 6. For all the samples of Thawrox 6 that have been tested during the performance and road trials, Figure 9 shows the percentage of the sample with particle size less than 0.6mm plotted with respect to the moisture content of the sample. Overall, it can be seen that moisture content has a significant effect on the particle size distribution of the salt, with a higher moisture content resulting in a lower proportion of finer particles.

The trials carried out on the A460 were with untreated salt of moisture content around 5 per cent. At this high level of moisture, the proportion of finer particles was reduced and this may have masked the effects of pre-wetting or treating the salt. In practice salt is normally supplied with a moisture content below 2 per cent and, if spread dry at such a moisture content, all of the fines are unlikely to stay on the road and may be transported by the wind and vehicle drafts to the verge and beyond. In these circumstances pre-wetting of the salt is an effective way to spread the fines to the target area either in solution or in suspension in the brine.

Some authorities use 3mm salt to reduce the time taken for salt to enter solution – being particularly important on lightly trafficked roads when there may be few vehicles to break-up larger salt grains and speed the dissolution process. Although normally de-dusted the dissolution process is greatly enhanced by pre-wetting such a fine salt.

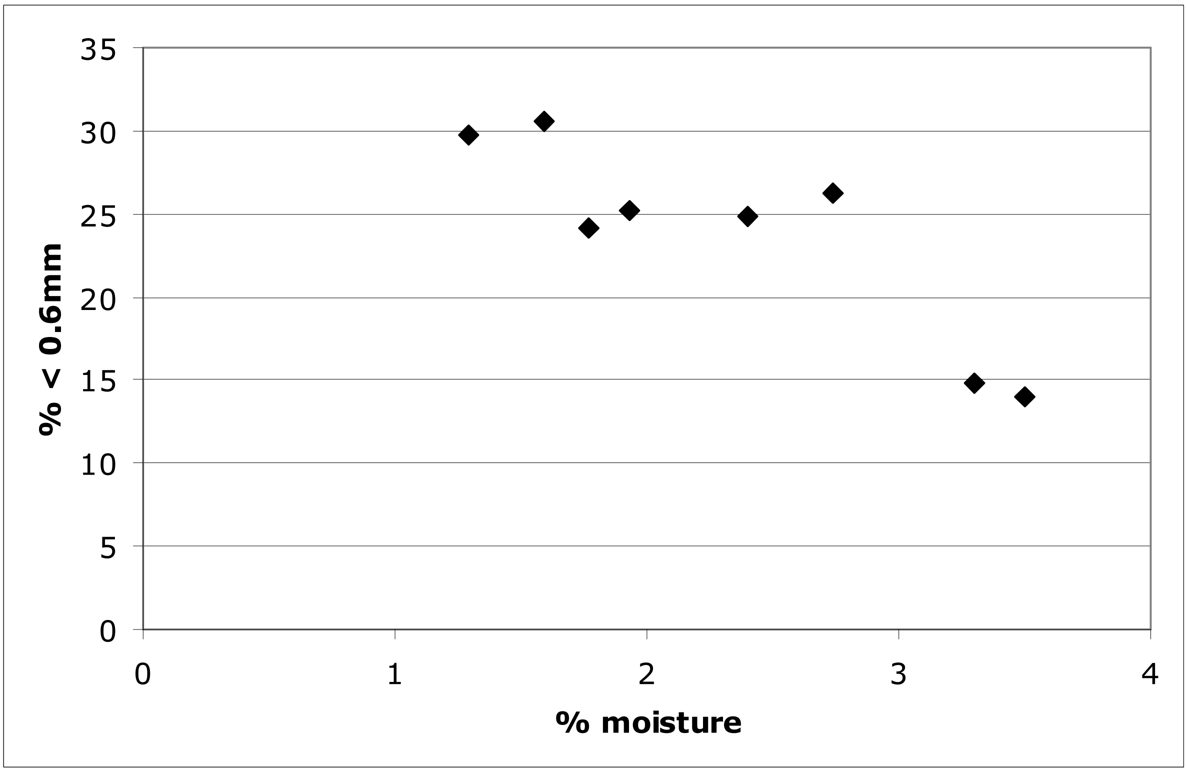


**Figure 9. Percentage by weight of Thawrox 6 with particle size less than 0.6mm**

The results from the Staffordshire trials would also appear to support earlier research carried out by TRL and also work carried out in Germany. The first trials conducted by TRL with pre-wetted salt were in the late 1980s (Parmenter, 1991). The performance of dry salt wetted to a moisture content of about 5 per cent and pre-wetted salt with mix proportions 70 per cent dry salt: 30 per cent brine by weight was compared. The salt grading is not reported. As was reported in the Staffordshire trial final report, the conclusions included the following:

- Wetting of salt up to a moisture content of about 5 per cent improves retention on the road. This confirms the findings of earlier German research.
- Wetting of salt appears to result in slightly improved spread patterns. This confirms the findings of earlier German research.
- Setting the spread width two metre less than the carriageway width reduces the amount of salt spread in verges and beyond thereby improving the spread pattern without the need for pre-wetting.
- At precautionary rates of spread there appears to be no significant difference in the residual salinity between salt at 5 per cent moisture content and that wetted with a 30 per cent solution. This confirms the findings of earlier German research.

The salt losses measured in the NSSRG trials on the A33 and the A52 with pre-wetted salt were higher than the loss measured on the A460 for comparable levels of traffic, however as discussed in Section 5.3 the surfacing was different for these trials.

The moisture content of the dry salt in the Staffordshire trials was similar to the moisture content discussed by Parmenter and the findings from the Staffordshire trials would seem to be consistent with this previous research on pre-wetted salting by TRL and in Germany.

### 5.3 Effect of surfacing type

The percentage losses after trafficking recorded for the trials carried out on the A460 appeared to be consistently lower than those for the other trials. The A460 trial site has a negatively textured thin surfacing, while the other road trials were carried out on positively textured HRA. Although the results from negatively textured surfaces are therefore limited, these results appear to suggest that salt loss due to trafficking may be reduced on negatively textured road surfaces, compared to that for positively textured road surfaces. This may be explained by the voids within the negatively textured surfacing retaining and accumulating salt and these being less subject to the effects of trafficking.

# 6 Review of trial methodology

During the course of the trials undertaken to date a number of issues have been highlighted with regard to the design of the trial methodologies. The practicalities of planning and undertaking both road and track trials to take place within limited weather windows cannot be overstated. Other issues have arisen with the configuration and settings of the equipment being utilised in the trials, checking and monitoring procedures for the equipment, and the overall performance of the equipment and de-icing material combinations utilised during the trials.

## 6.1 Spreading equipment/de-icer set-up and operation

The NSSRG trial procedures were devised to test each spreader/de-icer combination as would be employed by the local authority that supplied the spreader during a normal ‘live’ salting operation. Whilst the performance could only be assessed under the conditions prevailing during the trial, it was considered important that, as far as practicably possible, the spreading equipment was configured and set-up in the manner that it would be during normal operations.

The main issues highlighted during the trials are discussed below and it should perhaps be noted that, although they were identified during the course of detailed consideration and analysis of the results of scientific performance trials, many of them may well also have relevance to normal salting operations.

### *6.1.1 Incorrect spreader settings or set-up*

In several trials it became evident that incorrect equipment settings were employed for the particular de-icing material being spread or for the target spread width. For example, during performance trials of pre-wetted salting with the Epoke Sirius SH3590 equipment, the spinner speed was set incorrectly for the target spread width. The spinner speed used for the performance and road trial of pre-wetted salting with the Epoke Sirius SH3500 equipment was incorrect for the grade of salt, and this is the most likely explanation for the abnormally high wastage observed in this trial. In addition, the trial employing the Econ Unibody equipment produced highly unexpected and unusual results that the manufacturer could only replicate afterwards by removing an important part of the salt spreading mechanism. The equipment was calibrated by the manufacturer beforehand but this did not include a detailed assessment of the salt distribution profile.

### *6.1.2 Uncertainty in spreader settings and calibration*

In each trial, the spreading equipment has been configured and set-up by the local authority that supplied the spreader.

For the majority of trials there is no information available regarding the equipment calibration procedures utilised.

It is important to note here that even though spreading equipment may be successfully calibrated with respect to one de-icer type and target spread rate/spread pattern, if the de-icing material and/or the other target parameters are changed, the calibration may well not hold true.

There is limited information available regarding the specific equipment settings used in the great majority of the trials, e.g. information regarding specific spinner speeds, gate heights, chute settings etc. It is also not clear how these settings may have been changed between the equipment being used in the track and road trials.

### *6.1.3 Insufficient checking of spreader performance during trials*

Visual checks were made during the track trials to confirm that the spreading equipment was discharging de-icer satisfactorily. However, no discharge tests were performed during these track trials to confirm that the target salt discharge rate was being achieved.

During some of the road trials discharge tests were carried out and weighbridge measurements were taken. Test runs were also performed before some of the individual trials on the A460 in order to check the amounts of salt being discharged. However, during these road trials the agreement between the measured spread rates and the predicted spread rates based on the weighbridge measurements during the trials have generally been poor, possibly due to the weighing procedure.

In order for trials to robustly test the performance of equipment, it is crucial to ensure that the equipment is calibrated and set-up appropriately at the commencement of the trial and improvements in this aspect of the adopted NSSRG trials methodology are clearly needed.

#### *6.1.4 De-icer moisture content*

Pre-trial checks were not made on the condition of the de-icer for any of the trials to date.

In order to fully investigate the effects of moisture content on salt distribution and/or the effects of trafficking/time on residual salt levels, trials would need to be carried out where variations due to salt moisture content could be isolated from the effects of all other influencing parameters. This would be most easily achieved if the only variable was salt moisture content.

#### *6.1.5 Salt consolidation in the hopper*

Salt consolidation was observed within the hopper during a number of the trials, potentially leading to low or inconsistent discharge of the salt. The A9 road trial is an example of such a trial. In some trials this was likely a result of high moisture content of the salt and in other trials this may have been caused by the salt remaining undisturbed within the vehicle’s hopper for a lengthy period of time before the trial commenced or was compacted during the journey to TRL for testing.

This area is an example of improvements being introduced during the trial programme and, during the later track and road trials, care was taken to avoid consolidation by only loading the vehicle immediately before each trial commenced. Nevertheless, it is considered that relatively high moisture content in the de-icers could still have led to inconsistent flows during the trials.

#### *6.1.6 Brine proportion and concentration*

The A460 trials involved the use of pre-wetted salting and during the analysis phase of this trial it was found not to be possible to confirm whether the dry salt/brine mix properly corresponded to the trial log because there was no flow meter or other such device fitted to the spreading equipment to provide this information.

It is considered that this issue may well be applicable to ‘live’ salting operations as well as to future research and therefore recommendations have now been made that all equipment used for spreading brine solutions (whether this is for pre-wetted salting or for brine alone spreading) is equipped with flow meters for this purpose.

The above is to supplement the testing and analysis of the concentration of the brine solution to ensure that it is of the appropriate concentration before spreading commences. This is another potential issue with the results of the A460 trials and one which could have serious consequences to a ‘live’ salting operation if the concentration of the brine solution is too weak.

### 6.2 Accuracy and repeatability of salt distribution measurement technique

#### *6.2.1 Salt collection*

Another important issue with respect to the accuracy of the salt collection related to how much of the salt within each strip was collected. During most of the road trials undertaken to date all of the salt within the lanes for each strip was collected. However, during the track trials only one panel was placed within each test zone, as specified in BS 1622, resulting in only around half of the salt in each lane being collected. This issue has already been addressed to some extent through development of the performance trial methodology as the trial programme has progressed, with more salt being collected from the lanes and wider panels being used in the later trials.

Tests have been carried out by TRL to validate the wet wash collection procedure, the results of which are reported in Barker and Evans (2006). Varying amounts of dry untreated and treated salt, covering the range typically found during the salt trials, were spread within a series of test panels on a relatively impermeable, negatively textured surface. The salt in each panel was collected and measured using the standard wet wash procedure as used in all the trials. Considering each panel separately, the amount of salt measured varied between approximately 90 and 120 per cent of the amount actually spread. Totalling the amounts of salt measured and spread for all the panels for each de-icer (9 panels each), the amount of untreated salt measured was 98.7 per cent of the target amount while the amount of treated salt was 105.2 per cent of the target. It would therefore seem reasonable to state that the collection procedure is accurate to within ±5 per cent. Variations in the chloride content of the small salt samples collected and the samples used to prepare the control solutions would introduce inaccuracies.

### *6.2.2 Longitudinal snaking*

The results from the majority of the trials undertaken to date have shown significant longitudinal variation, or snaking, which is demonstrated by varying amounts of salt being collected from each test strip. The results from the strips are averaged, but there remains uncertainty in whether this is fully representative of the actual amount of de-icer discharged by the spreader, as this will be dependent on the position of each strip in relation to the snaking pattern being produced by the spreading equipment.

Figure 10 gives an example of how the salt distribution may vary relative to the test strip placements and clearly illustrates the potential for the variability in the measurement. This variability will be present for both the de-icer distribution before trafficking and also in the measurement of relative loss with trafficking.

The methodology employed during the M62 road trials was developed in an attempt to take more account of this issue by the use of 4 rather than 3 strips. However, it is still considered likely that the effects of longitudinal snaking would have influenced this trial to some degree.

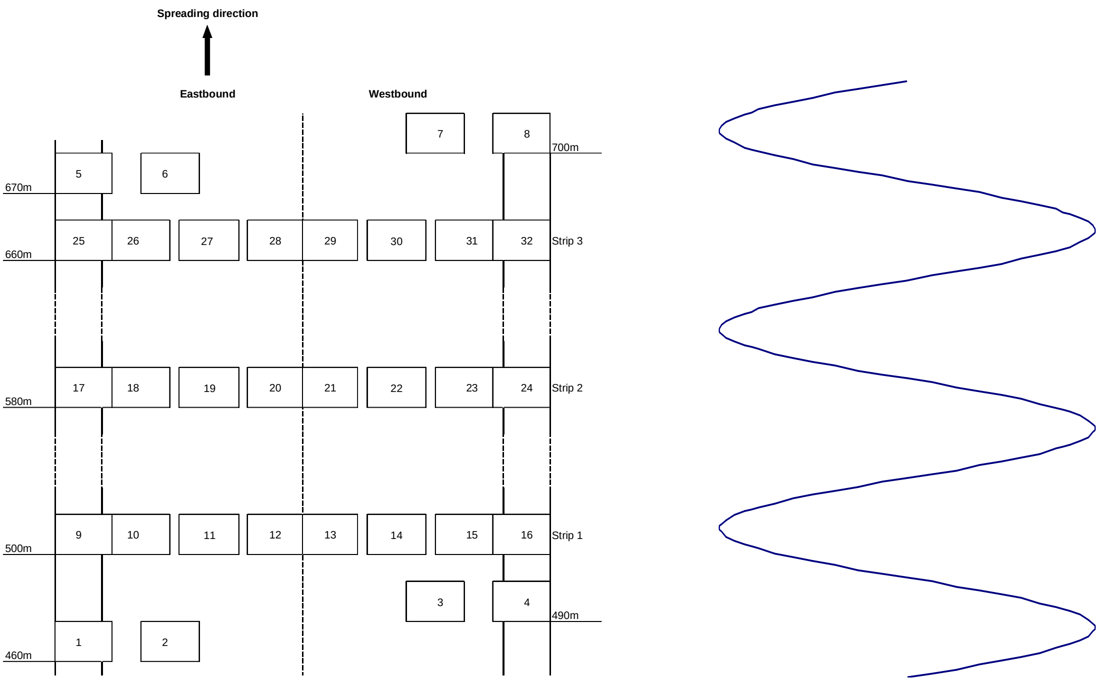


**Figure 10. Example of varying salt distribution relative to strip positions**

### *6.2.3 Weighbridge and static discharge measurements*

During some of the trials, weighbridge measurements and static discharge tests were made to confirm the spreader was operating correctly.

Before the trials on the A9, static discharge measurements were made for the treated salt. The Giletta spreader was calibrated against four conveyor chain speeds/discharge weights:

| Weight | Calibration outcome |
|---|---|
| 25kg: | 25kg |
| 40kg: | 34kg; belt speed increased to give 39kg |
| 80kg: | 78kg |
| 125kg: | 140kg; belt speed decreased |

The spreader was not calibrated for the untreated salt and it was assumed that the same settings were used for both salt types. Despite this checking, the spread rates measured in the trial were still significantly below the target spread rate, possibly as a result of non-uniform flow of the salt. As indicated previously, observations made during the trial also indicated that significantly more salt had been discharged outside of the test area.

After the trials on the M62, static discharge tests (‘nosebag’ tests) were performed to verify the spreader performance. Table 24 compares the amount of salt discharged that was predicted from the ‘nosebag’ tests and the amount of salt collected from the test strips. As can be seen from these results there was reasonable agreement between the amounts of salt discharged and collected as a percentage of the target. The target amounts were calculated as follows:

Target amount of salt discharged = (spread rate x width of lanes 1 to 3 + 0.5 x spread rate x width of hard shoulder) x length of carriageway spread.

Target amount of salt collected = (spread rate x width of lanes 1 to 3 + 0.5 x spread rate x width of hard shoulder) x length of carriageway from which salt was collected.

**Table 24. Comparison of salt discharged in 'nosebag' tests and salt collected from test strips**

| Hopper load (%) | Spread rate (g/m²) | Salt discharged predicted from 'nosebag' tests as % of target (salt collected as % of target) | |
|---|---|---|---|
| | | Treated | Untreated |
| 10 | 15 | 117 (102) | N/A |
| 100 | 15 | 118 (93) | N/A |
| 10 | 20 | 142 (115) | 160 (102) |
| 100 | 20 | 131 (115) | 140 (133) |

During the trials on the M62 and A460 the spreader was weighed before and after each trial. Table 25 and Table 26 compare the amount of salt discharged and the amount of salt collected from the test strips as a percentage of the target.

**Table 25. Quantities of salt discharged from the hopper during each trial run on M62**

| Trial N° | Salt type | Target spread rate (g/m²) | Hopper (%) | Hopper load (kg) | | Salt discharged (kg) | Amount of salt discharged as % of target | Amount of salt collected as % of target |
|---|---|---|---|---|---|---|---|---|
| | | | | Pre-run | Post-run | | | |
| 1 | Untreated | 10 | 100 | 20580 | 20420 | 160 | 289 | 79 |
| 2 | Treated | 10 | 100 | 21700 | 21380 | 320 | 302 | 131 |
| 3 | Treated | 20 | 100 | 22380 | 21820 | 560 | 265 | 122 |
| 4 | Untreated | 20 | 100 | 21760 | 21060 | 700 | 331 | 141 |
| 5 | Untreated | 20 | 10 | 12020 | 11580 | 440 | 208 | 84 |
| 6 | Untreated | 20 | 10 | 12000 | 11560 | 440 | 208 | 121 |
| 7 | Treated | 20 | 10 | 12200 | 11680 | 520 | 246 | 110 |
| 8 | Treated | 20 | 10 | 12000 | 11460 | 540 | 255 | 130 |
| 9 | Treated | 15 | 100 | 20920 | 20800 | 120 | 75 | 79 |
| 10 | Treated | 15 | 10 | 12930 | 12600 | 330 | 208 | 103 |
| 11 | Treated | 15 | 100 | 23580 | 23260 | 320 | 201 | 96 |

**Table 26. Quantities of de-icer discharged from the hopper during each trial run on A460**

| Trial N° | De-icer type | Target salt spread rate (g/m²) | Weight of spreader (kg) | | De-icer discharged (kg) | Amount of salt discharged as % of target | Amount of salt collected as % of target |
|---|---|---|---|---|---|---|---|
| | | | Pre-run | Post-run | | | |
| 1 | Untreated | 20 | 14480 | 14140 | 340 | 213 | 94 |
| | Treated | 20 | 14930 | 14760 | 170 | 104 | 77 |
| 2 | Untreated | 20 | 14841 | 14701 | 140 | 86 | 82 |
| | Pre-wetted | 15.6 | 15011 | 14841 | 162 (+ 8kg brine) | 129 | 99 |
| 3 | Untreated | 20 | 14379 | 14283 | 96 | 59 | 82 |
| | Treated | 20 | 13942 | 13842 | 100 | 62 | 62 |

There was generally poor agreement between the amount of salt discharged, as indicated by the weighbridge measurements, and the amount of salt collected for both the M62 and A460. For the M62, the amounts of salt discharged relative to the target were nearly all significantly greater than amounts collected. For the A460, the difference between the results was not consistent, with the amount of salt discharged both higher and lower than the amount collected. Also, the measurement of the amount of brine discharged was very low.

However, during the detailed consideration and analysis of the results of the A460 trials, it was concluded that the weighbridge was exhibiting a fault and that for this, and other reasons specific to that trial, the weighbridge measurements were considered to be in error by up 50kg and therefore did not accurately represent the amount of salt discharged. Weighbridge errors are thought to have been unlikely during the M62 trials but it appears that there may have been some errors made in the estimate of the length of carriageway spread as, supposedly, for the same spread rate and spread length, the amount of salt discharged in Trials 2 to 8 on the M62 ranged from 440 to 700kg.

For the trials on the A48(M), weighbridge measurements were made before and after the trials. Data was also available from the spreader's onboard monitoring system regarding amounts of de-icer discharged, spreader speed and distances travelled. The measurements from the weighbridge and the data from the spreader showed good agreement and corresponded with the target spread rate, taking into the account the distances that the de-icer was spread.

## 6.3 Summary

It is clear from the above that the NSSRG trial programme to date has highlighted a number of significant issues associated with the design of the trial methodologies, as well as with the configuration and settings of the equipment utilised. Some of these issues have been at least partially addressed by developing the trial methodologies and equipment checking procedures as the programme has progressed. However, it is still considered that these issues will require careful consideration and management so as to minimise the likelihood that they will adversely affect future NSSRG trials.

To this end, and with consultation with NSSRG Members, a check list has been developed for use in all future NSSRG trials and a series of recommendations have been made regarding the design and management of future trials.

The check list is provided at Appendix G and the recommendations are discussed in detail in the following sections of this report. However, it is crucial that the objectives of future NSSRG trials are carefully considered to ensure that they are both useful and achievable and that their methodologies are designed to ensure that the trials are properly controlled and that their findings will be applicable to wider scenarios than those specific to the precise circumstances of each trial. It is considered that this may mean that the objectives for individual future trials will perhaps need to be more limited than those of some of the trials undertaken in the programme to date, and that the number of influencing variables will also require limiting, with the other parameters being carefully controlled and/or monitored.

# 7 Discussion

One of the main challenges when undertaking research in the winter maintenance field is the large number of parameters that affect the performance of de-icers, and it is clear from this review that the NSSRG trials undertaken to date have highlighted the need for these variables to be controlled whenever possible, and recorded and monitored when this is not possible. The difficulty in controlling 'real world' variables leads to a need to take particular care when interpreting the results of individual trials and applying these to wider scenarios.

Some of the individual NSSRG trials undertaken to date have involved different grades of salt, different spread widths and different spreader types for each de-icer. Trials of different spreaders have involved different de-icer types, grades, spread widths and moisture contents. This has reduced the potential for undertaking robust comparisons across the results of different trials, which is only possible when all the influencing parameters have been properly accounted for. It should be noted that this issue is not specific to the NSSRG trial results and our experience is that a great deal of winter maintenance research undertaken outwith the NSSRG research programme also includes the variation of a number of influencing parameters and this creates difficulties in assessing the effects of changing each parameter. Therefore, it is recommended that highway authorities carefully consider the research supporting claims made regarding new techniques, equipment and materials and satisfy themselves that apparently positive results from the research are directly attributable to that product.

NSSRG performance trials undertaken to date have measured the spread rate and salt distribution profiles for a relatively large number of combinations of spreader and de-icer type and, as discussed within earlier sections of this report, the results have highlighted a number of areas where spreader performance has not achieved the standards as laid out in BS1622. The spreading equipment was configured and set up by the local authority supplying the spreader in these trials and the de-icers were tested in the condition as supplied. It has subsequently been established that in a relatively large proportion of the trials, the spreading equipment may not have been optimally set up for the specific de-icer and/or spread rate/pattern being tested. It is considered that issues such as those experienced during the trials with calibration, incorrect equipment settings, de-icer condition and possible equipment malfunctioning may well therefore not be limited to these trials but that they may also be experienced during 'live' salting operations albeit that these may not be routinely identified.

It is considered that the level of performance measured by the trials may well represent the general performance levels being achieved by authorities across the UK in practice and those authorities are recommended to undertake their own performance checks etc of 'live' salting operations. Indeed, the NSSRG trials to date have highlighted the importance of correct calibration for the particular de-icer type and spread conditions required, and the need to regularly check the performance of spreading equipment.

With regard to the performance of different de-icer types, the results of the NSSRG road trials undertaken to date have not identified any significant differences that can be directly attributable to the use of these different materials. However, it is considered that such differences may exist, although they may also be currently being masked by the existing variability in spreader performance etc.

The road trials have also focussed on the distribution of the residual salt on the road and it should be stressed that different de-icer types may offer other advantages. For example, pre-wetted salt will almost certainly provide anti-icing action immediately on spreading while treated salt has been claimed to offer advantages in relation to corrosion etc.

The overall aim of the NSSRG is to assist in providing guidance for highways authorities on the most appropriate salting technique and spread rates. The variability in distribution highlighted in the results of the trials to date would suggest that authorities should exercise caution when considering the reduction of salt spread rates and, before instigating such a reduction, should satisfy themselves that the spreading equipment and set-up they employ are delivering consistent and accurate spread patterns to the whole of the target area.

The NSSRG trials to date have been designed to investigate only a relatively limited number of parameters. Investigation of, for example, the specific effects of moisture content and grading of de-icer on distribution and residual salt levels, would require trials designed specifically for this purpose. In order to provide unbiased comparisons, the spreading equipment utilised in any such trial would require separate calibrations so that the distribution is optimised for each de-icer.

The value of the NSSRG research programme to date is extremely difficult to assess in terms of money and will vary significantly from the point of view of the interested party and how the research is utilised. For example, if a highway authority were to instigate an improved performance checking regime of 'live' salting operations as a result of the recommendations of this report, this could considerably improve the authority's risk portfolio and further Best Practice etc. It also could potentially lead to environmental benefits and savings in salt, as well as potentially reduce the number of accidents that occur during winter conditions. However, it is unlikely that any of these individual improvements and savings would be entirely and directly attributable to the research recommendation. Having stated the above, highway winter maintenance is a direct, safety related service that is generally viewed by the UK public as being of particular importance to their everyday activities. The service is now directly incorporated into legislation across Great Britain in a way which reflects this importance but which also provides the potential for highway authorities to face litigation when accidents arise on roads adversely affected by winter conditions. Changes in the way in which Police investigations of road traffic accidents are conducted and the introduction of Corporate Manslaughter legislation later this year are also bringing highway maintenance and other road services into sharp focus. When these factors are coupled with the costs of carrying out highway winter maintenance operations, the purchase price of equipment and materials, the potential detrimental environmental side-effects of the over-use of de-icing materials and the variable nature of the UK weather and climate, it can be seen that properly managed independent research into the efficacy of highway winter maintenance operations and the performance of de-icer application systems, techniques and materials is of particular importance to the nation as a whole. Specific individual organisations undertake their own programmes of research in this field. However, the NSSRG holds a unique position in comprising member authorities from across the whole of the country, as well as representatives from a wide cross-section of manufacturers and suppliers. The NSSRG research programme is therefore considered to be of particular importance to highway winter maintenance activities across the UK and its findings are already proving extremely valuable in shaping the future of this highly important field.

# 8 Future research programme direction

In order to retain the full support of its members into the future the NSSRG must build upon the experiences and results from Phases 1 and 2 of the research programme and remain focussed on the issues that are important to those members. These issues change over time and the research programme must be flexible and informed by current and future developments in the field. Indeed, the NSSRG research programme should itself be influential in determining future developments in UK highway winter maintenance practices.

It is clear that the aims of Phases 1 and 2 of the research programme were ambitious and covered a wide scope of activity. It is also clear in hindsight that some of those aims were perhaps somewhat overambitious and have not been entirely met by the programme to date. For example, despite much work and many individual performance trials having been completed, the matrix of the performance of available spreading equipment has not been completed and has now been somewhat overtaken by events, with new equipment and different de-icers and techniques entering the marketplace.

Therefore, it is recommended that, although certain individual performance trials may still be deemed useful, the aim of completing a full matrix of all available equipment and materials is dropped from the future research programme.

Current issues of great interest to member authorities appear to include a number of questions relating to spread rates of de-icers. For example, authorities are questioning whether the traditionally used spread rates are equally applicable to treated salt and/or wetted salt, and whether the use of such materials and techniques would allow reduced spread rates with no consequential increase in risk of ice formation.

It is clear that individual authorities, manufacturers and other organisations here and abroad have undertaken research and trials on this issue, and some authorities are now utilising reduced spread rates on the basis of this work and their experiences. However, there does not appear to be a common consensus and authorities are currently looking for reliable, independent guidance on this issue for dry, treated and pre-wetted salting.

In order to determine how much de-icer is required to keep a surface free of ice, the following must be considered: de-icer type (dry, treated and pre-wetted) and state (solid or in solution), surfacing type (positively or negatively textured) and state (dry, damp or wet), initial salt distribution profile, trafficking, precipitation, road surface temperature, and the residual salt level, including the variation with repeated treatments.

It is considered that the NSSRG is well placed to undertake a programme of work directed at providing this guidance. Furthermore, in keeping with the aims of ensuring best value, it is known that a number of NSSRG members (authorities, manufacturers and suppliers) have already been involved in this area of work and that they are likely to be willing to share their results and experiences with the NSSRG as a whole. Indeed, it is considered that the NSSRG should approach other organisations outwith the NSSRG and the UK, so that their work can be included and reviewed for applicability to UK authorities in general. This process should ensure that existing knowledge is properly understood and reviewed so that any necessary further work required before guidance can be provided is minimised and focussed. It is suggested that this model, of using the extensive knowledge base and contacts of NSSRG members, could also be utilised in other subject areas.

In addition to the above, it is considered that some remaining fundamental questions relating to de-icing operations could potentially be addressed by undertaking cost-effective, focussed laboratory, track and/or road trials. Such questions may include issues for example such as the optimum moisture content of salt for even distribution etc, or could build directly from previous work such as a project to investigate whether the apparent drop in dry surface skidding resistance following salt application that was noted in the recent NSSRG skidding resistance laboratory trials report is a genuine effect or whether it is an erroneous result arising from the laboratory trial methodology. It is therefore recommended that such ‘quick win’ opportunities are identified and considered for inclusion in future NSSRG research programmes.

It can be seen from the above that the recommendations for future work arising from this review report include building upon the work undertaken to date, reasserting the emphasis of providing practical guidance, using the existing knowledge and expertise of NSSRG members to best advantage, maximising the potential for specific issue ‘quick wins’ and addressing the all important issues of safe salting.

# 9 Recommendations for future trial methodologies

This review of the NSSRG trial programme to date has resulted in a number of specific recommendations for future trial methodologies, such that:

- A suitably qualified and experienced person should be present at each trial with specific responsibility for ensuring that the trial equipment is satisfactorily calibrated and configured and that de-icing materials are of the appropriate quality and composition.
- Whenever practicable, manufacturers of the trialled spreading equipment should be present at each trial. They should, at least, be specifically invited to attend each trial.
- The NSSRG trial checklist should be employed during all trials.
- Spreading equipment should be calibrated and appropriately configured for the specific de-icer being trialled and for each spread rate and spread width.
- Spreading equipment should be calibrated as close to the commencement of the trial as practicality allows with the de-icing material that is to be used in the trial.
- Spreading equipment performance and de-icer condition should be checked immediately prior to each trial.
- Spreading vehicles should be driven and operated by a suitably experienced and qualified operator.
- The spread distribution should be checked visually during a pre-trial test run.
- Where practicable, static discharge tests should be performed on each day of a trial and reliable weighbridge measurements should be made during the trial to confirm that the spreading equipment is operating within acceptable limits. This process should include direct measurements of brine concentration and discharge during trials involving pure brine solutions and/or pre-wetted salting.
- All available information regarding the configuration of the spreading equipment during the trials should be recorded.
- Where possible, data from on-board monitoring equipment should be collected to assist in confirming the configuration and performance of spreading equipment.
- A detailed check list should be used to ensure all actions have been carried out for each trial.
- During performance trials, the area of surface from which results are taken should be the full target spread width, margin and verge, with the trial panels marked out accordingly.

# 10 Conclusions

The NSSRG trial programme to date has tested the spread rate and distribution patterns for a wide range of equipment types and materials in both track based and road based trials, and techniques for the measurement of residual salt levels and other test methods have been evaluated and developed. The variations in measured performance of the equipment and materials during the trials have been relatively large, and this may relate to the various equipment configurations and settings currently used by highway authorities, as well as to a number of other influencing variables that altered between the trials. This is considered to be an important finding but it has also reduced the potential for the trials to provide robust comparisons regarding the performance of different de-icers and equipment types, and the programme has therefore not yet resulted in the provision of advice regarding optimum salt grades and spread rates for different materials and equipment combinations.

The research to date has however successfully produced valuable results in the specific objective areas, as well as in other closely allied areas. These include the production of detailed performance reports for a considerable number of specific equipment and de-icer combinations, with the performance trials highlighting that:

1. As currently configured and operated by highway authorities, salt spreading equipment may be delivering less than the targeted salt spread rates within traffic lanes (trials have consistently demonstrated this effect).
2. As currently configured and operated by highway authorities, salt spreading equipment may be producing relatively inconsistent performance (repeat tests under similar environmental conditions have produced variations of up to 30 per cent of the target spread rate in the amount of salt collected from traffic lanes).
3. Current salt spreading equipment generates longitudinal and transverse variation in spread and these ‘snaking effects’ are of a similar magnitude whether dry, treated or pre-wetted salt is used.
4. Variations in the performance of different spreading equipment as currently configured and operated by highway authorities appear to be greater than variations resulting from the use of different available techniques and materials. For example, it is considered likely that current variations in the performance of the equipment configurations being operated by authorities across the country are larger than the variation in performance that an authority would achieve by changing from untreated to treated salt, or from dry salting to pre-wetted salting etc.
5. Before purchase, highway authorities should request that manufacturers demonstrate their equipment is capable of achieving the required distribution specification for the relevant de-icing material, technique and road network. The most appropriate settings to achieve the specification should be provided by manufacturers and carefully noted and utilised by authorities.
6. Salt spreading equipment requires calibration and set-up for the specific de-icer type, grading and moisture content being used. There is also evidence to suggest that calibration is required for the specific spread rate and spread pattern being used.
7. Variations in stockpile moisture content will affect spreader performance. De-icing materials should therefore be stored in a controlled manner to minimise such variations and authorities should regularly check the moisture content of each stockpile. Where appropriate, equipment settings should be adjusted to account for the measured moisture content.
8. Relevant highway authority personnel should receive specific training in the set-up and calibration of the spreading equipment, perhaps most appropriately from the manufacturer.
9. Highway authorities should exercise caution when considering the reduction of salt spread rates to less than 10 $g/m^2$ and, before instigating such a reduction, should satisfy themselves that the spreading equipment and set-up they employ are delivering consistent and accurate spread patterns to the whole of the target area.
10. There is evidence that trafficking does not redistribute de-icing materials sufficiently to eliminate initial ‘snaking effects’, an important factor when considering the reduction of spread rates.

11. Residual salt levels reduce markedly during the initial 12 hours after distribution regardless of whether dry, treated or pre-wetted salting techniques are employed. Trial results indicate that as much as approximately one half of the initial material can be lost during this period on a heavily trafficked road in dry conditions.
12. There is some evidence to suggest that salt loss due to trafficking is reduced on negatively textured road surfaces, compared to that for positively textured road surfaces.
13. Whenever liquids are employed for de-icing purposes, distribution systems should be equipped with flow meters so that the rate of spread of the liquid onto the road can be monitored and checked during and after the operation. This is in addition to ensuring that the concentration of the liquid solution is correct prior to the commencement of the operation.
14. Improvements and developments in trial methodology have been notable features of the NSSRG research programme and, as is usual in applied research, some of the lessons in this regard have been relatively hard won. One important conclusion that can be drawn from the trials to date is that each future trial should be carefully designed around a single set of achievable objectives. Although it is sensible to take maximum advantage of trials and research that have been designed around the aims and objectives of an individual sponsoring authority, care must be taken so that the scope of the trial is not broadened to the extent that interpretation and application of the results is jeopardised.
15. Recommendations for the future direction of the NSSRG research programme that have arisen from this review report include building upon the work undertaken to date, reasserting the emphasis of providing practical guidance, using the existing knowledge and expertise of NSSRG members to best advantage, maximising the potential for specific issue ‘quick wins’ and addressing the all important issues of safe salting.
16. In addition to the overall findings discussed above, this review of the NSSRG trial programme to date has resulted in a number of specific recommendations being made regarding future trial methodologies. These are detailed in the previous section of this report.

## Acknowledgements

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# Appendix A. Comparison of total amounts of de-icer discharged

**Table A1. Overall discharged salt for different de-icer types**

| Spreader type | No. of lanes (target spread width, m) | Type of salting | Quantity of salt discharged as percentage of the target quantity (%) | | | |
|---|---|---|---|---|---|---|
| | | | Asymmetric | | Symmetric | |
| | | | Hopper full | Hopper 10 per cent full | Hopper full | Hopper 10 per cent full |
| Schmidt | 3-lanes + HS (13.0) | Dry (10g/m$^2$) | 95 | 107 | 107 | 107 |
| | | Dry (20g/m$^2$) | 87 | 81 | 77 | 77 |
| | | Pre-wetted (10g/m$^2$) | 85 | 95 | 146 | 120 |
| | | Pre-wetted (20g/m$^2$) | 80 | 92 | 104 | 102 |
| Modified Schmidt | 3-lane + HS (12.0) | Dry (10g/m$^2$) | 145* | | 129* | |
| | | Dry (20g/m$^2$) | 100* | | 111* | |
| | | Pre-wetted (10g/m$^2$) | 101* | | 161* | |
| | | Pre-wetted (20g/m$^2$) | 82* | | 87* | |
| M62 road trials | 3-lane + HS (13.2) | Dry (10g/m$^2$) | Not tested | | 71 | |
| | | Dry (20g/m$^2$) | | | 128 | 93** |
| | | Treated (10g/m$^2$) | | | 119 | |
| | | Treated (20g/m$^2$) | | | 111 | 109** |
| A460 road trials | 2-lanes | Dry (Trial 2) | 82 | Not tested | | |
| | | Dry (Trial 3) | 82 | | | |
| | | Pre-wetted (Trial 2) | 99 | | | |
| | | Treated (Trial 3) | 62 | | | |
| A9 road trials | 2-lanes | Dry | 36 | | | |
| | | Treated | 47 | | | |

* hopper one third full

** average of two tests

**Table A2. Ratio of amounts of pre-wetted to dry salt discharged**

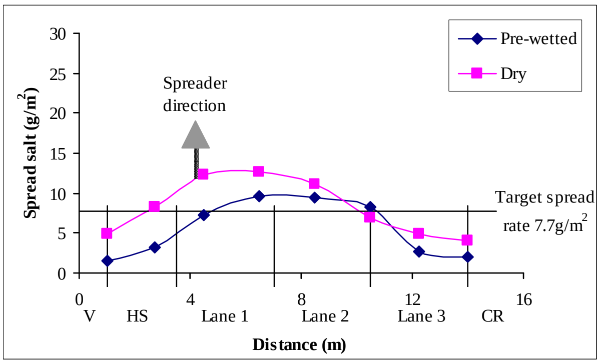
| Spreader type | No. of lanes (target spread width, m) | Type of salting | Ratio of amount of salt discharged | | | |
|---|---|---|---|---|---|---|
| | | | Asymmetric | | Symmetric | |
| | | | Hopper full | Hopper 10 per cent full | Hopper full | Hopper 10 per cent full |
| Schmidt | 3-lanes + HS (13.0) | $10g/m^2$ | 0.69 | 0.68 | 1.05 | 0.86 |
| | | $20g/m^2$ | 0.71 | 0.87 | 1.04 | 1.02 |
| Modified Schmidt | 3-lane + HS (12.0) | $10g/m^2$ | 0.54 | | 0.96 | |
| | | $20g/m^2$ | 0.63 | | 0.60 | |
| A460 road trials | 2-lanes | $20g/m^2$ (Trial 2) | 0.93 | Not tested | | |

**Table A3. Ratio of amounts of treated to dry salt discharged**

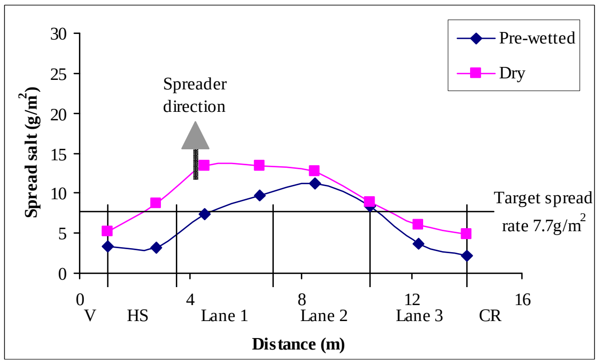
| Spreader type | No. of lanes (target spread width, m) | Type of salting | Ratio of amount of salt discharged | | | |
|---|---|---|---|---|---|---|
| | | | Asymmetric | | Symmetric | |
| | | | Hopper full | Hopper 10 per cent full | Hopper full | Hopper 10 per cent full |
| M62 road trials | 3-lane + HS (13.2) | $10g/m^2$ | N/A | | 1.68 | N/A |
| | | $20g/m^2$ | | | 0.87 | 1.17 |
| A460 road trials | 2-lanes | $20g/m^2$ (Trial 3) | 0.76 | N/A | | |
| A9 road trials | 2-lanes | $10g/m^2$ | 1.31 | | | |

# Appendix B. Comparison of distribution profiles

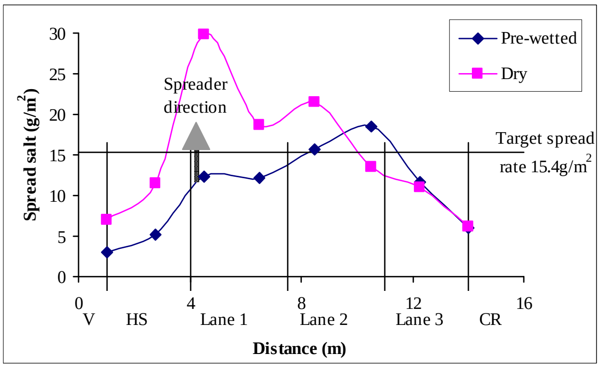
## B.1 Schmidt Stratos



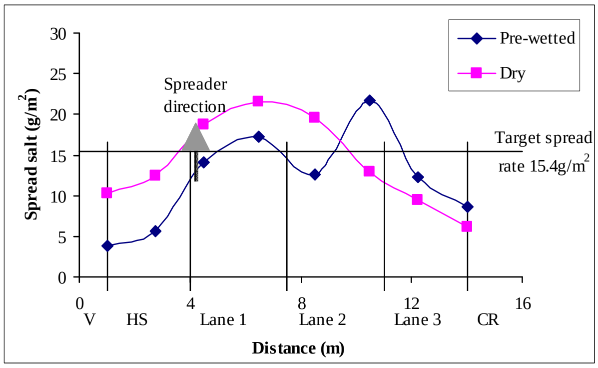

**a) asymmetric , 10g/m$^2$ - hopper full**



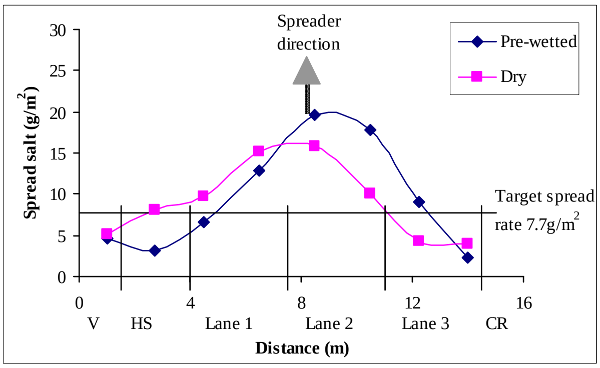

**b) asymmetric , 10g/m$^2$ hopper 10% full**



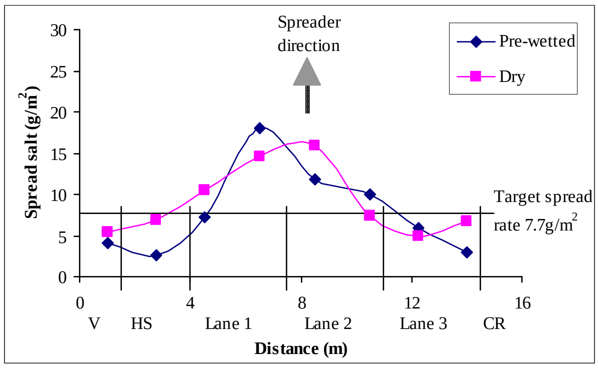

**c) asymmetric, 20g/m$^2$ – hopper full**



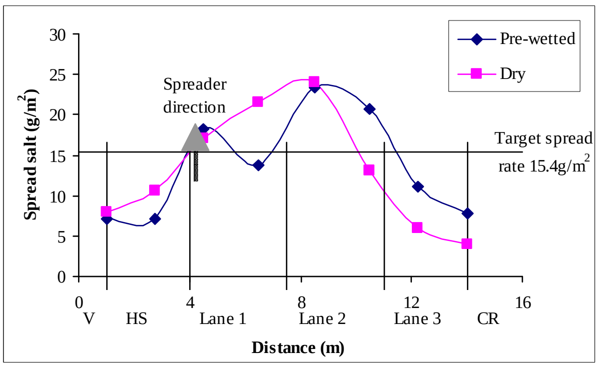

**d) asymmetric , 20g/m$^2$ hopper 10% full**



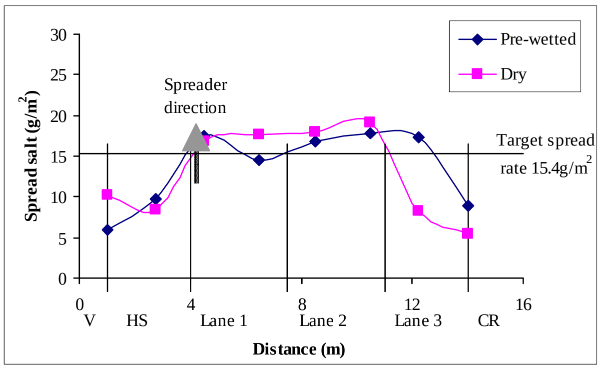

**e) symmetric, 10g/m$^2$ –hopper full**




**f) symmetric , 10g/m$^2$ hopper 10% full**

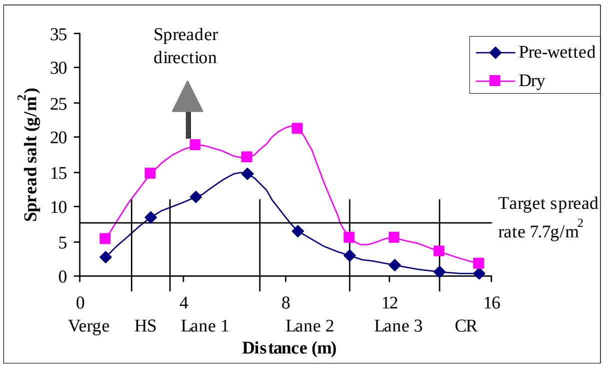



**g) symmetric, 20g/m$^2$ – hopper full**

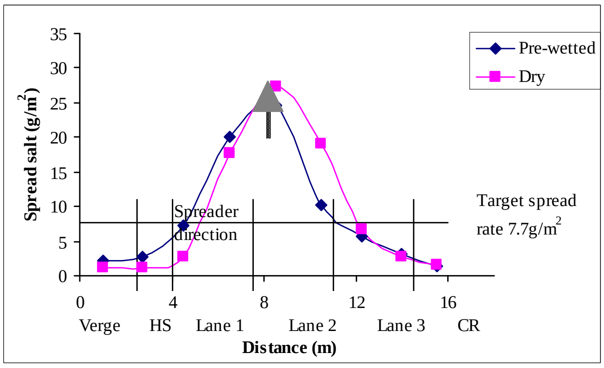



**h) symmetric, 20g/m$^2$ - hopper 10% full**

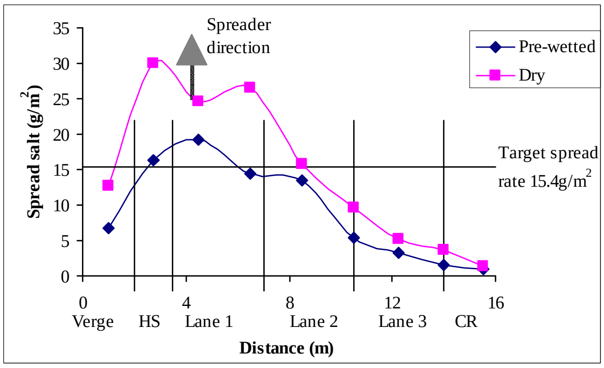
## B.2 Modified Schmidt Stratos



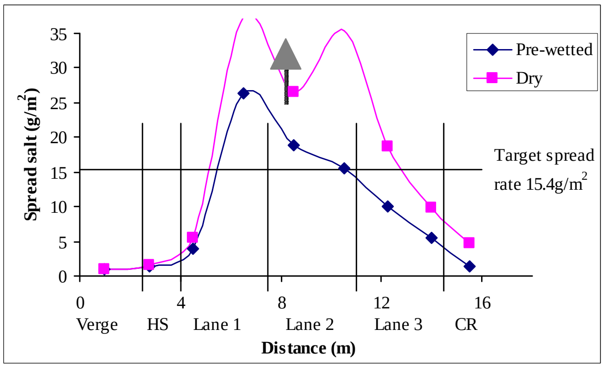

**a) asymmetric spreading, 10g/m²**




**b) symmetric spreading, 10g/m²**

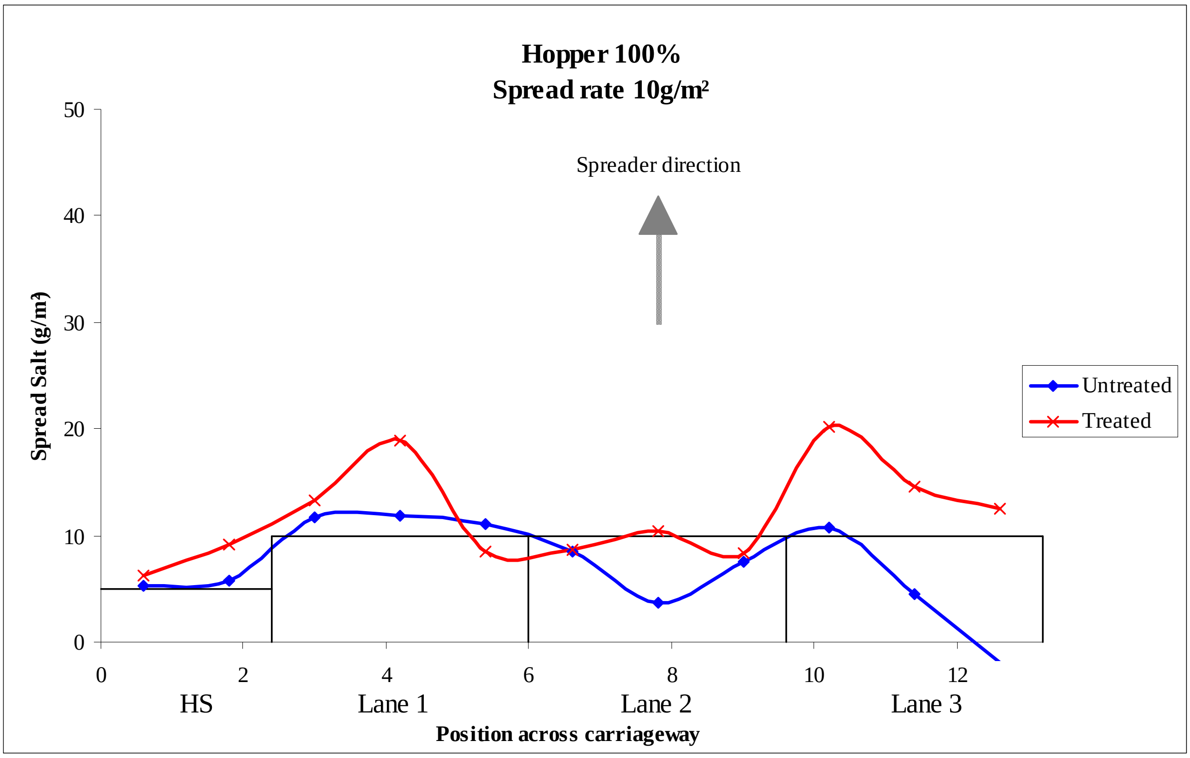



**c) asymmetric spreading, 20g/m²**

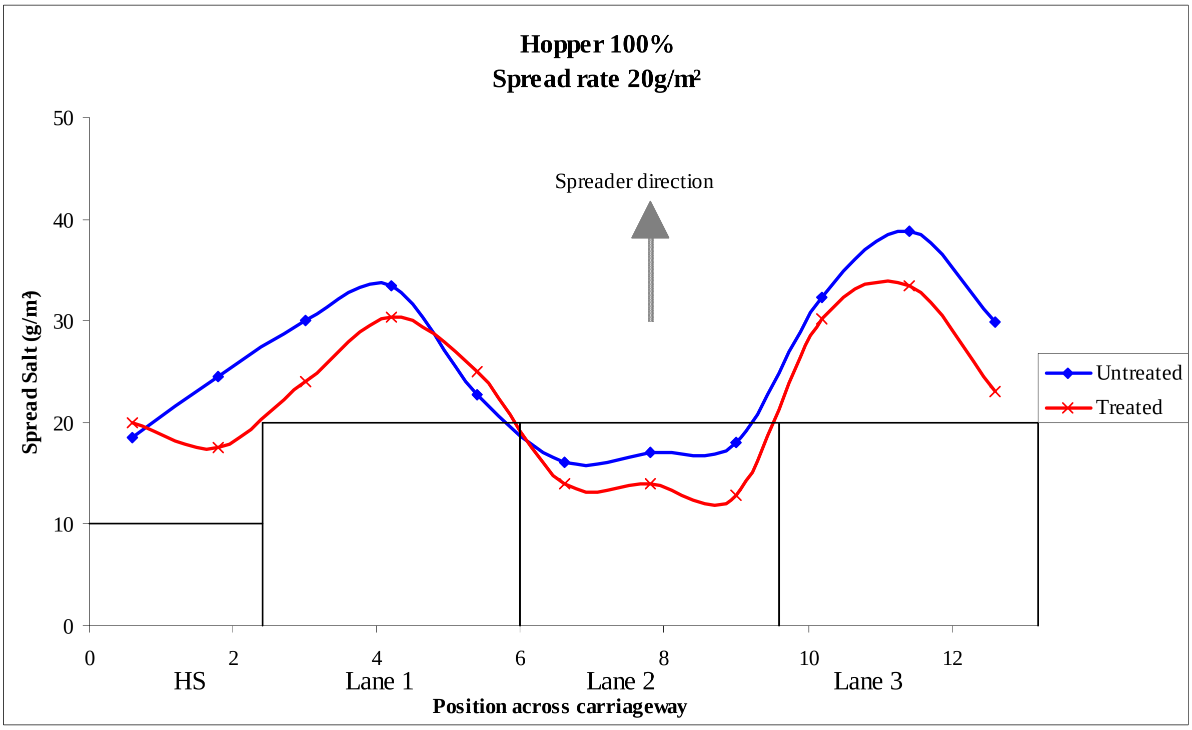



**d) symmetric spreading, 20g/m²**

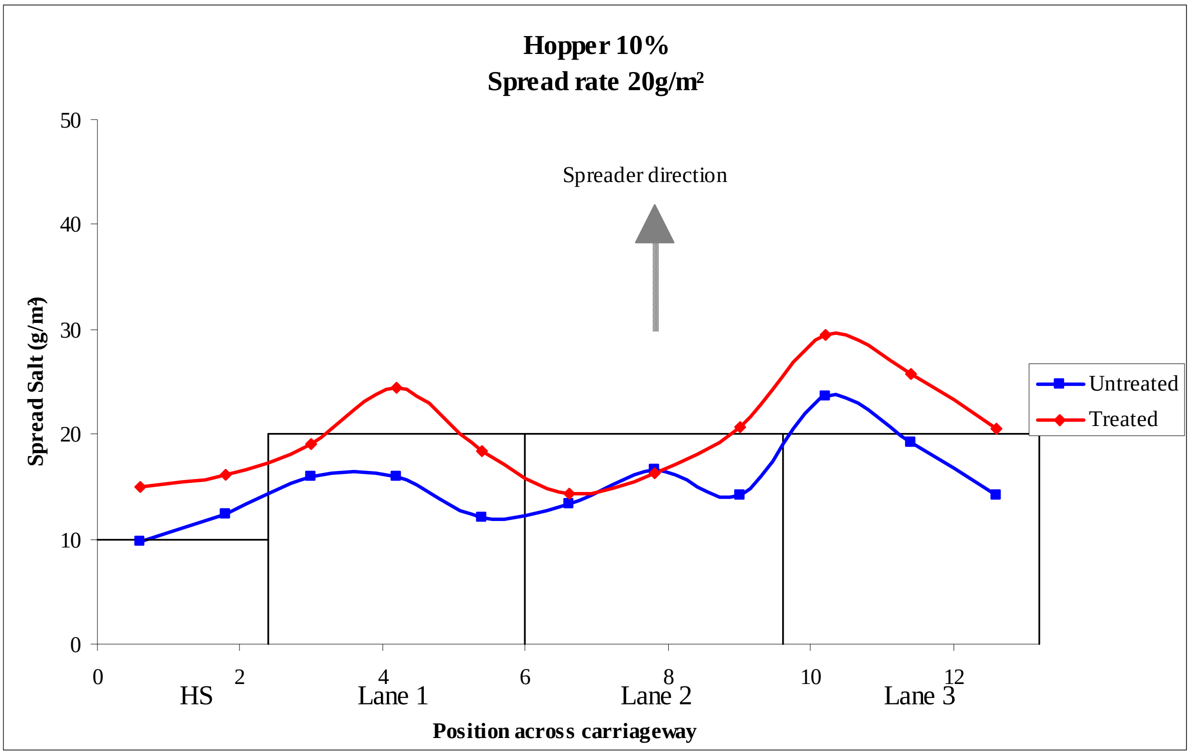
## B.3 M62 road trials



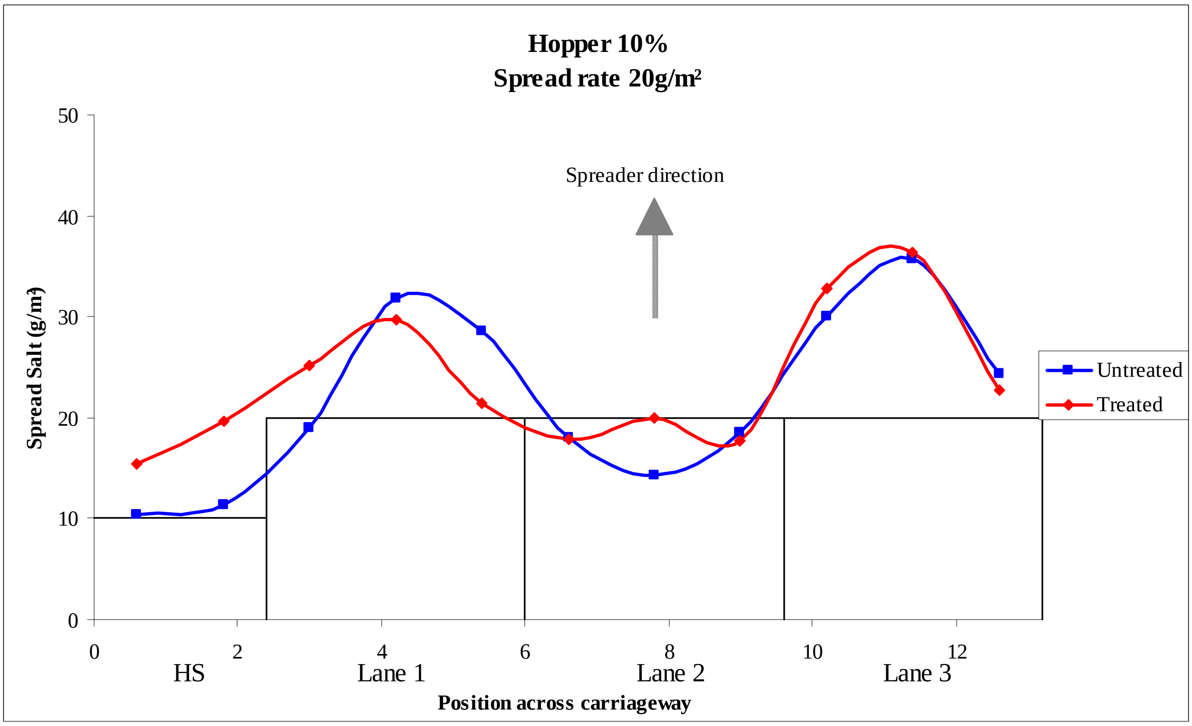

**Comparison of distributions with spread rate 10g/m² and full hopper**




**Comparison of distributions with spread rate 20g/m² and full hopper**

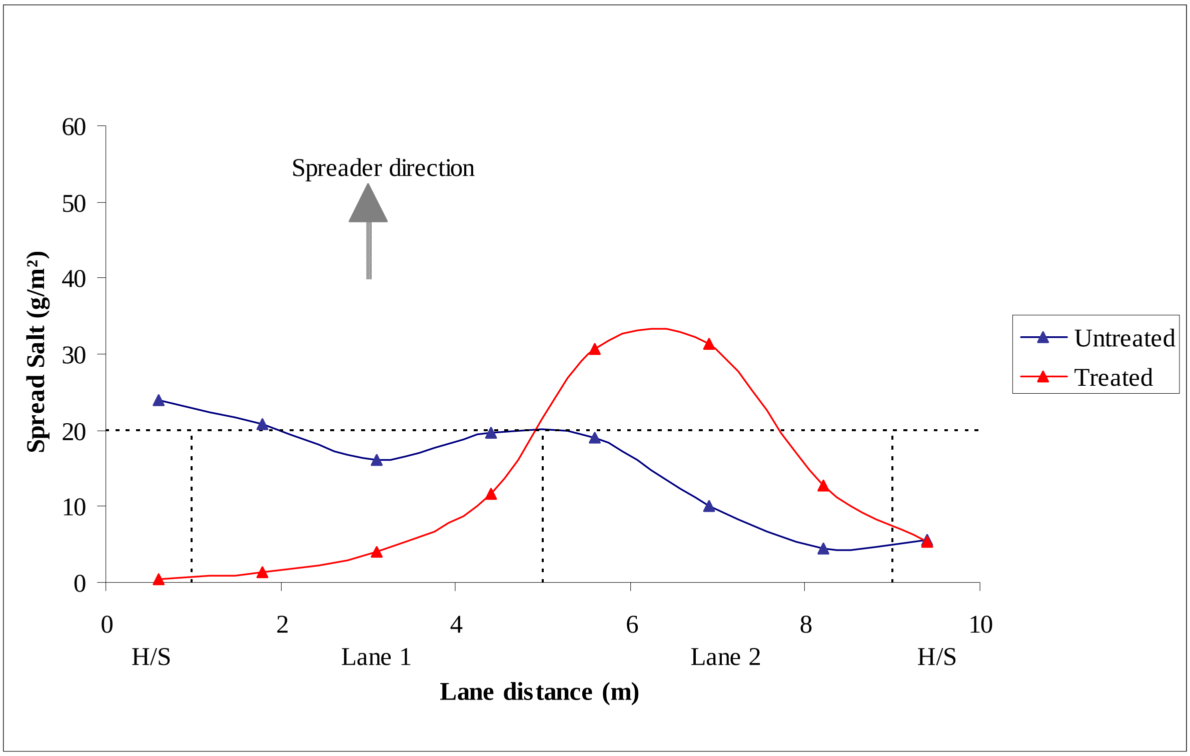



**Comparison of distributions with spread rate 20g/m² and 10 per cent full hopper**

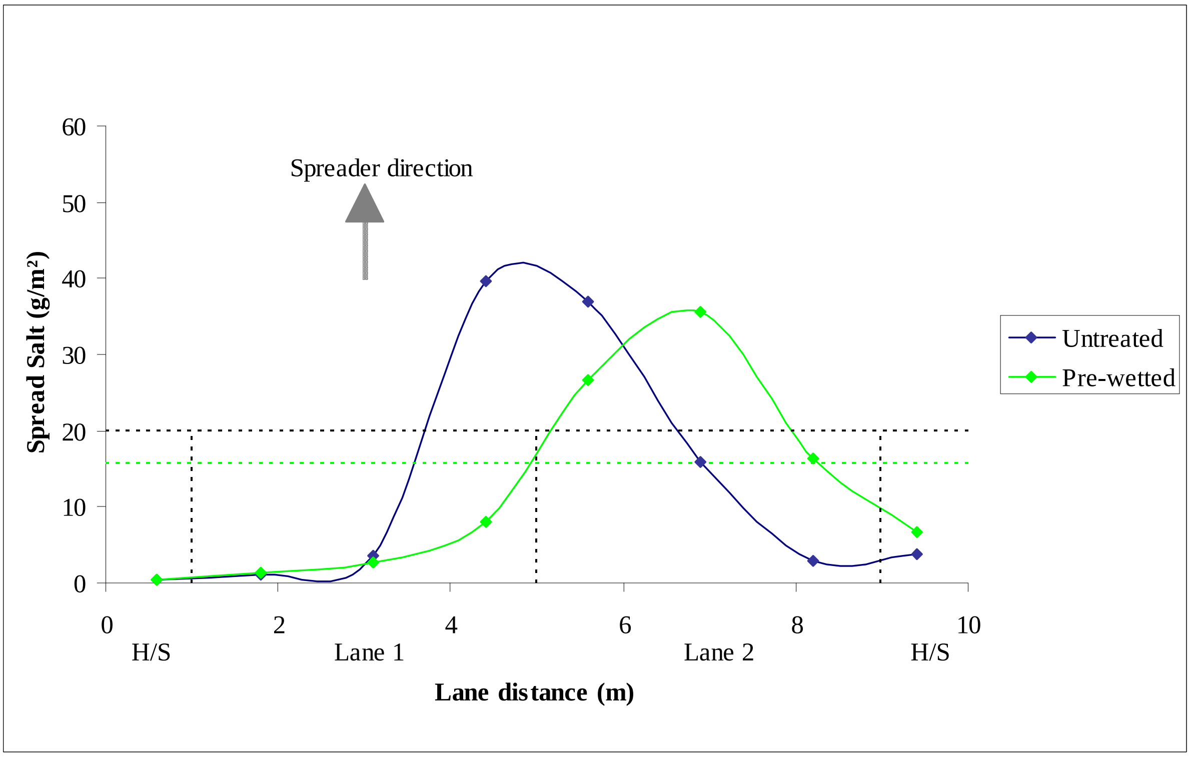



**Comparison of distributions with spread rate 20g/m² and 10 per cent full hopper (repeat tests)**

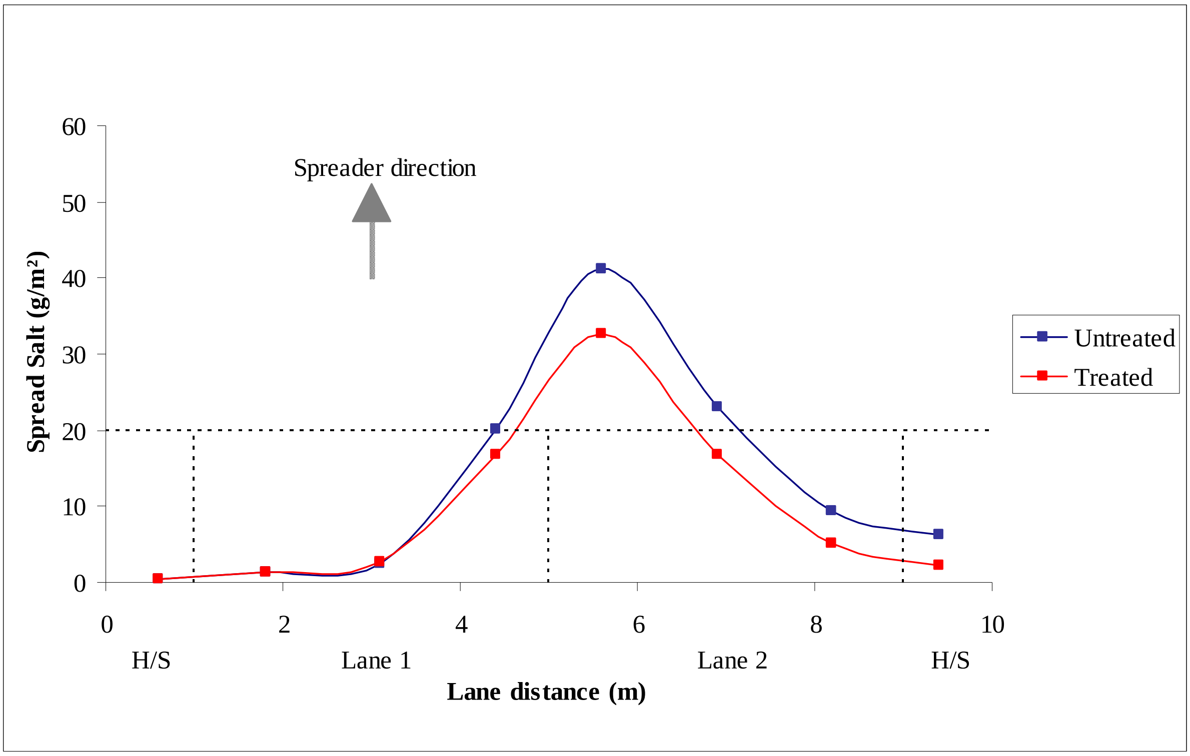
## B.4 A460 road trials



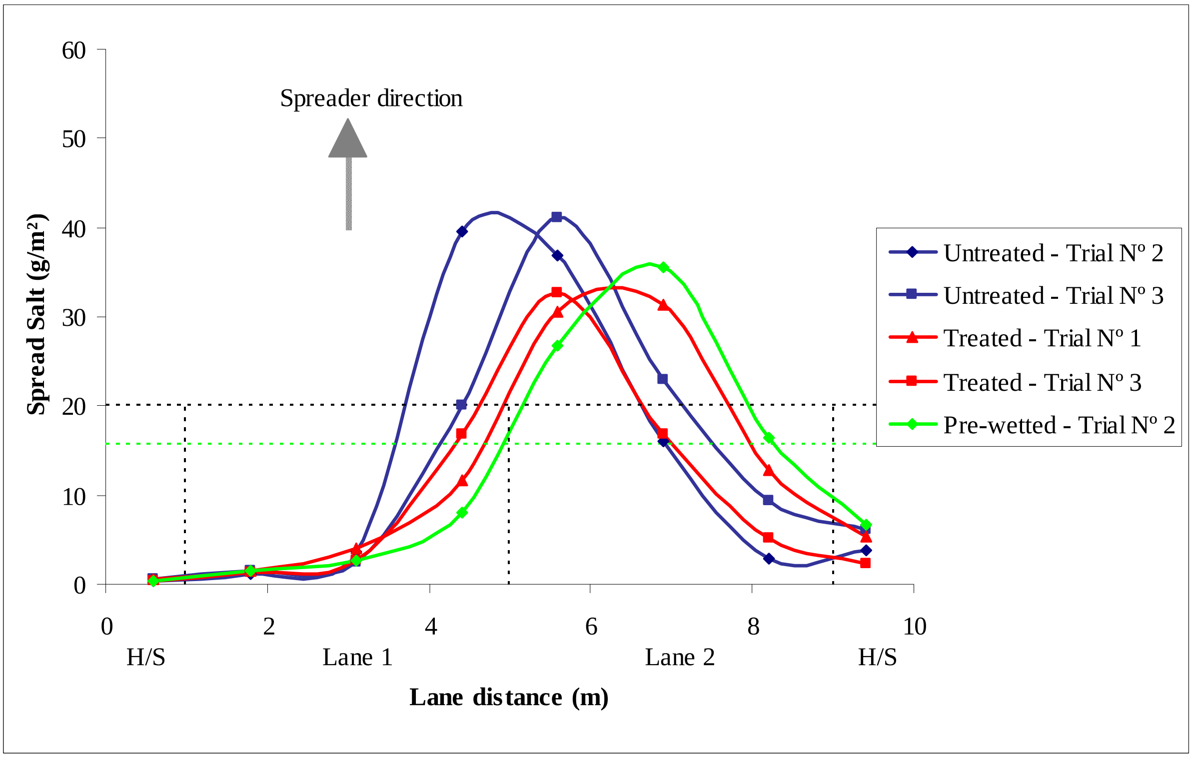

**Comparison of untreated and treated salt distributions for Trial N° 1**




**Comparison of untreated and pre-wetted salt distributions for Trial N° 2**

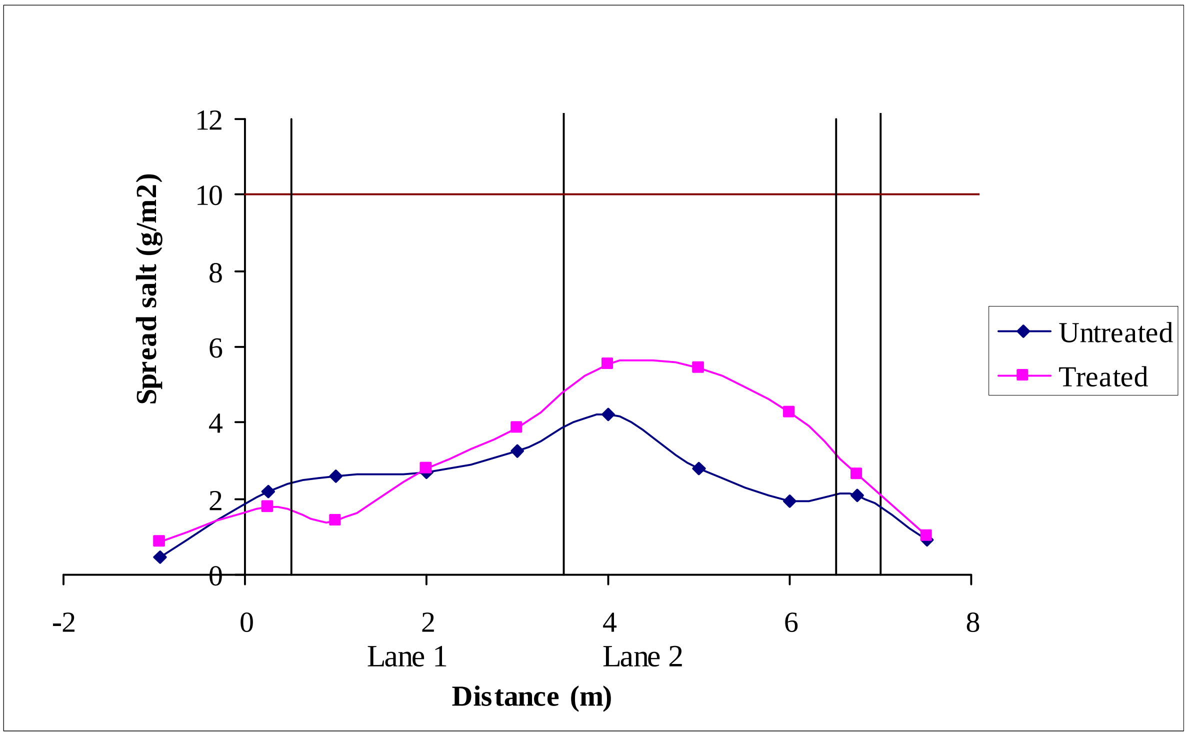



**Comparison of untreated and treated salt distributions for Trial N° 3**




**Comparison of salt distribution profiles**

## B.5 A9 road trials




**Comparison of untreated and treated salt distributions**

# Appendix C. Comparison of spread rates in the target area

**Table C1. Average spread rates achieved in target area for asymmetric spreading**

| Spreader type | Type of salting | Quantity of salt discharged as percentage of the target quantity (%) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Hopper full | | | | | Hopper 10 per cent full | | | | |
| | | HS | Lane 1 | Lane 2 | Lane 3 | Avg. of lanes | HS | Lane 1 | Lane 2 | Lane 3 | Avg. of lanes |
| Schmidt | Dry (10g/m$^2$) | 69 | 124 | 101 | 53 | 93 | 73 | 134 | 117 | 65 | 105 |
| | Dry (20g/m$^2$) | 49 | 125 | 94 | 52 | 90 | 58 | 100 | 90 | 47 | 79 |
| | Pre-wetted (10g/m$^2$) | 33 | 107 | 119 | 53 | 93 | 43 | 109 | 133 | 60 | 101 |
| | Pre-wetted (20g/m$^2$) | 28 | 80 | 104 | 78 | 87 | 32 | 100 | 103 | 91 | 98 |
| Modified Schmidt* | Dry (10g/m$^2$) | 147 | 181 | 161 | 49 | 130 | N/A | | | | |
| | Dry (20g/m$^2$) | 150 | 127 | 78 | 30 | 78 | | | | | |
| | Pre-wetted (10g/m$^2$) | 110 | 167 | 87 | 22 | 92 | | | | | |
| | Pre-wetted (20g/m$^2$) | 106 | 111 | 73 | 22 | 69 | | | | | |
| Econ Zero C A460 road trials | Dry (Trial 2) | | 70 | 89 | | 80 | N/A | | | | |
| | Dry (Trial 3) | | 38 | 118 | | 78 | | | | | |
| | Pre-wetted (Trial 2) | | 25 | 162 | | 94 | | | | | |
| | Treated (Trial 3) | | 33 | 87 | | 60 | | | | | |
| Giletta A9 road trials** | Dry (10g/m$^2$) | | 27 | 28 | | 28 | N/A | | | | |
| | Treated (10g/m$^2$) | | 25 | 48 | | 36 | | | | | |

* hopper one third full

** average of two tests

**Table C2. Average spread rates achieved in target area for symmetric spreading**

| Spreader type | Type of salting | Quantity of salt discharged as percentage of the target quantity (%) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Hopper full | | | | | Hopper 10 per cent full | | | | |
| | | HS | Lane 1 | Lane 2 | Lane 3 | Avg. of lanes | HS | Lane 1 | Lane 2 | Lane 3 | Avg. of lanes |
| Schmidt | Dry ($10g/m^2$) | 78 | 129 | 134 | 50 | 104 | 74 | 128 | 122 | 61 | 104 |
| | Dry ($20g/m^2$) | 57 | 98 | 97 | 30 | 75 | 52 | 86 | 92 | 43 | 74 |
| | Pre-wetted ($10g/m^2$) | 54 | 132 | 244 | 97 | 158 | 49 | 173 | 143 | 67 | 128 |
| | Pre-wetted ($20g/m^2$) | 60 | 101 | 145 | 72 | 106 | 69 | 102 | 112 | 90 | 101 |
| Modified Schmidt* | Dry ($10g/m^2$) | 17 | 113 | 238 | 68 | 140 | N/A | | | | |
| | Dry ($20g/m^2$) | 14 | 119 | 152 | 87 | 119 | | | | | |
| | Pre-wetted ($10g/m^2$) | 56 | 189 | 240 | 68 | 166 | | | | | |
| | Pre-wetted ($20g/m^2$) | 14 | 109 | 114 | 58 | 94 | | | | | |
| Foden 4000 M62 road trials | Dry ($10g/m^2$) | 56 | 116 | 65 | 44 | 75 | N/A | | | | |
| | Dry ($20g/m^2$)** | N/A | | | | | 55 | 103 | 79 | 123 | 102 |
| | Treated ($10g/m^2$) | 77 | 136 | 91 | 158 | 128 | N/A | | | | |
| | Treated ($20g/m^2$)** | N/A | | | | | 83 | 115 | 89 | 140 | 115 |

* hopper one third full

** average of two tests

# Appendix D. Comparison of longitudinal variation in the spread rate

**Table D1. Range in spread rate achieved within lanes for each strip for Schmidt performance trials**

| Spreader type | No. of lanes (target spread width, m) | Type of salting | Hopper | Range as % of average spread rate | | Ratio dry / pre-wetted |
|---|---|---|---|---|---|---|
| | | | | Dry | Pre-wetted | |
| Schmidt | 3-lanes + HS (13.0) | $10g/m^2$ Symmetric | Full | 21 | 66 | 0.32 |
| | | $20g/m^2$ Symmetric | | 32 | 72 | 0.44 |
| | | $10g/m^2$ Asymmetric | | 15 | 23 | 0.65 |
| | | $20g/m^2$ Asymmetric | | 31 | 42 | 0.74 |
| | | $10g/m^2$ Symmetric | 10 per cent full | 28 | 49 | 0.57 |
| | | $20g/m^2$ Symmetric | | 11 | 101 | 0.11 |
| | | $10g/m^2$ Asymmetric | | 15 | 11 | 1.36 |
| | | $20g/m^2$ Asymmetric | | 36 | 56 | 0.64 |

**Table D2. Range in spread rate achieved within lanes for each strip for Modified Schmidt performance trials (hopper one third full)**

| Spreader type | No. of lanes (target spread width, m) | Type of salting | Range as % of average spread rate | | Ratio dry / pre-wetted |
|---|---|---|---|---|---|
| | | | Dry | Pre-wetted | |
| Schmidt | 3-lanes + HS (12.0) | $10g/m^2$ Symmetric | 38 | 54 | 0.70 |
| | | $10g/m^2$ Asymmetric | 60 | 24 | 2.50 |
| | | $20g/m^2$ Symmetric | 32 | 23 | 1.39 |
| | | $20g/m^2$ Asymmetric | 15 | 35 | 0.43 |

**Table D3. Range in spread rate achieved within lans for each strip for A460 road trials**

| Spreader type | No. of lanes (target spread width, m) | Type of salting | Trial No. | Range as % of average spread rate | | | Ratio between dry and pre-wetted/treated |
|---|---|---|---|---|---|---|---|
| | | | | Dry | Pre-wetted | Treated | |
| Econ Zero C | 3-lanes + HS (12.0) | 20g/m$^2$ Asymmetric | 1 | 9 | - | 14 | 0.64 |
| | | | 2 | 28 | 33 | | 0.85 |
| | | | 3 | 29 | - | 52 | 0.56 |

**Table D4. Range in spread rate achieved within lanes for each strip for M62 road trials**

| Spreader type | No. of lanes (target spread width, m) | Type of salting | Hopper | Range as % of average spread rate | | Ratio dry / treated |
|---|---|---|---|---|---|---|
| | | | | **Dry** | **Treated** | |
| Foden 4000 | 3-lanes + HS (13.0) | 10g/m$^2$ Symmetric | Full | 111 | 40 | 2.78 |
| | | 20g/m$^2$ Symmetric | 10 per cent full | 34* | 22* | 1.55 |
| | | 20g/m$^2$ Symmetric | Full | 41 | 85 | 0.48 |

* average of two trials

# Appendix E. Effect on de-icer distribution before trafficking

**Table E1. Difference between discharge rate when hopper full and when 10 per cent full**

| Spreader type | No. of lanes (target spread width, m) | Type of salting | Difference in salt discharged (% of target spread rate) | |
|---|---|---|---|---|
| | | | Asymmetric | Symmetric |
| Econ – 1995 model | 2-lane (6.0) | Dry (10g/m$^2$) | -23 | 41 |
| | | Dry (20g/m$^2$) | 2 | 2 |
| Econ Low-throw – 1999 model | 2-lane (6.0) | Dry (10g/m$^2$) | -42 | 1 |
| | | Dry (20g/m$^2$) | -4 | -24 |
| Epoke Sirius SH3590 | 3-lane (9.0) | Pre-wetted (10g/m$^2$) | -23 | -57 |
| | | Pre-wetted (20g/m$^2$) | -10 | -12 |
| | 2-lane (7.0) | Dry (10g/m$^2$) | -16 | -2 |
| | | Dry (20g/m$^2$) | -7 | 28 |
| Schmidt | 3-lanes + HS (13.0) | Dry (10g/m$^2$) | -12 | 0 |
| | | Dry (20g/m$^2$) | 6 | 0 |
| | | Pre-wetted (10g/m$^2$) | -10 | 26 |
| | | Pre-wetted (20g/m$^2$) | -12 | 2 |
| Econ Zero C Mk 4 – 2002 model | 2-lane (6.0) | Dry (10g/m$^2$) | -98 | -56 |
| | | Dry (20g/m$^2$) | -50 | -35 |
| | 2-lane (6.0) | Pre-wetted (10g/m$^2$) | 36 | 34 |
| | | Pre-wetted (20g/m$^2$) | 13 | 7 |
| Epoke Sirius SH3500 | 2-lane (7.0) | Pre-wetted (10g/m$^2$) | -30 | -25 |
| | | Pre-wetted (20g/m$^2$) | -25 | -24 |
| Epoke Sirius SH3500 (repeat) | 2-lane (6.0) | Pre-wetted (10g/m$^2$) | -44 | -107 |
| | | Pre-wetted (20g/m$^2$) | -10 | -63 |
| Giletta 80501D | 2-lane (6.0) | Dry (10g/m$^2$) | -59 | NA |
| | | Dry (20g/m$^2$) | -5 | |
| Foden 4000 M62 Road Trial | 3-lane + HS (13.2) | Dry (20g/m$^2$) | NA | 35 |
| | | Treated (15g/m$^2$) | NA | -6 |
| | | Treated (20g/m$^2$) | NA | 2 |

**Table E2. Difference between discharge rate for asymmetric and symmetric spreading**

| Spreader type | No. of lanes (target spread width, m) | Type of salting | Difference in salt discharged (% of target spread rate) | |
|---|---|---|---|---|
| | | | Hopper full | Hopper 10 per cent full |
| Econ – 1995 model | 2-lane (6.0) | Dry (10g/m$^2$) | -12 | 52 |
| | | Dry (20g/m$^2$) | 1 | 1 |
| Econ Low-throw – 1999 model | 2-lane (6.0) | Dry (10g/m$^2$) | -44 | -1 |
| | | Dry (20g/m$^2$) | 10 | -10 |
| Epoke Sirius SH3590 | 3-lane (9.0) | Pre-wetted (10g/m$^2$) | -54 | -88 |
| | | Pre-wetted (20g/m$^2$) | -26 | -28 |
| | 2-lane (7.0) | Dry (10g/m$^2$) | 1 | 15 |
| | | Dry (20g/m$^2$) | -20 | 15 |
| Schmidt | 3-lanes + HS (13.0) | Dry (10g/m$^2$) | -12 | 0 |
| | | Dry (20g/m$^2$) | 10 | 4 |
| | | Pre-wetted (10g/m$^2$) | -61 | -25 |
| | | Pre-wetted (20g/m$^2$) | -24 | -10 |
| Econ Zero C Mk 4 – 2002 model | 2-lane (6.0) | Dry (10g/m$^2$) | -31 | 11 |
| | | Dry (20g/m$^2$) | -31 | -16 |
| | 2-lane (6.0) | Pre-wetted (10g/m$^2$) | -73 | -75 |
| | | Pre-wetted (20g/m$^2$) | -35 | -41 |
| Epoke Sirius SH3500 | 2-lane (7.0) | Pre-wetted (10g/m$^2$) | -68 | -63 |
| | | Pre-wetted (20g/m$^2$) | -31 | -30 |
| Epoke Sirius SH3500 (repeat) | 2-lane (6.0) | Pre-wetted (10g/m$^2$) | -80 | -143 |
| | | Pre-wetted (20g/m$^2$) | -8 | -61 |

**Table E3. Difference between spread rates for asymmetric and symmetric spreading**

| Spreader type | Type of salting | Difference in salt discharged (% of target spread rate) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Hopper full | | | | | Hopper 10 per cent full | | | | |
| | | HS | Lane 1 | Lane 2 | Lane 3 | Avg. of lanes | HS | Lane 1 | Lane 2 | Lane 3 | Avg. of lanes |
| Econ – 1995 model | Dry (10g/m$^2$) | | 9 | -34 | | -13 | | 32 | 47 | | 40 |
| | Dry (20g/m$^2$) | | 42 | 9 | | 26 | | 19 | 2 | | 11 |
| Econ Low-throw - 1999 model | Dry (10g/m$^2$) | | 38 | -78 | | -20 | | -1 | 45 | | 22 |
| | Dry (20g/m$^2$) | | 73 | -20 | | 27 | | -3 | 15 | | 6 |
| Epoke Sirius SH3590 | Pre-wetted (10g/m$^2$) | | -25 | -4 | -25 | -18 | | -89 | 4 | 7 | -26 |
| | Pre-wetted (20g/m$^2$) | | -7 | 30 | 14 | 12 | | -32 | 77 | 15 | 20 |
| | Dry (10g/m$^2$) | | -11 | 42 | | 16 | | 65 | -6 | | 30 |
| | Dry (20g/m$^2$) | | -12 | 11 | | -1 | | 43 | 22 | | 33 |
| Schmidt | Dry (10g/m$^2$) | | -5 | -33 | 3 | -12 | -1 | 6 | -5 | 4 | 2 |
| | Dry (20g/m$^2$) | | 27 | -3 | 22 | 15 | 6 | 14 | -2 | 4 | 5 |
| | Pre-wetted (10g/m$^2$) | | -25 | -125 | -44 | -65 | -6 | -64 | -10 | -7 | -27 |
| | Pre-wetted (20g/m$^2$) | | -21 | -41 | 6 | -19 | -37 | -2 | -9 | 1 | -3 |
| Econ Zero C Mk 4 – 2002 model | Dry (10g/m$^2$) | | -39 | 19 | | -10 | | 14 | 58 | | 36 |
| | Dry (20g/m$^2$) | | -32 | 4 | | -14 | | -34 | 14 | | -10 |
| | Pre-wetted (10g/m$^2$) | | -50 | -4 | | -27 | | -50 | -10 | | -30 |
| | Pre-wetted (20g/m$^2$) | | -35 | 69 | | 17 | | -17 | 39 | | 11 |
| Epoke Sirius SH3500 | Pre-wetted (10g/m$^2$) | | -39 | -70 | | -55 | | -57 | -48 | | -53 |
| | Pre-wetted (20g/m$^2$) | | 10 | -53 | | -22 | | -23 | -24 | | -24 |
| Epoke Sirius SH3500 (repeat) | Pre-wetted (10g/m$^2$) | | -7 | -101 | | -54 | | -107 | -36 | | -72 |
| | Pre-wetted (20g/m$^2$) | | 26 | 0 | | 13 | | -30 | -29 | | -30 |
| Modified Schmidt | Dry (10g/m$^2$) | | 68 | 77 | 19 | 9 | Not tested | | | | |
| | Dry (20g/m$^2$) | | 8 | 74 | 57 | 41 | | | | | |
| | Pre-wetted (10g/m$^2$) | | | 22 | 153 | 46 | | | | | |
| | Pre-wetted (20g/m$^2$) | | 2 | 41 | 36 | 25 | | | | | |

**Table E4. Difference between wastage for asymmetric and symmetric spreading**

| Spreader type | Type of salting | Difference in wastage (% of total discharged) | | | | | |
|---|---|---|---|---|---|---|---|
| | | Hopper full | | | Hopper 10 per cent full | | |
| | | Nearside (left)verge and margin | Offside (right) verge and margin | Total wastage | Nearside (left) verge and margin | Offside (right) verge and margin | Total wastage |
| Econ – 1995 model | Dry (10g/m$^2$) | 2 | 2 | 4 | -1 | -3 | -4 |
| | Dry (20g/m$^2$) | -1 | -25 | -26 | 0 | -10 | -10 |
| Econ Low-throw – 1999 model | Dry (10g/m$^2$) | 4 | -20 | -16 | -28 | 8 | -20 |
| | Dry (20g/m$^2$) | 7 | -30 | -23 | -15 | 0 | -15 |
| Epoke Sirius SH3590 | Pre-wetted (10g/m$^2$) | -23 | 0 | -23 | -29 | 0 | -29 |
| | Pre-wetted (20g/m$^2$) | -32 | 1 | -31 | -36 | 0 | -36 |
| | Dry (10g/m$^2$) | -13 | 0 | -13 | -12 | -2 | -14 |
| | Dry (20g/m$^2$) | -14 | -4 | -18 | -20 | -3 | -23 |
| Schmidt | Dry (10g/m$^2$) | -2 | 2 | 0 | -2 | 2 | 0 |
| | Dry (20g/m$^2$) | -3 | 2 | -1 | -3 | 2 | -1 |
| | Pre-wetted (10g/m$^2$) | -3 | 1 | -2 | -2 | 1 | -1 |
| | Pre-wetted (20g/m$^2$) | -3 | 2 | -1 | -2 | 3 | 1 |
| Econ Zero C Mk 4 – 2002 model | Dry (10g/m$^2$) | -14 | -8 | -22 | -14 | -7 | -21 |
| | Dry (20g/m$^2$) | -18 | 10 | -8 | -7 | 7 | 0 |
| | Pre-wetted (10g/m$^2$) | -17 | -6 | -23 | -30 | 0 | -30 |
| | Pre-wetted (20g/m$^2$) | -35 | -1 | -36 | -38 | -1 | -39 |
| Epoke Sirius SH3500 | Pre-wetted (10g/m$^2$) | 0 | 1 | 1 | -1 | 5 | 4 |
| | Pre-wetted (20g/m$^2$) | 8 | -10 | -2 | 4 | -2 | 2 |
| Epoke Sirius SH3500 (repeat) | Pre-wetted (10g/m$^2$) | 3 | -8 | -5 | -12 | -2 | -14 |
| | Pre-wetted (20g/m$^2$) | -2 | -11 | -13 | -6 | -1 | -7 |

| Spreader type | Type of salting | Difference in wastage (% of total discharged) | | | | | |
|---|---|---|---|---|---|---|---|
| | | Hopper full | | | Hopper 10 per cent full | | |
| | | Nearside (left)verge and margin | Offside (right) verge and margin | Total wastage | Nearside (left) verge and margin | Offside (right) verge and margin | Total wastage |
| Modified Schmidt | Dry (10g/m$^2$) | 4 | 1 | 5 | Not tested | | |
| | Dry (20g/m$^2$) | 10 | -2 | 8 | | | |
| | Pre-wetted (10g/m$^2$) | 2 | -1 | 1 | | | |
| | Pre-wetted (20g/m$^2$) | 7 | -1 | 6 | | | |

**Table E5. Difference between total discharge rate for spread rate 10g/m$^2$ and 20g/m$^2$**

| Spreader type | No. of lanes (target spread width, m) | Type of salting | Difference in salt discharged (% of target spread rate) | | | |
|---|---|---|---|---|---|---|
| | | | Asymmetric | | Symmetric | |
| | | | Hopper full | Hopper 10 per cent full | Hopper full | Hopper 10 per cent full |
| Econ – 1995 model | 2-lane (6.0) | Dry | -19 | 6 | -6 | -45 |
| Econ Low-throw – 1999 model | 2-lane (6.0) | Dry | -15 | 23 | 39 | 14 |
| Epoke Sirius SH3590 | 3-lane (9.0) | Pre-wetted | -16 | -3 | 12 | 57 |
| | 2-lane (7.0) | Dry | 21 | 30 | 0 | 30 |
| Schmidt | 3-lanes + HS (13.0) | Dry | 8 | 26 | 30 | 30 |
| | | Pre-wetted | 5 | 3 | 42 | 18 |
| Econ Zero C Mk 4 – 2002 model | 2-lane (6.0) | Dry | 6 | 54 | 6 | 27 |
| | | Pre-wetted | -8 | -31 | 30 | 3 |
| Epoke Sirius SH3500 | 2-lane (7.0) | Pre-wetted | 7 | 12 | 44 | 45 |
| Epoke Sirius SH3500 | 2-lane (6.0) | Pre-wetted | -36 | -2 | 36 | 80 |
| Giletta 80501D | 2-lane (6.0) | Dry | -43 | 11 | | |
| Foden 4000 | 3-lane + | Dry | | | -57 | |

| Spreader type | No. of lanes (target spread width, m) | Type of salting | Difference in salt discharged (% of target spread rate) | | | |
|---|---|---|---|---|---|---|
| | | | Asymmetric | | Symmetric | |
| | | | Hopper full | Hopper 10 per cent full | Hopper full | Hopper 10 per cent full |
| M62 Road Trial | HS (13.2) | Treated (10 and 15 g/m²) | | | 16 | |
| | | Treated (10 and 20g/m²) | | | 8 | |

**Table E6. Difference between spread rates in target area for asymmetric spreading at 10g/m² and 20g/m²**

| Spreader type | Type of salting | Difference in salt discharged (% of target spread rate) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Hopper full | | | | | Hopper 10 per cent full | | | | |
| | | HS | Lane 1 | Lane 2 | Lane 3 | Avg. of lanes | HS | Lane 1 | Lane 2 | Lane 3 | Avg. of lanes |
| Econ – 1995 model | Dry | | -31 | -25 | | -28 | | 5 | 5 | | 5 |
| Econ Low-throw – 1999 model | Dry | | -17 | -9 | | -13 | | -7 | 30 | | 12 |
| Epoke Sirius SH3590 | Pre-wetted | | -11 | -1 | -21 | -11 | | -13 | -8 | 9 | -4 |
| | Dry | | 43 | -3 | | 20 | | 73 | -17 | | 28 |
| Schmidt | Dry | | -1 | 7 | 1 | 2 | | 34 | 27 | 18 | 26 |
| | Pre-wetted | | 27 | 15 | -25 | 6 | | 9 | 30 | -31 | 3 |
| Econ Zero C Mk 4 - 2002 model | Dry | | 8 | 24 | | 16 | | 51 | 64 | | 58 |
| | Pre-wetted | | 33 | -40 | | -4 | | -18 | -41 | | -30 |
| Epoke Sirius SH3500 | Pre-wetted | | 9 | 6 | | 8 | | 8 | 8 | | 8 |
| Epoke Sirius SH3500 (repeat) | Pre-wetted | | -24 | -56 | | -40 | | -22 | 22 | | 0 |
| Modified Schmidt | Dry | | 54 | 83 | 19 | 52 | | | | | |
| | Pre-wetted | | 56 | 14 | 0 | 23 | | | | | |

**Table E7. Difference between spread rates in target area for symmetric spreading at 10g/m² and 20g/m²**

| Spreader type | Type of salting | Difference in salt discharged (% of target spread rate) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Hopper full | | | | | Hopper 10 per cent full | | | | |
| | | HS | Lane 1 | Lane 2 | Lane 3 | Avg. of lanes | HS | Lane 1 | Lane 2 | Lane 3 | Avg. of lanes |
| Econ – 1995 model | Dry | | 2 | 18 | | 10 | | -8 | -40 | | -24 |
| Econ Low-throw – 1999 model | Dry | | 18 | 49 | | 34 | | -9 | | | -5 |
| Epoke Sirius SH3590 | Pre-wetted | | 7 | 33 | 18 | 19 | | 44 | 65 | 17 | 42 |
| | Dry | | 42 | -34 | 0 | 4 | | 51 | 11 | 0 | 31 |
| Schmidt | Dry | | 31 | 37 | 20 | 29 | 22 | 42 | 30 | 18 | 30 |
| | Pre-wetted | | 31 | 99 | 25 | 52 | -20 | 71 | 31 | -23 | 26 |
| Econ Zero C Mk 4 – 2002 model | Dry | | 15 | 9 | | 12 | | 3 | 20 | | 12 |
| | Pre-wetted | | 48 | 33 | | 41 | | 15 | 8 | | 12 |
| Epoke Sirius SH3500 | Pre-wetted | | 58 | 23 | | 41 | | 42 | 32 | | 37 |
| Epoke Sirius SH3500 (repeat) | Pre-wetted | | 9 | 45 | | 27 | | 55 | 29 | | 42 |
| Modified** Schmidt | Dry | | -6 | 86 | -19 | 20 | | | | | |
| | Pre-wetted | | 80 | 126 | 10 | 72 | | | | | |

**Table E8. Difference between wastage at spread rates of 10g/m² and 20g/m² for asymmetric spreading**

| Spreader type | No. of lanes (target spread width, m) | Type of salting | Difference in salt discharged (% of target spread rate) | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | Hopper full | | | Hopper 10 per cent full | | |
| | | | Nearside | Offside (right) | Total wastage | Nearside | Offside (right) | Total wastage |
| Econ – 1995 | 2-lane (6.0) | Dry | 6 | 8 | 14 | 4 | -5 | -1 |
| Econ Low-throw – 1999 model | 2-lane (6.0) | Dry | -1 | 0 | -1 | -3 | 9 | 6 |
| Epoke Sirius SH3590 | 3-lane (9.0) | Pre-wetted | -2 | -1 | -3 | 1 | 0 | 1 |
| | 2-lane (7.0) | Dry | 1 | -1 | 0 | 1 | -2 | -1 |
| Schmidt | 3-lanes + HS (13.0) | Dry | 1 | 0 | 1 | -1 | 1 | 0 |
| | | Pre-wetted | 0 | -2 | -2 | 1 | -3 | -2 |
| Modified scmidt | 3-lanes + HS (12.0) | Dry | -5 | 1 | -4 | | | |
| | | Pre-wetted | -3 | -1 | -4 | | | |
| Econ Zero C Mk 4 – 2002 model | 2-lane (6.0) | Dry | -6 | -19 | -25 | -7 | -9 | -16 |
| | | Pre-wetted | 3 | -6 | -3 | 1 | 1 | 2 |
| Epoke Sirius SH3500 | 2-lane (7.0) | Pre-wetted | 3 | -8 | -5 | 4 | -3 | 1 |
| Epoke Sirius SH3500 (repeat) | 2-lane (6.0) | Pre-wetted | 4 | 4 | 8 | -3 | 2 | -1 |
| Giletta 80501D | 2-lane (6.0) | Dry | 4 | -2 | 2 | 3 | -8 | -5 |

**Table E9. Difference between wastage at spread rates of 10g/m² and 20g/m² for symmetric spreading**

| Spreader type | No. of lanes (target spread width, m) | Type of salting | Difference in salt discharged (% of target spread rate) | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | Hopper full | | | Hopper 10 per cent full | | |
| | | | Nearside | Offside (right) | Total wastage | Nearside | Offside (right) | Total wastage |
| Econ – 1995 model | 2-lane (6.0) | Dry | 3 | -19 | -16 | 5 | -12 | -7 |
| Econ Low-throw – 1999 | 2-lane (6.0) | Dry | 2 | -10 | -8 | 10 | 1 | 11 |
| Epoke Sirius SH3590 | 3-lane (9.0) | Pre-wetted | -11 | 0 | -11 | -6 | 0 | -6 |
| | 2-lane (7.0) | Dry | 0 | -5 | -5 | -7 | -3 | -10 |
| Schmidt | 3-lanes + HS (13.0) | Dry | 0 | 0 | 0 | -2 | 1 | -1 |
| | | Pre-wetted | 0 | -1 | -1 | 1 | -1 | 0 |
| Modified scmidt | 3-lanes + HS (12.0) | Dry | 1 | -2 | -1 | 0 | 0 | 0 |
| | | Pre-wetted | 2 | -1 | 1 | 0 | 0 | 0 |
| Econ Zero C Mk 4 – 2002 model | 2-lane (6.0) | Dry | -10 | -1 | -11 | 0 | 5 | 5 |
| | | Pre-wetted | -15 | -1 | -16 | -7 | 0 | -7 |
| Epoke Sirius SH3500 | 2-lane (7.0) | Pre-wetted | 11 | -19 | -8 | 9 | -10 | -1 |
| Epoke Sirius SH3500 (repeat) | 2-lane (6.0) | Pre-wetted | -1 | 1 | 0 | 3 | 3 | 6 |

# Appendix F. Effects of trafficking

**Table F1. Percentage of salt loss due to trafficking across the two lanes for A331 pre-wetted salt trial**

| Hours of trafficking | Lane 1 | Lane 2 | Average |
|---|---|---|---|
| 1 | 18 | - 2 | 3 |

**Table F2. Percentage of salt loss due to trafficking across the two lanes for A52 pre-wetted salt trial**

| Hours of trafficking | Lane 1 | Lane 2 | Average |
|---|---|---|---|
| 1 | 24 | -3 | 6 |
| 20 | 58 | 63 | 61 |

**Table F3. Percentage of salt loss due to trafficking across the two lanes for A33 pre-wetted salt trial**

| Hours of trafficking | Lane 1 | Lane 2 | Average |
|---|---|---|---|
| 1 | 10 | 10 | 10 |
| 20 | 73 | 52 | 62 |

**Table F4. Percentage of salt loss due to trafficking across the two lanes for A9 comparative trial**

| Type of operation | Untreated salt | | | Treated salt | | |
|---|---|---|---|---|---|---|
| | Lane 1 | Lane 2 | Average | Lane 1 | Lane 2 | Average |
| **1 hour** | 54 | -9 | 23 | 31 | -21 | 2 |
| **18 hours** | 79 | 72 | 75 | 73 | 79 | 78 |

**Table F5. Percentage of salt loss due to trafficking across the two lanes for A460 comparative trial: dry and pre-wetted salt**

| Type of operation | Untreated salt | | | Pre-wetted salt | | |
|---|---|---|---|---|---|---|
| | Lane 1 | Lane 2 | Average | Lane 1 | Lane 2 | Average |
| 10 hours | 43 | 30 | 36 | 30 | 52 | 49 |
| 16 hours | 49 | 37 | 42 | 35 | 57 | 54 |
| 36 hours | 55 | 44 | 49 | 50 | 71 | 68 |

**Table F6. Percentage of salt loss due to trafficking across the two lanes for A460 comparative trial: dry untreated and treated salt**

| Type of operation | Untreated salt | | | Treated salt | | |
|---|---|---|---|---|---|---|
| | Lane 1 | Lane 2 | Average | Lane 1 | Lane 2 | Average |
| 10 hours | 28 | 45 | 41 | -13 | 38 | 24 |
| 16 hours | 38 | 53 | 50 | 8 | 53 | 41 |
| 36 hours | 48 | 56 | 54 | 34 | 62 | 54 |

# Appendix G. Salting trial actions checklist

| At least one week before trial | Body responsible | Confirmed | Performance/Road |
|---|---|---|---|
| Provide details of trial site: location, street lighting, length available for test strips, curvature, lane widths, margin/verge details, cross fall, gradient, surface course type and condition | Local authority | | Road |
| Confirm trial site is suitable for trial | TRL | | Road |
| Provide details of spreader make, model and registration number | Local authority | | Performance/Road |
| Provide details of de-icer type and grain size, and moisture content and grading on delivery | Salt supplier | | Performance/Road |
| Provide details of de-icer type (dry/treated/prewet etc.), spread width, spread rate and mode of symmetry for trial | Local authority | | Performance/Road |
| Provide grading and target moisture content range for de-icer for trial and, where applicable, dry component:brine mix proportions and brine concentration | Local authority | | Performance/Road |
| Provide details of spreader calibration: date, spreader settings (gate height, belt speed, spinner speed etc.), measurements made during calibration, de-icer used with grading and moisture content, standard to which spreader was calibrated | Vehicle operator | | Performance/Road |
| Provide details of spreader settings for trial | Local authority | | Performance/Road |
| Provide hopper load for trial | Local authority | | Performance/Road |
| Confirm that calibration settings are relevant to settings for the trial, e.g. spread width, spread rate | Spreader manufacturer | | Performance/Road |
| Provide limits on wind speed for trial | Spreader manufacturer | | Performance/Road |
| Provide photo of where de-icer is stored | Local authority | | Performance/Road |
| Confirm that representative from the spreader manufacturer will be available for the pre-trial spreading check and actual trial | Spreader manufacturer | | Performance/Road |

| **At least one week before trial** | **Body responsible** | **Confirmed** | **Performance/Road** |
|---|---|---|---|
| Confirm that a spreader driver trained for the trial spreader will be available for the pre-trial spreading check and actual trial | Local authority | | Performance/Road |
| Confirm whether or not traffic counts can be provided | Local authority | | Road |
| Confirm whether GPS data logging is available | Local authority | | Performance/Road |
| Demonstrate that weighbridge is calibrated and measurements are repeatable | Local authority | | Road |
| Decide whether or not to proceed | TRL | | Performance/Road |
| | | | |
| **Day before trial, including pre-trial spreading check** | **Body responsible** | **Confirmed** | **Performance/Road** |
| Confirm that environmental conditions are appropriate - wind speed, humidity, temperature | TRL | | Performance/Road |
| Confirm hopper has been unloaded and reloaded to ensure de-icer is not consolidated | Local authority | | Performance/Road |
| Provide details of hopper load (laden and unladen vehicle weights) | Local authority | | Performance/Road |
| Confirm that hopper load is as specified | TRL | | Performance/Road |
| Confirm spreader driver is trained for spreader | Local authority | | Performance/Road |
| Confirm that spreader settings are correct | Vehicle operator | | Performance/Road |
| Collect sample of dry component of de-icer in nosebag before spreading check and provide details of moisture content and grading | Local authority | | Performance/Road |
| For pre-wetted and brine spreading, collect brine sample and provide details of brine concentration | Local authority | | Performance/Road |
| Complete pre-trial spreading check run and assess de-icer distribution visually in presence of TRL and spreader manufacturer | Local authority | | Performance/Road |
| Collect sample of dry component of de-icer in nosebag after pre-trial spreading check and determine moisture content and grading | Local authority | | Performance/Road |

| At least one week before trial | Body responsible | Confirmed | Performance/Road |
|---|---|---|---|
| Provide details of weight of dry component and, where applicable, liquid component discharged and spread length | Local authority | | Performance/Road |
| For pre-wetted and brine spreading, collect brine sample and determine brine concentration | Local authority | | Performance/Road |
| Provide details of all changes in spreader setting made by spreader manufacturer resulting from visual assessment - and why necessary (spreading check should be repeated if adjustments are made) | Spreader manufacturer / vehicle operator | | Performance/Road |
| Decide whether or not to proceed | TRL | | Performance/Road |
| | | | |
| **Day of trial** | **Body responsible** | **Confirmed** | **Performance/Road** |
| Confirm that environmental conditions are appropriate - wind speed, humidity, temperature | TRL | | Performance/Road |
| Confirm that dry component moisture content and, where appropriate, brine concentration and dry component:brine mix proportions during pre-trial spreading check were within target | Local authority | | Performance/Road |
| Confirm hopper has been unloaded and reloaded to ensure de-icer is not consolidated | Local authority | | Performance/Road |
| Provide details of hopper load (laden vehicle weight) | Local authority | | Performance/Road |
| Confirm that hopper load is as specified | TRL | | Performance/Road |
| Confirm spreader driver is trained for spreader | Local authority | | Performance/Road |
| Confirm that spreader settings are those required for trial | Vehicle operator | | Performance/Road |
| Ensure spreader driver is familiar with trial site and where spreading is to start and stop | Vehicle operator | | Performance/Road |
| Install traffic management to isolate trial site from live traffic | Local authority | | Road |
| When possible, wet wash road to remove detritus and residual salt (not possible if | Local authority | | Performance/Road |

| At least one week before trial | Body responsible | Confirmed | Performance/Road |
|---|---|---|---|
| temperatures are below freezing) | | | |
| Mark up trial site and locations where spreading is to start and finish | TRL | | Performance/Road |
| Wet wash and vacuum reference panels to recover background residual salt | TRL | | Performance/Road |
| Collect sample of dry component of de-icer in nosebag before trial | Local authority | | Performance/Road |
| For pre-wetted and brine spreading, collect brine sample before trial | Local authority | | Performance/Road |
| Record road surface state (wet/dry/moist) and condition | TRL | | Performance/Road |
| Complete trial run under supervision of spreader manufacturer | Local authority | | Performance/Road |
| Provide details of spreader speed, position on lane during spreading, details of where spreading started and stopped and, therefore, spread length | Vehicle operator | | Performance/Road |
| Provide any data logged during the trial | Local authority | | Performance/Road |
| Collect sample of dry component of de-icer in nosebag after trial | Local authority | | Performance/Road |
| For pre-wetted and brine spreading, collect brine sample after trial | Local authority | | Performance/Road |
| Provide details of weight of dry component and, where applicable, liquid de-icer discharged. | Local authority | | Performance/Road |
| Collect de-icer from test strips at time required | TRL | | Road |
| Provide traffic counts in each lane, as appropriate | Local authority | | Road |
| For trials to determine effects of trafficking, record weather conditions | TRL | | Road |