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Decision Support System for Winter Maintenance: Feasibility Demonstration

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16. Abstract

Approaches to the use of chemical freezing-point suppressants for snow and ice control are beginning to change in North America and have already changed in some European countries. Where rock salt was formerly applied at a fixed rate after the beginning of snow accumulation, recent advances in information technology, spreading equipment and chemicals allow the application of freezing point suppressants prior to snowfall, the adjustment of rates in association with weather conditions or levels of service, and the use of alternative chemicals either with rock salt or instead of rock salt.

Selection of alternative chemicals, application rates, application methods and timing of operations increases the burden of decision making on field staff, few of whom have experience or training in the new methods. One solution proposed for this problem is to develop a computer-based decision support tool which can assist staff in planning chemical applications within two hours of or during snow control operations.

The objectives of this project were to report on existing work in developing decision support tools to select chemical applications appropriate to winter weather conditions, to describe in detail those which are at or near an operational state, and to assess the feasibility of implementation as part of a road weather information system (RWIS).

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DECISION SUPPORT SYSTEM FOR WINTER MAINTENANCE: FEASIBILITY DEMONSTRATION

Final Report
August 2000

Project Champion
Max Perchanok
Ontario Ministry of Transportation

Co-Project Champions
Curt Pape
Minnesota Department of Transportation

Lee Smithson
Iowa Department of Transportation

Dan Eriksson
Swedish National Road Authority

Alfred Uzokwe
Pennsylvania Department of Transportation

Authors
Max Perchanok, Curt Pape, Lee Smithson, Dan Eriksson, Alfred Uzokwe

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A report from
Aurora Program
Iowa State University
2711 South Loop Drive, Suite 4700
Ames, IA 50010-8664
Phone: 515-294-7684
Fax: 515-294-0467
www.aurora-program.org

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1. INTRODUCTION AND OBJECTIVES

Approaches to the use of chemical freezing-point suppressants for snow and ice control are beginning to change in North America and have already changed in some European countries. Where rock salt was formerly applied at a fixed rate after the beginning of snow accumulation, recent advances in information technology, spreading equipment and chemicals allow the application of freezing point suppressants prior to snowfall, the adjustment of rates in association with weather conditions or levels of service, and the use of alternative chemicals either with rock salt or instead of rock salt.

Selection of alternative chemicals, application rates, application methods and timing of operations increases the burden of decision making on field staff, few of whom have experience or training in the new methods. One solution proposed for this problem is to develop a computer-based decision support tool which can assist staff in planning chemical applications within two hours of or during snow control operations.

The objectives of this project were to report on existing work in developing decision support tools to select chemical applications appropriate to winter weather conditions, to describe in detail those which are at or near an operational state, and to assess the feasibility of implementation as part of a road weather information system (RWIS).

2. METHODOLOGY

The project included a review of published information, personal interviews with agencies or persons involved with existing systems, detailed description and demonstration of existing systems, comparison of data requirements in comparison with outputs from RWIS, and assessment of the feasibility of implementation.

3. RESULTS

3.1 State-of-the-Art Review

A literature review identified the following decision-support systems for winter operations:

(a) an Expert System development project by the Swedish National Road Administration (SNRA) (Axelson and Malmberg, 1991),

(b) a table-based menu for anti-icing developed by the FHWA (Ketcham et al, 1995),

(c) a computerized adaptation of the FHWA menu (MTO, 1999), and;

(d) an Expert System development by Swedish Road and Transport Research Institute (VTI) (Ljungberg, 2000).

3.1.1 SNRA

The SNRA Expert System project report was translated from Swedish to English for this project and is attached as Appendix A. The project was a comprehensive plan for an integrated RWIS network, development of methods for interpolation of road weather information between stations, and automated selection of chemical applications based on an Expert System model. The translated report describes the development process in detail, the weather condition categories and recommended application rates.

The logic used to prescribe salt application on the basis of road-weather conditions was inferred from tables in the report. The key factors appear to be, in order of priority:

(a) the air temperature – if the air temperature is above +10°C, no actions are required. If the air temperature is below +10°C, actions are advised based on other factors as follows.

(b) whether precipitation is currently occurring, and whether or not it is forecasted to occur – all four possible cases are covered by the SNRA System (Table 1). The type of precipitation (e.g., rain, snow, etc) does not appear to be a factor in the decision tree.

(c) the current and forecast pavement condition – a wide range of possibilities are considered (Table 1). The combinations vary with the precipitation case under consideration (Table 1).

The type of surface condition is defined based on standard categories such as wet, moist, snow, snow slush, ice, and frost. The dew point and the pavement temperature are used in combination with each other to specify the surface conditions further as shown in Table 2.

(d) the pavement temperature – the cases specified vary to some extent with the pavement and the precipitation condition cases under consideration (Appendix E in SNRA report).

For a large number of cases, actions are advised for pavement temperatures in the following ranges: >0°C ; -2/0 °C ; -4/-2 °C ; -6/-4 °C ; -8/-6 °C ; -10/-8 °C ; and < -10°C.

(e) the type of salt material – actions are advised for “moist salt”, and “solution”, which are assumed to refer to pre-wetted salt and brine, respectively. In many cases, application rates are provided for both materials in g/m^2. For the cases where both materials are specified, the application rates by mass for the solution material are always twice of those for moist salt. The solution material is not advised for cases requiring “moist salt” application rates greater than 20 g/m^2.

The reference basis for the rates quoted is not stated in the Manual. It is assumed that rates for moist salt are the mass of dry salt and for solution are the mass of NaCl brine at a concentration near the saturation point. The mass rate of solution added to dry salt to create moist salt is not specified.

(f) the winter road maintenance standard class (which is defined based on the type of road, the traffic volume, and the pavement temperature) – the Manual defines the various classes considered (Table 7 in Appendix E of SNRA reportE). However, it is not clear how the advised actions are affected by the winter road maintenance standard class.

The material application recommendations were not integrated as part of the SNRA RWIS and the material application recommendations have to some extent been superceded since the report was written.

Table 1. Summary: SNRA action table summary by case

Precipitation Currently Occurring ?	Precipitation Forecast To Occur ?	Current Pavement Condition	Forecast Pavement Condition	Table in Appendix E With Advised Actions
Yes	Yes	Dry	Various[1]	Table 2
Yes	Yes	Not dry[2]	Not important	Table 3
Yes	No	Various[3]		Table 4
No	Yes	Various[4]		Table 5
No	No	Various[5]		Table 6

Notes:

1. The forecast pavement conditions are: moist ; wet ; light frost ; heavy frost ; thin ice ; thick ice ; snow slush ; wet snow ; and dry snow.
2. The current pavement conditions included are: moist ; wet ; light frost ; heavy frost ; thin ice ; thick ice ; snow slush ; wet snow ; and dry snow.
3. The following pavement surface condition combinations are considered:

Current Condition	Forecast Condition
dry ; light frost ; heavy frost ; thin ice ; thick ice ; snow slush ; wet snow ; dry snow	not important
moist	dry ; moist ; wet ; light frost ; heavy frost ; thin ice ; thick ice ; snow slush ; wet snow ; dry snow
wet	dry ; moist ; wet ; light frost ; heavy frost ; thin ice ; thick ice ; snow slush ; wet snow ; dry snow

4. The following pavement surface condition combinations are considered:

Current Condition	Forecast Condition
moist ; wet ; light frost ; heavy frost ; thin ice ; thick ice ; snow slush ; wet snow ; dry snow	not important
dry	moist ; wet ; light frost ; heavy frost ; thin ice ; thick ice ; snow slush ; wet snow ; dry snow

5. The following pavement surface condition combinations are considered:

Current Condition	Forecast Condition
light frost ; heavy frost ; thin ice ; thick ice ; snow slush ; wet snow ; dry snow	not important
dry	dry ; moist ; wet ; light frost ; heavy frost
moist	dry ; moist ; wet ; light frost ; heavy frost ; ice ; snow cover
wet	dry ; moist ; wet ; light frost ; heavy frost ; ice

Table 2. Effect of pavement temperature and dew point on surface condition category

Pavement Surface Condition Category	Pavement Temperature (°C)[1]	Delta (in °C[1] ; defined as pavement temperature-dew point)
heavy frost	< 0	> 2
light frost	< 0	<= 2
wet	>= 0	> 2
moist	>= 0	<= 2

Notes:

1. Units not specified in SNRA Translation – presumed to be °C.

3.1.2 VTI

VTI is in the early stages of development of an Expert System for Winter Road Maintenance (Ljungberg, 2000 and personal communication). The purpose of this project is to develop a set of rules for material application primarily for frost accumulation, based on road weather forecasts 2 to 4 hours ahead, using liquid and pre-wet chemicals. The knowledge base on which the rules are based is derived from interviews with road managers and takes into account the managers' level of experience and the success of recommended operations. The ultimate objective is to integrate the Expert System with the SNRA RWIS display. The Expert System is scheduled for completion in late 2000 and integration with the RWIS system will follow that.

3.1.3 FHWA

FHWA developed a set of rules for application of chemicals for anti-icing (Ketcham et al, 1995). The objective of this project was to demonstrate the effectiveness of pre-treatment (anti-icing) in comparison with reactive treatment (de-icing) and to provide guidance to field staff in the selection and application of chemicals. It included a review of practice in the United States and other countries, field testing of the recommended practices on U.S. highways, and recommendation of chemical application rates according to current and forecast pavement temperature, snowfall and dewpoint conditions. The following data are required to obtain a recommendation from the FHWA Tables:

The Weather Event, or Type of Precipitation: the possible choices are:

(a) freezing rain
(b) a light snow storm
(c) a light snow storm with period(s) of moderatre or heavy snow
(d) a moderate to heavy snow storm
(e) frost or black ice
(f) sleet

- the current pavement temperature and trend
- the current dew point and trend (for a frost or black ice event)
- the pavement condition: the possible choices are: (a) dry; (b) wet; (c) slush; (d) light snow cover, and; (e) packed snow
- the traffic (for a frost or black ice event): the possible choices are : (a) heavy (>10,000/day) ; (b) moderate (2400-10,000/day), and; (c) light (<2400/day)
- the snow type: the possible choices are either: (a) light, or: (b) heavy (note 1)

Notes:
1. "Light" vs "Heavy" Snow - "Light" snow is considered to be snow that is falling at less than 12 mm (0.5 inches) per hour. "Heavy" snow is considered to be snow that is falling at more than 12 mm (0.5 inches) per hour.

Recommended treatments are provided in the tables for each of the six Weather Events

Treatments recommended in the FHWA guide include plowing, initial application of material, and subsequent application of material. The guide is intended for anti-icing only and therefore does not include conditions with existing snowpack. The recommended dry material is rock salt. Solution used for direct application or for pre-wetting the dry salt includes NaCl, $MgCl_2$, $CaCl_2$, KAc and CMA. Properties of these materials are compared in the text but no recommendation is made as to which should be used under the tabulated conditions.

Recommended material form includes two or three options (dry, pre-wet, solution) under some environmental condition classes, and recommended application rates in many cases include a range rather than a single value.

3.1.4 Comparison of SNRA Expert System and FHWA Anti-icing Manual Approaches

The SNRA and the FHWA systems are based on the same general types of inputs.

The differences between them are largely a matter of detail as opposed to principle. The FHWA system is event-based as, to first level, it recommends actions for six generic types of Weather Events. Within the context of a particular Weather Event, actions are next defined with respect to the pavement temperature and its trend.

In contrast, the SNRA system recommends actions to a first level based on whether or not precipitation is occurring, and whether or not precipitation is forecast to occur. Actions are further specified with respect to the current and forecasted pavement surface condition, and the current pavement temperature.

The two systems are similar in that they both recommend actions for different forms of salt. However, the SNRA system differs from the FHWA one in that it only specifies one application rate for each salt material whereas the FHWA tables specify a range of application rates. The SNRA system specifies application rates for much narrower pavement temperature ranges than does the FHWA one.

3.1.5 MTO

The FHWA Manual of Practice was considered for implementation by MTO in 1996 but could not be used directly for three reasons:

a. the detailed tabular format is too complex for field operations
b. the recommended treatments for many of the weather conditions include a wide range of application rates and more than one choice of salt form (eg, dry salt vs pre-wetted salt vs brine); field staff require specific instructions which would include a single material and application rate for a given weather condition
c. the recommended treatments did not include road weather conditions at temperatures colder than -10^{o}C or snow-packed conditions.

The De-icing Anti-icing Response Treatment (DART) program was developed address these problems. Its purpose was to adapt the FHWA manual to a computerized format and to evaluate the effectiveness of the recommended treatments. The first stage of this project involved transferring the FHWA tables to a database format using Microsoft Access and converting all units to metric. This is essentially an automated look-up table using boolean logic with formatted input and output screens. These are (Appendix B):

i. a data entry screen
ii. a recommended actions screen
iii. an archiving screen.

The data entry screen is a pro-forma in which the operator types or selects from pull-down menus, current and forecast weather and traffic conditions required for material selection. The recommended actions screen displays the type and quantity of chemical which should be spread. The archive screen allows users to save the input conditions, the actions taken, and to key in observed results of the operation. This information can be used at a later date to track the effectiveness of the recommended actions and to revise the tables. System operation is described in Appendix B.

Three versions have been produced. Version 100 (which was written in Access 2.0) was mainly derived from the FHWA anti-icing tables with several modifications and extensions to fill gaps in the FHWA tables. The recommended actions screen presents a range of application rates and materials for each weather condition as in the FHWA tables, and does not include material applications for temperatures lower than -10°C or for snowpacked roads.

Version 200 (which was written in Access 2.0) includes material applications for any temperature condition and for snowpack (de-icing). Conditions outside the FHWA tables are based on standard MTO practices using dry salt and abrasives (MTO, 1999). Version 300 (which was written in Access 97) was developed to assist in MTO's field evaluation of recommended actions. Where a range of materials or application rates are recommended these are presented separately as the low, mid and high end of the application rate range, and an associated text box shows the spreader control settings required to achieve these rates for the recommended material. The settings are specific to the spreader vehicles and routes used in the MTO tests and are not applicable elsewhere.

All versions are password protected at two levels. The lower level provides access to the run-time version with complete operational functionality. The higher level provides access to the tables and boolean logic and permits changes to be made to the application rate tables and formats. The higher level access is retained by MTO and the software developer. The run-time version of DART300 has been provided to members of Aurora.

DART is a stand-alone program which can run on any PC with Microsoft Access. Integration with MTO's RWIS is planned at a later date.

3.2 MTO Evaluation of Recommended Application Rates

The actions recommended in the FHWA anti-icing manual are not well defined in a number of cases. For a single environmental condition, more than one material (i.e.,sodium, calcium or magnesium chloride) or phase (i.e.,dry, pre-wet or liquid chemical) and a range of application rates may be specified. While this provides flexibility and adaptability to various agencies and to different levels of service it is not useful for operations personnel who desire clear, specific instructions.

A study was begun by MTO in 1996-97 to evaluate the effectiveness of the recommended applications and to identify the specific material and application rate which is most effective under each environmental condition (Perchanok, 1999). This required the identification of objective and repeatable data collection methods and measures of performance. As measures of performance were not known at the outset, data collection methods were used which could provide various different measures.

Evaluations were conducted during every winter storm event on a dedicated, 15 km stretch of in-service highway since 1996-97 and this will continue in 2000-01. The highway section is equipped with an ice detection sensor station and RWIS forecast provided by a weather service, time-lapse surveillance cameras monitoring the highway surface at several locations, and a mobile data collection system consisting of a van equipped with a video camera, Global Positioning System(GPS) and infra-red thermometer, and towing a variable-slip friction trailer (Perchanok, 1999). Spreader vehicles are equipped for application of dry, liquid and pre-wet materials at several application rates, and with Automatic Vehicle Location systems (AVL) based on either distance travelled from the patrol yard or on GPS position. A system of test stations and protocols is in place in which each material application is a comparison of different materials at the same application rate, or the same material at up to five different application rates. Road conditions are measured using either video (% cover across the pavement at each test station) or friction (average sliding resistance in 300 m long sections at each test station) prior to each material application and at regular intervals of either 5 minutes (video) or approximately 30 minutes (friction) until bare pavement is reached or until the next application.

Each material application in each test section is classified as an event. 12 test stations are available although material applications are not unique at every station. Approximately 700 events have been acquired to date. Three measures of effectiveness have been defined for testing purposes:

(a) elapsed time between material application and bare pavement (defined as 10% snow cover)
(b) rate of clearing (rate of change of snow cover from time of material application until snow cover is 10%)
(c) binary measure where effective is defined as: snow cover is reduced between t_0 and t_x, where t_0 is time of material application and x is 30 minutes, 1 hour, or 2 hours.

Comparisons should account for differences between test cases due to: air or surface temperature, drifting, initial snow cover, traffic, sunlight and prior applications or retention of salt on the surface between applications. Variables have been introduced to account for each of these. Study variables are defined in Appendix C.

Two types of analysis have been used thus far; sorting of data into similar conditions, and multi-variate linear regression. Sorting analysis is a more straightforward approach but requires a large database because sorting into similar conditions for several variables results in small samples for each relevant action. Sample results from sorting analyses are shown in Appendix C for dry salt, pre-wet salt and salt/sand mixes. This analysis will be completed after data collection during winter 2000-01.

3.3 Feasibility of Integration with RWIS

Inputs required by DART are based on the approach used by FHWA in developing material application tables for anti-icing. This classifies road weather conditions into six different storm types, and for each storm type into ranges of surface temperature, temperature trends, relative humidity, snowfall and traffic. The required input is not limited to the types of information normally provided by RWIS.

Integration of DART with RWIS may require changes to weather condition classification to correspond with information types which are available from RWIS. A survey was carried out to compare the outputs available from various RWISs with the inputs required for the DART program. The full report is presented in Appendix D. The conclusions are:

(a) <u>defining the weather event, or type of precipitation</u> - none of the RWISs provide the required output directly. However, this discrepancy could be resolved relatively simply. Furthermore, the information available from RWISs, in combination with weather forecasts, would allow a wider range of cases to be considered by DART.

(b) defining the current and forecast pavement temperature – these are provided by RWISs in combination with forecasts.

(c) defining the current and forecast dew point – these are provided by RWISs in combination with forecasts.

(d) defining the pavement surface condition – none of the RWISs provided all of the required information although they all provide part of it. None of the RWISs could identify slush, or packed snow.

(e) defining the traffic volume - this is not part of current RWIS systems. However, it was generally felt that this capability could be added relatively simply. One RWIS manufacturer cautioned that it might be advisable to collect this information separately because often, traffic counters are not located in optimal locations for RWIS systems.

(f) defining the snow accumulation on the road – this information is not available from any of the RWIS systems although some provide forecasts of snow accumulation vs time, or measurements made at other locations. One RWIS manufacturer cautioned that relevant data (obtained on roads where traffic flows occur) would be very difficult to obtain.

(g) defining the snow type (i.e., "heavy" versus "light" based on the snowfall rate) – this was not available from all systems. However, it was generally felt that this capability could be added with relatively little effort.

(h) integrating DART with RWIS systems – this has only been investigated in a preliminary manner. It appears that it would be possible to accomplish this automatically, and one RWIS manufacturer provided a sample input data file that might be used as an input. More work is required before definitive statements can be made.

4. CONCLUSIONS AND RECOMMENDATIONS

SNRA and FWHA took similar approaches to classifying environmental conditions for material application. The six storm types subdivided by temperature, snow fall and dew point conditions in a computer-based decision support system at MTO.

Continuing work at MTO has the objective of measuring the effectiveness of alternative material application guidelines to determine which ones are most effective under each of the environmental classifications. Data collection methods have been developed, objective measures of performance have been defined and analysis is under way. Completion of the analysis is planned for the summer of 2001.

An alternative approach is being used by VTI, where a knowledge base is being constructed of application guidelines used by operational staff, and confidence will be determined by the degree of similarity among knowledge sources.

Both MTO and VTI plan to integrate decision support systems with existing RWIS. In the case of MTO this will require changing some of the input parameters for DART or output from RWIS. One parameter, snow accumulation on the road, cannot be provided by any available RWIS. A new sensor or method of estimation will have to be developed, or the program logic changed so that snow accumulation is not required. The preliminary analysis indicates that initial snow cover is a very important parameter.

The current version of DART, like the FHWA study, specifies more than one material and application rate for many environmental conditions. Once the data analysis is complete a single material and rate should be specified, and the recommended actions screen simplified. The current version includes spreader control settings specific to MTO test conditions. This feature should be made adjustable by each user as spreader settings are unique to each piece of equipment and material.

Integration of DART with RWIS is a system-specific process which requires close liason with the RWIS software and forecast vendors. It is recommended that this be undertaken by MTO with the current version of DART to provide a case study and that experience gained be shared with other agencies.

5. REFERENCES

Axelson, M. and A. Malmberg, 1991. Expert-System Based Road Salting; A Preliminary Study and Prototype. Publication No. 1991:41, Production Division, Swedish National Road Administration, Borlange. (Translated from Swedish by R. V. Wahlgren, Atmoswater Research, for Ontario Ministry of Transportation).

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MTO, 1999. Maintenance Manual. Maintenance Office, Ontario Ministry of Transportation, St. Catharines, Ontario, Canada, May, 1999.

Perchanok, 1999. Evaluation of RWIS and Anti-icing at the Maintenance 2001 Test Site. Presented at TRB Annual Meeting, Washington, January 1999.

APPENDIX A:

File List

A. English Translation of "Expert-System Based Road Salting; A Preliminary Study and Prototype"

- SNRAtranslation.pdf
- App E_SNRA Rules.doc

B. DART Technical and Operating Guide

- DartV1Ss.pdf (version 100 screens)
- DartV2Ss.pdf (version 200 screens)
- DartV3Ss.pdf (version 300 screens)
- operating notes (folder of 4 files in .rtf format)
- technical basis (folder of 5 files in .rtf format)
- actions log.doc

C. Sample Evaluation of DART Recommended Actions in MTO Maintenance 2001 Project

- explain.doc (variable definitions for main analysed database 1996-2000)
- explain SCinit.doc (variable definitions for sorted database, 1999-2000 only)
- Appendix C.doc (preliminary analysis of 1999-2000 data)

D. Feasibility of Integrating DART with RWIS

- report.doc (work task report by Fleet Technology Limited)

Vägverket (Swedish National Road Administration)

Authors:
Lennart Axelson
Åke Malmberg

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A PRELIMINARY STUDY AND A PROTOTYPE

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EXPERTSYSTEMBASERAD VÄGSALTNING

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Fleet Technology Ltd.
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1999

Bygg– och Driftproduktion (BDd)
(Production Division)

FIELD OF ACTIVITY: WINTER ROAD MAINTENANCE
PROJECT NAME: VVEXP
PROJECT MANAGER: LENNART AXELSON, BDd
PROJECT LEADER: LENNART AXELSON, BDd Tel 0243-754 33

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LIST OF ANNEXES

SUMMARY

Salting of roads with high average daily traffic is done today in most parts of the nation. Decisions as to salting and scope of the work are made by a road contractor who has responsibility for winter road maintenance in a road district. Decisions are based on data from the road weather information system (RWIS, Swedish initials VVIS), the contractor's observations and own experience.

To support decision-making, the knowledge a contractor uses in interpreting RWIS data is loaded into an expert-system. The expert-system bases its suggestions on data from the RWIS, answers to questions posed to the user, together with processing assisted by the imbedded knowledge-base. The system is a prototype and will, together with a preliminary study, provide a decision-base for further development of technical knowledge within the Swedish National Road Administration (SNRA) with respect to winter road maintenance.

The preliminary study shows that a knowledge-system can be used for decision support in the context of winter road maintenance. The prototype can, through limited further development, be used next winter in parallel with existing systems and be evaluated in actual operating conditions.

New sensors for the measurement stations can be developed and thereby relieve users of manually collecting data. The knowledge-system can in the future obtain meteorological information directly from the Swedish Meteorological and Hydrological Institute's (SMHI) computer system and by interpreting weather radar images.

1 INTRODUCTION

In the type of software called expert-systems, one tries in a simplified manner to model human experts' ways of solving problems. One makes use of expert knowledge within a defined field to solve problems with various logical methods.

This preliminary study of an expert-system for winter road maintenance has focussed on finding methods for coordinating road weather information system (RWIS) data and human expert knowledge with rules in the software. These rules can later be refined as the system is used.

1.1 Goals

Build a functioning prototype of a expert-system which assists in deciding when salting should commence. The system should advise timely action (starting time for salting). The system should even recommend salt quantity in g/m^2 and width of the application. The prototype will be used as a decision-base for possible further work with expert-systems.

1.2 Organization and schedule

The preliminary study was carried out as a project with the following participants:

Jonny Karlsson	VFX, Söderala Work District
Jörgen Gustafsson	VFE, Kisa Work District
Peter Eriksson	SNRA Production Division
Jon-Olav Upsal	SNRA Production Division
Åke Malmberg	Österstund Technical Institute, responsible for design
Inge Nordbø	SINTEF*, Trondheim
Lennart Axelson	SNRA Production Division, project leader

90-06 to 90-09	Theoretical knowledge-base gathering and modelling
90-10 to 91-03	Field studies, two or three work districts
91-04 to 91-05	Modelling
91-06	Final account

For detailed schedule see Annex 1.

* [SINTEF is the Norwegian acronym for The Foundation of Scientific and Industrial Research at the Norwegian Institute of Technology. Trans.]

2 STRATEGY

2.1 Planning

Personnel were allocated to the project from the Swedish National Road Administration (SNRA), the Östersund Institute of Technology (HÖS) and SINTEF in Trondheim. Two research areas, Söderala and Kisa, were designated by SNRA. The project schedule is given in Annex 1. The strategy can be roughly divided into an engineering knowledge acquisition phase, modelling, implementation, and validation.

2.2 Knowledge Acquisition (KA)

Knowledge acquisition took place through education, interviews, meetings with experts, and a literature review. The interviews were done through active participation in the field at the two research areas under real weather situations. The field studies took place during November to December 1990. During the field interviews and meetings with experts, a tape-recorder was used for documentation. The meetings with experts took place in undisturbed settings away from the regular work-place and took from one to two days. A more detailed description of the elements of knowledge acquisition is presented in Annex 3.

2.3 Modelling

Knowledge acquisition is an iterative process. It is therefore necessary to represent in some form the knowledge that has been gathered to allow the experts to verify that the model agrees with reality. This process can take several iterations before the model is acceptable. To represent the model, the Systematic Grammar Network (SGN), Annex 13, was used. During the modelling phase it became obvious that the knowledge-base should be divided into modules (Annex 12). The model was thus divided into pavement weather, atmospheric weather, pavement condition, detection, event recorder, and remote processing unit (RPU) station modules. In the pavement condition module the pavement condition is determined now and in two hours from input for precipitation and temperatures. The detection module decides which treatment should be recommended from the variables like pavement condition, temperature and precipitation. The event module gives a translation of treatment action codes to a more descriptive text and the RPU station module gives a translation of station codes to names and road numbers. The remaining modules are required for technical programming reasons and do not carry out actual processing. The knowledge-base in this prototype comprises a bit more than one thousand (1000) rules.

2.4 Implementation

The choice of tool (Nexpert Object) was done without any formal survey of systems available in the market. The goal set for the project was to construct a prototype and the tool used for constructing the prototype need not necessarily be the same as the one in an actual production version. So as not to waste valuable time in an evaluation, a tool was chosen which some of those involved in the project had experience with. The demands on the tool were as follows:

- development should be possible on powerful work-stations

- the target system shall be possible to implement in the PC-environment
- the system should be able to be used in the UNIX, DOS, and VMS environments
- the development platform should be mobile between different computer architectures

One of the goals set for the prototype was that it should be able to be evaluated under realistic conditions in the field. To accomplish this a shell has been developed (C) around Nexpert Object. This is to shield the inexperienced user from the Nexpert environment.

During field operations there is likely to be limited time to answer questions and experiment with the system. The shell has therefore been designed to relieve the user as much as possible of the need to answer questions. The system gathers continually data via serial ports and presents results on the user's video terminal. Processing takes about 5 seconds. In the first version, the VAX-based RWIS system has been replaced by a PC (PC-VAX).

A simple protocol has been defined for communication between the expert-system and the RWIS, or between the expert-system and PC. The protocol is described in Annex 4. In the protocol, consideration has been given to the possibility that communication with the RWIS might be done via terminal switches with unforeseen specifications. All characters that are transmitted belong to one of the groups: numerals, letters, or delimiters. No control characters are used. The only verification of correctly received blocks is the length of the block.

2.4.1 PC Architecture

The PC system can be divided roughly into three parts:

- Knowledge-base (KB)
- Nexpert Object routines
- Shell

The knowledge-base has been divided into modules using the reasons applied during modelling. The following modules have been defined:

- classes	(vv_c)
- pavement weather	(vv_y)
- atmospheric weather	(vv_l)
- pavement condition	(vv_v)
- detection	(vv_d)
- events	(vv_f)
- RPU station	(vv_m)
- common rules	(vv_r)

The knowledge-base modules are described in Annex 12.

Nexpert Object runs normally in Windows 3.0. In the prototype a library of Nexpert Object functions is used. The same functions that are in Windows 3.0 are accessible by calling functions in the library. Nexpert's inference engine starts up as a server and runs independently of other activities in DOS. The server uses enhanced memory and does not present a load to the DOS environment. For reliable operation the computer should have at least 4 Mb of RAM.

The shell (VVEXP) was written in C (MS 5.0) to be compatible with Nexpert's function library. VVEXP is in a continuous loop involving data input via serial ports, building objects in the Nexpert environment, processing and presentation of results. VVEXP's structure is described in Annex 5.

2.4.2 VAX Architecture

The RWIS data is represented in VAX VMS as a database (RDB). In the VAX- environment software (COBOL) has been developed to extract desired measurement data from the database and send it to the VVEXP shell. Annex 6 describes the VAX program structure.

2.5 Validation

It is extremely important that the expert-system contains a correct knowledge-base. To validate this, an emulation program was designed for the PC. By using a PC (PCVAX) to emulate the VAX system during trials, arbitrarily chosen measurement values can be transmitted from the PCVAX to the the expert-system. The results can be reviewed later without time constraints. VVEXP logs in a file all incoming data and conclusions drawn. The file can be used to advantage to validate the knowledge-base. A short description of the PC-VAX software is in Annex 10.

3 DEVELOPMENT

The preliminary study and prototype have been put forth as the basis for decisions about further developments with expert-systems in the SNRA.

3.1 Concluding prototype development

The prototype has in its present version been designed to communicate with a PC which emulates a VAX as described earlier. The communications protocol allows, however, connection to a VAX system without any changes. The addition of the shell to Nexpert Object is necessary so that users are given the opportunity to answer questions about the pavement condition and precipitation forecasts. It is desirable that the user not have to answer more questions than necessary so the shell should therefore work with answers to earlier questions as long as the present conditions remain unchanged. Field data from the RPU stations is continually being received via the serial ports. The lead time for the addition of the shell should permit the system to be used under realistic conditions during the winter of 91/92. VVEXP can be placed to advantage in those highway districts that were test districts and run parallel to the regular decision-support systems. After the winter season, these test districts can be evaluated.

3.2 Possible development into a production system

The knowledge-base is in its present form only complete for the highway districts that were involved in the project. With development of the production system, the knowledge-base should be supplemented with information specific to highway districts throughout the nation. The prototype contains knowledge for processing information from one RPU station at a time. By studying several RPU stations simultaneously, knowledge about a weather system's path can be obtained. It should later be possible to forecast with good precision the weather at stations in the weather system's trajectory. Meteorologists' knowledge about the weather situation should also improve the system. Forecasts from the Swedish Meteorological and Hydrological Institute (SMHI) can simply be manually input but an automatic link between computer systems would be more effective.

3.3 Graphical representation

Presentation of results from the system prototype are in the form of text messages to the user. Graphical displays are now available on the market and have been tested at SNRA in other contexts. Output from VVEXP could be directed to a graphical display in the form of a regional map. Highway sections could be marked in different colours indicating the various levels of action that are required.

3.4 Field data collection via vehicles

Telecommunications is evolving at a fast pace. There are no technical restrictions to equipping SNRA's vehicles with sensors and communication equipment for transmission of field data via radio. The telephone company offers "mobitex" and packet-radio. In both cases, a protocol guarantees error-free and reliable transmission. When the vehicle is out of the radio range, communication reverts to standby mode and as soon as the vehicle is within range stored information is transmitted.

3.5 Direct control of salting

A highway section is presently salted with constant flow for the entire section. Through climate mapping there exists information about variations within a section. Through the same type of radio-link as described earlier, control of the salt truck's flow is processed by a computer in the highway district and variable salting of the highway section is accomplished. This method requires that the truck be equipped with a position-finder.

3.6 New types of sensors

It is desirable that the user is freed from manual input of field data and the need to answer questions. New sensors can be developed which will relieve the user from reporting in. An example of such a sensor is one reading the amount of salt on the road surface.

3.7 Statistical analysis of earlier situations

By analysing data from previous years, the probability can be calculated that a certain weather situation will occur provided that given conditions are met. An effort to forecast local weather is described in Annex 14.

3.8 Feedback of results

An important part of the system's development should be that experiences of results from inputs to the system when in use be fed back to improve system proficiency.

4 CONCLUSION, HOW DO WE PROCEED?

To suggest future uses we should define the concept of an expert-system. Edward A. Feigenbaum of Stanford University stated that an expert-system is an intelligent computer program that uses knowledge and deductive procedures for problems that are difficult enough to require significant human expertise for their solution. The required proficiency for performance at this level together with using deductive procedures can be thought of as a model of the leading specialists in the field.

The expert-system in the highways department can therefore give:

- support and help in difficult situations, there is "someone" to ask. This is especially applicable to new inexperienced staff.
- one doesn't lose expertise when someone resigns, expert knowledge is not bound, in the same way as now, to one specific person.
- one has use for an expert-system in all fields, wherever one has need of experts.

Some concrete examples:

- construction, e.g. in winter.
- maintenance activities, e.g. bridge repairs.
- traffic control/monitoring
- sorting and evaluation of incoming data to Regional Centre (RC)
- education in all fields
- interpretation of camera images to decide, e.g. wear, texture, friction and standards.

It is nevertheless important that an expert-system not make the user passive. In the same way that one gains knowledge from human experts, one must gain knowledge from the computers. Therefore, it has to be possible to have a dialogue with the computer and ask why the computer gives this particular recommendation or answer to a specific question. In the same way that we today question recommendations from human experts, in different parts of production, construction, and operation, expert-systems will, in the near future, be a natural and self-evident assistant to optimize the enterprise. In the first instance there are various detailed parameters that need to be evaluated before decisions can be made. Therefore, a continuation of expert-system development, especially in winter road maintenance, should give us competence and experience for further development in other fields.

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Schedule

1 Formalities

1.1 Contract with Östersund Technical Institute (HÖs)
1.2 Contract with SINTEF
1.3 Project and schedule

2 Development environment

2.1 Installation and preparation of MAC-environment tools
2.2 Test and transfer of knowledge-bank between MAC and SUN environments

3 Contact activities

3.1 Contact with field personnel
3.2 Project meeting with field personnel in attendance

4 Operating environment

4.1 Installation and preparation of tools in the PC-environment

5 Knowledge acquisition

5.1 Education in winter road maintenance
5.2 Field studies in two work areas

6 Knowledge modelling

6.1 Structuring knowledge
6.1.1 Draft model
6.1.2 Conceptual model
6.1.2.1 Object model
6.1.2.2 Rule model
6.1.2.3 Problem solving model
6.2 Development of demonstration model

7 Demonstration

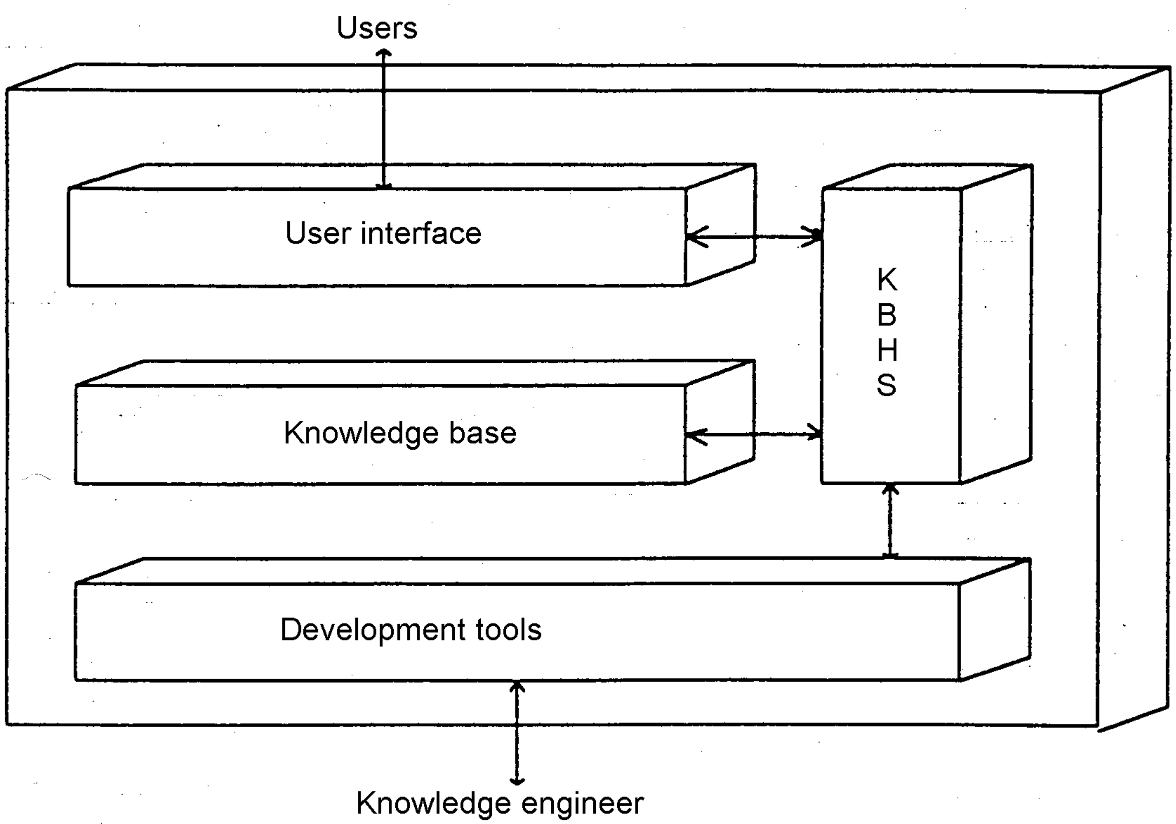
7.1 Demonstration for SNRA's personnel

8 Evaluation

8.1 System in operating tests in the field

Activity	Planned	Start	Complete	Comments
1.1	90-07-01	90-07-01	90-08-04	
1.2	90-07-01	90-07-01		
1.3	90-08-13	90-08-20		Revised continuously
2.1	90-08-13	90-07-04	90-08-31	
2.2	90-08-27	90-09-01	90-09-20	
3.1	90-08-20	90-08-20	90-08-22	
3.2	90-09-20	90-10-02	90-10-02	
4.1	90-10-01			
5.1	90-09-24	90-09-24	90-09-28	
5.2	90-11-01	90-11-14		Prelim. up to and including March 91
6.1.1	90-10-23	90-10-23		
6.1.2.1	90-11-23	90-11-23		
6.1.2.2	91-01-15	91-02-01	91-05-01	
6.1.2.3	90-11-23	91-02-01	91-05-01	
6.1	90-11-01	90-11-23		
6.2	91-03-01	91-05-01	91-06-15	
7.1	91-05-31	91-06-24		
8.1	91-06-01			Preliminary Fall 1991

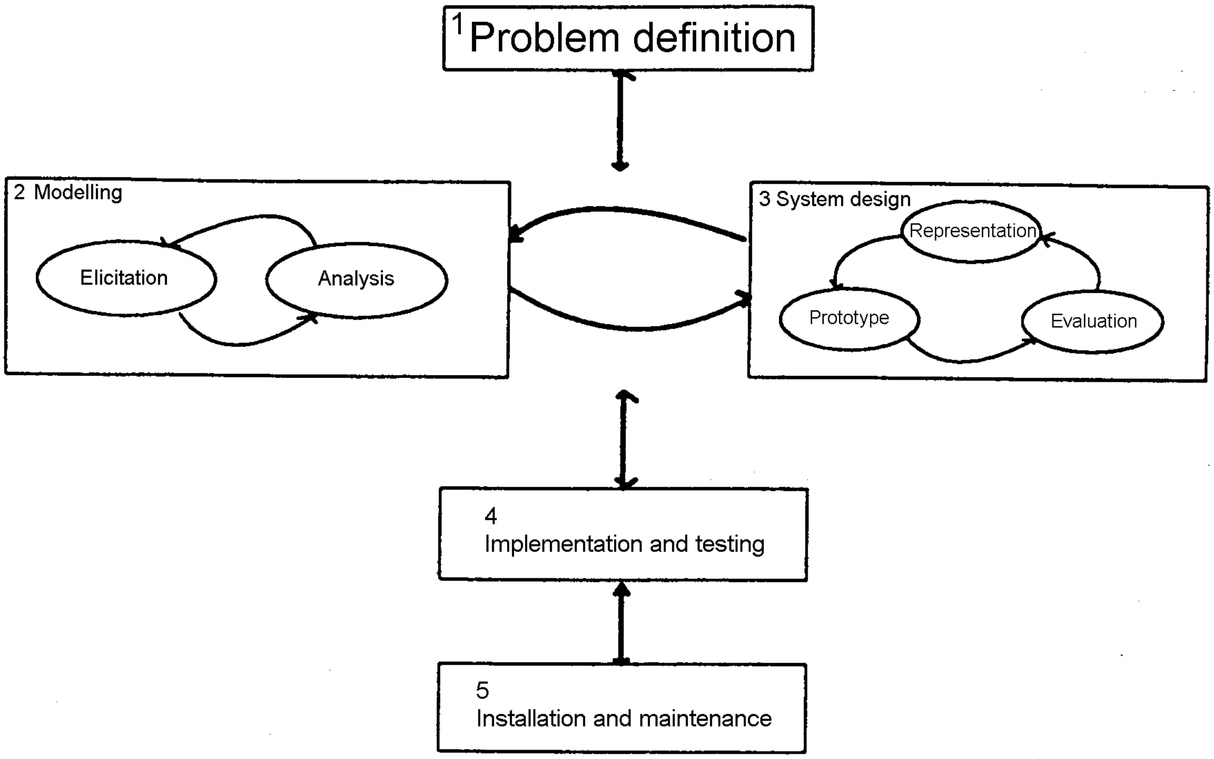
Expert-system - schematic



Explanations

Interface	The user interface is found in all shells. This is to relieve the system developer from the burden of designing the interface themselves. The interface makes it possible, in most cases, to be independent of the applications or information underlying the shell.
KBHS	Knowledge Base Handling System is the mechanism that carries out the processing. Rules and facts in the knowledge-base are combined to find the answer to the question that is posed (the hypothesis).
KB	Knowledge Base contains the rules and facts that are embedded in the shell. The knowledge-base is the only part of the system which is specific to an application.
Development	Development assistance is an interface for the system developer. The interface is usually graphical so as to clearly show the designer the rules, classes, and objects. Tree structures show relationships clearly. Tools are also included to verify that the knowledge-base does not contain contradictions or circular reasoning.

Knowledge Acquisition



Explanations

Knowledge Acquisition	The process of collecting and analysing knowledge with the goal of developing a knowledge base.
Elicitation	Knowledge tapping: Can consist of interviews, somebody solves a problem “out loud”, machine learning or grids. The Knowledge Engineer (KE) constructs a “mental” model.
Analysis	KE constructs a “rough draft model”. This is used to construct a conceptual model. The latter is a more formal description of knowledge than the former.
Implementation	Knowledge is represented by a machine-internal model.

VAX-PC Communication

Communication between VAX and PC occurs via the RS232-C interface and a simple protocol. Fig. 1 shows the VAX side of the protocol and Fig. 2 shows the PC side. In the present implementation ACK is set to the character “%” (hex 25) and NACK to “&” (hex 26). Allowable characters over the communications link are ASCII characters in the interval hex 20 to hex 7F.This is because control characters or ASCII characters greater than 7F can influence communications equipment in the network.

There is no verification of received blocks in the form of checksum calculations. If the block length does not agree with expectations, however, the data in the block are regarded as erroneous and the block is eliminated. No re-transmission is requested but the next block is read and handled. Since the transmission from the VAX-system occurs from a looped file the block appears again with the same or updated contents.

Sensors for precipitation forecasts (ndb_p) or real-time pavement conditions (vaglag_nu) are not incorporated into the present RPU stations. The user therefore answers questions where these variables are specified. During communication with the VAX system the user is prompted for these values for each RPU station upon start-up. When field data for the station is reported again the user needs only answer questions if any of the values input earlier do not agree with the real values for *ndp_p* and *vaglag_nu*. These values change rarely and the users need only check the information on the video screen at regular intervals to see if changes are required.

During validation of the knowledge- base it is necessary to test by sending a block of arbitrary data from a PC (VAX-PC) that emulates the VAX system. The user fills in a form in a window on the screen with those values which represent a reading from a RPU station. In the window, the user is even required to fill in a field (ndb_p and vaglag_nu) which in normal operation are not included in the field data from the VAX system. The protocol therefore allows two types of blocks, a shorter one without *ndb_p* and *vaglag_nu* and a longer one where these fields are included. The receiver recognizes which block length is being used and adjusts questions to the user as appropriate.

Field types

If not otherwise stated, fields are right justified. Padding to specified character length is by blanks (hex 20).

INTEGER	String of numbers with possibly a sign. Represents integers.
REAL	String of numbers with possibly a sign. Represents real values which are obtained by dividing the character string’s value by 10.
STRING	Can contain all characters that are allowed in a block.

Block types

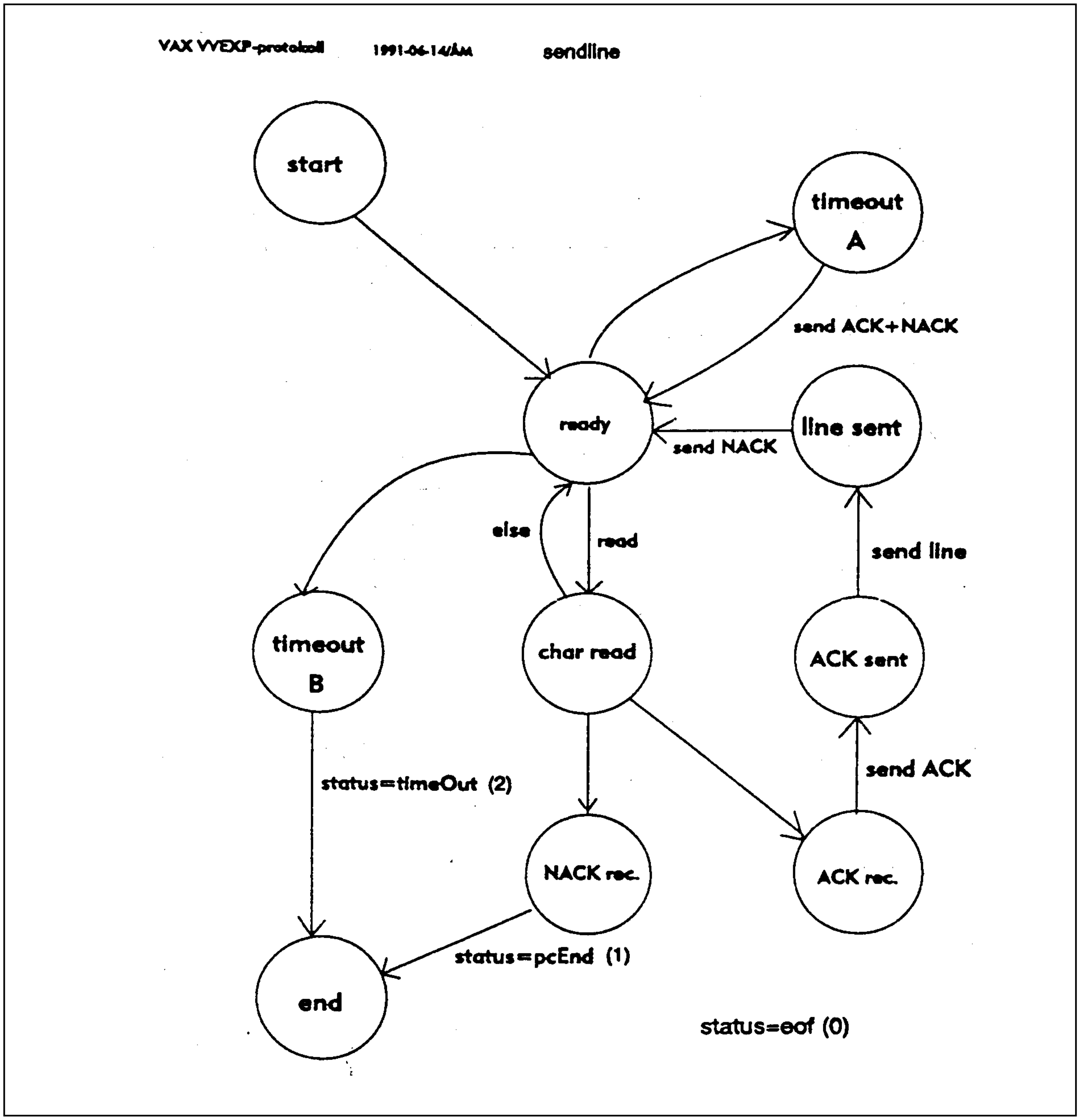
Type	Use
1	Transmission from VAX
91	Transmission from PC emulating VAX

Description of block type 1

Field number	Field name	Start position	End position	Type	Field Name (English)
1	typ	1	2	Integer (=1)	type
2	mstn	3	7	String, left justified	RPU station
3	dat	8	15	Integer	date
4	tid	16	19	Integer	time
5	tyt_m	20	23	Real	pavement temp (measured)
6	frys_temp	24	27	Real	freezing temperature
7	dt_m	28	31	Real	dewpoint (measured)
8	tlu	32	35	Real	air temperature
9	ndb_mstn	36	36	String	precipitation at station
10	lu_fu	37	38	Integer	air humidity
11	virik	39	40	String	wind direction
12	vimax	41	43	Integer	wind speed, maximum
13	vimed	44	46	Integer	wind speed, average
14	vars	47	48	String	system message
15	mstn_fel_kod	49	52	Integer	station error code
16	tyt_p	53	56	Real	pavement temp (forecast)
17	dt_p	57	60	Real	dewpoint (forecast)

Description of block type 91

Field number	Field name	Start position	End position	Type	Field Name (English)
1	typ	1	2	Integer (=91)	type
2	mstn	3	7	String, left justified	RPU station
3	dat	8	15	Integer	date
4	tid	16	19	Integer	time
5	tyt_m	20	23	Real	pavement temp (measured)
6	frys_temp	24	27	Real	freezing temperature
7	dt_m	28	31	Real	dewpoint (measured)
8	tlu	32	35	Real	air temperature
9	ndb_mstn	36	36	String	precipitation at station
10	lu_fu	37	38	Integer	air humidity
11	virik	39	40	String	wind direction
12	vimax	41	43	Integer	wind speed, maximum
13	vimed	44	46	Integer	wind speed, average
14	vars	47	48	String	system message
15	mstn_fel_kod	49	52	Integer	station error code
16	tyt_p	53	56	Real	pavement temp (forecast)
17	dt_p	57	60	Real	dewpoint (forecast)
18	ndb_p	61	70	String	precipitation (forecast)
19	vaglag_nu	71	80	String	real-time pavement condition



VAX VVEXP-protokoll
1991-06-14/ÅM
sendline
start
timeout A
send ACK+NACK
ready
line sent
send NACK
else
read
send line
timeout B
char read
ACK sent
status=timeOut (2)
send ACK
NACK rec.
ACK rec.
status=pcEnd (1)
end
status=eof (0)

Fig. 1

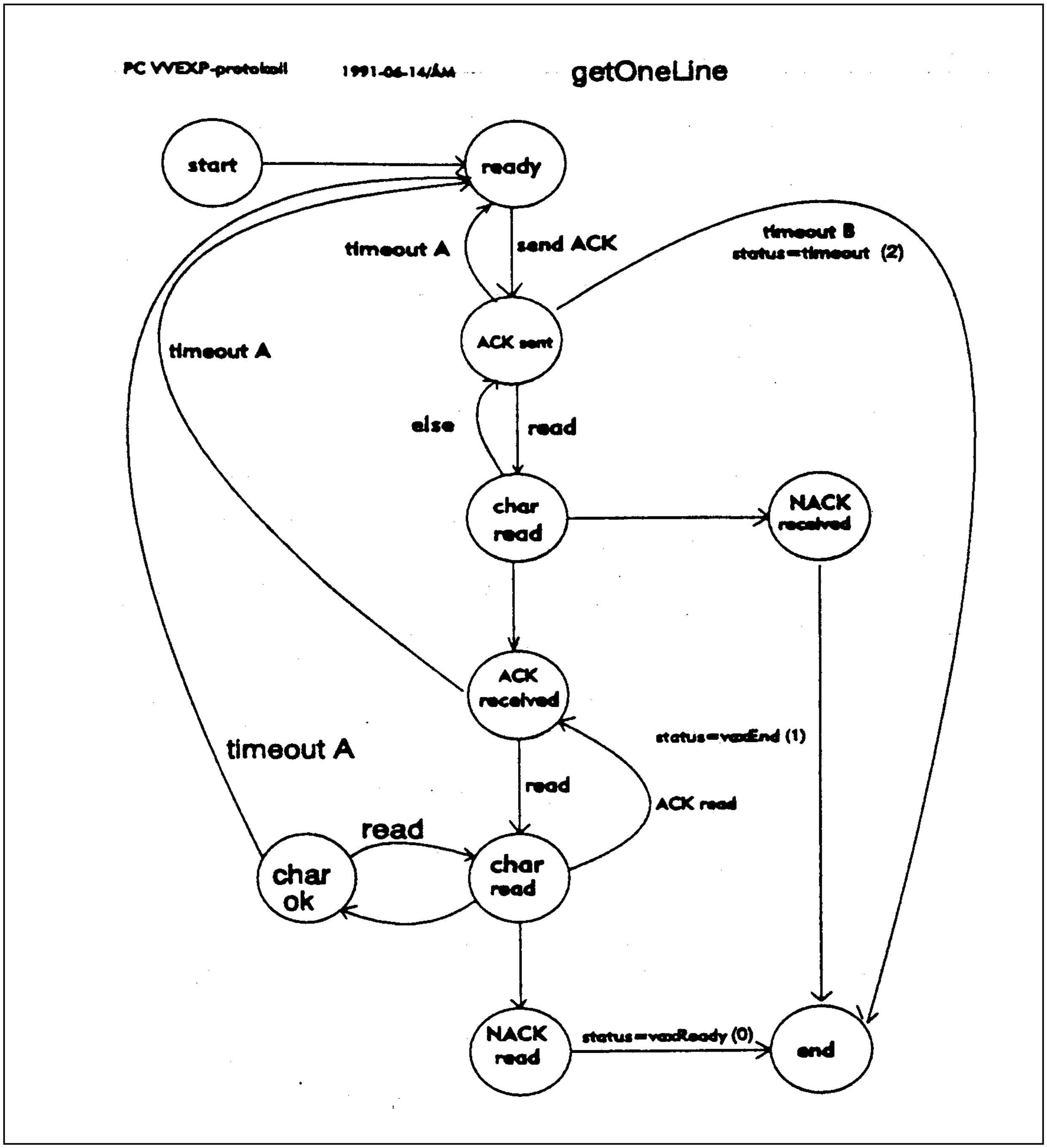
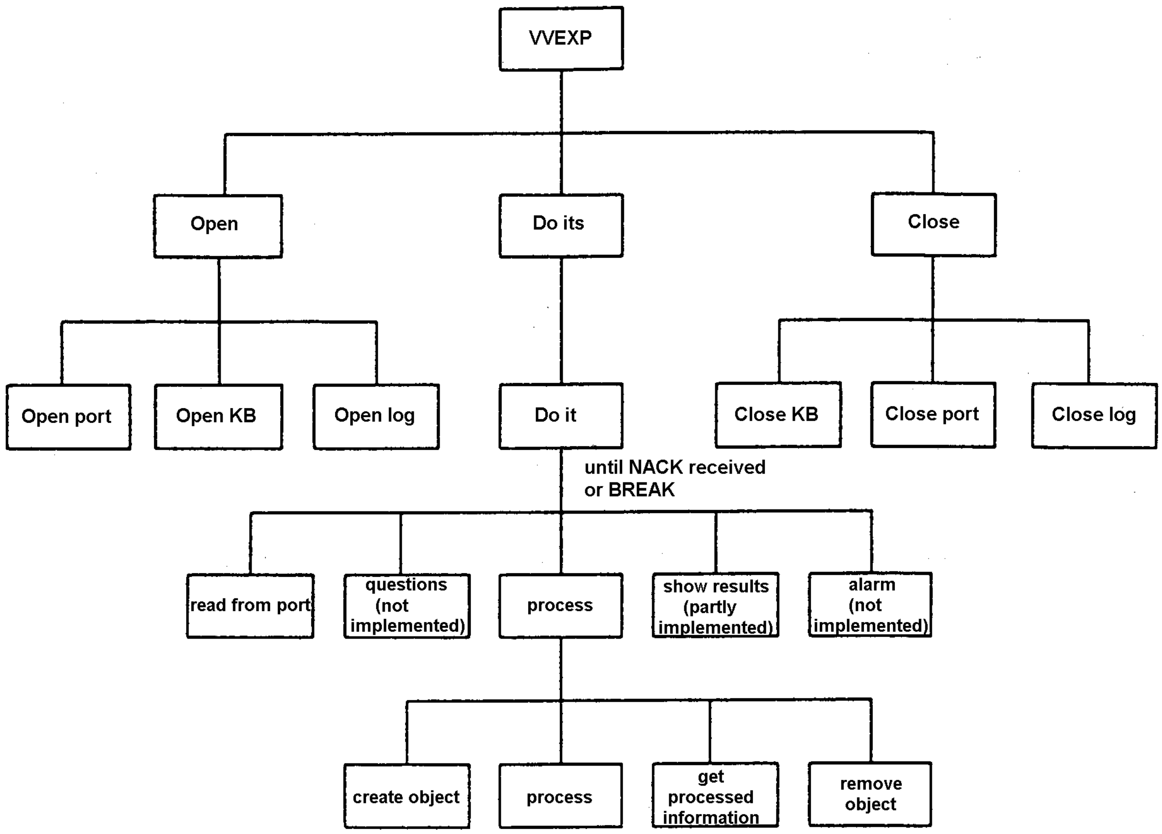

PC VVEXP-protokoll
1991-06-14/ÅM
getOneLine
start
ready
timeout A
send ACK
timeout B
status=timeout (2)
ACK sent
timeout A
else
read
char read
NACK received
ACK received
status=vaxEnd (1)
timeout A
read
ACK read
read
char ok
char read
NACK read
status=vaxReady (0)
end

Fig. 2

PC-system Structure



Explanations

The expert-system, VVEXP works in the present version with one RPU station at a time. Measured values, forecast values for precipitation (ndb_p) and current pavement condition (vaglag_nu) are received by the serial port from a PC simulating the VAX-system. The protocol is the same as for connection to a real VAX-system, but in the latter case neither ndb_p or vaglag_nu are accessible from the measurement station but the user must instead answer questions about those variables. The function “processing” in the flowchart calls a C-library with functions that give access to NEXPERT OBJECT outside the usual Windows 3.0 development environment.

KB = knowledge-base

VAX-system Structure

The VAX-system can operate in two modes:

1 Read RPU station values from the RWIS data base (RWIS-DB) in real-time (see Fig. 1).

2 Read RPU station values which have been loaded from a data centre (see Fig. 2).

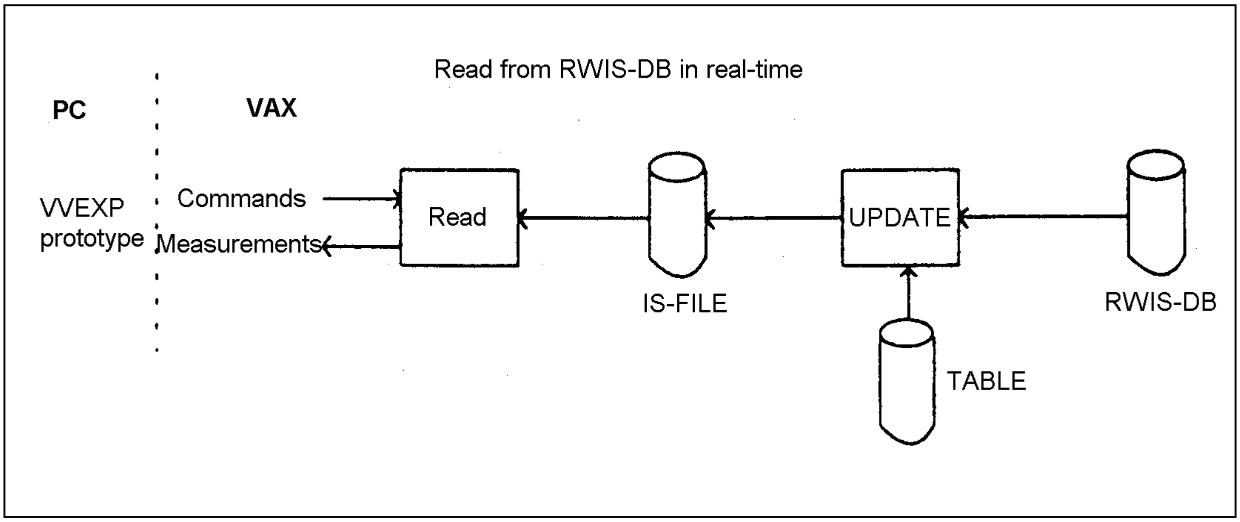


Fig. 1

Explanations for Fig. 1

RWIS_DB Database in the VAX-system with the actual measurements from the road weather information system (RWIS) remote processing unit (RPU) stations.

UPDATE Gets the latest measurements for RPU stations requested from TABLE and updates IS-FILE. UPDATE runs every nth minute or at stated times.

IS-FILE Information system file contains the latest set of measurements from the stations of interest. The file loops, that is, when the last record is read the next record is read from the beginning of the file. For every RPU station there is exactly one record.

READ Communicates with the knowledge-system in the PC according to stated protocol. When prompted, delivers measurements from IS-FILE for the next RPU station in turn. At the end of file READ begins with the first record in IS-FILE.

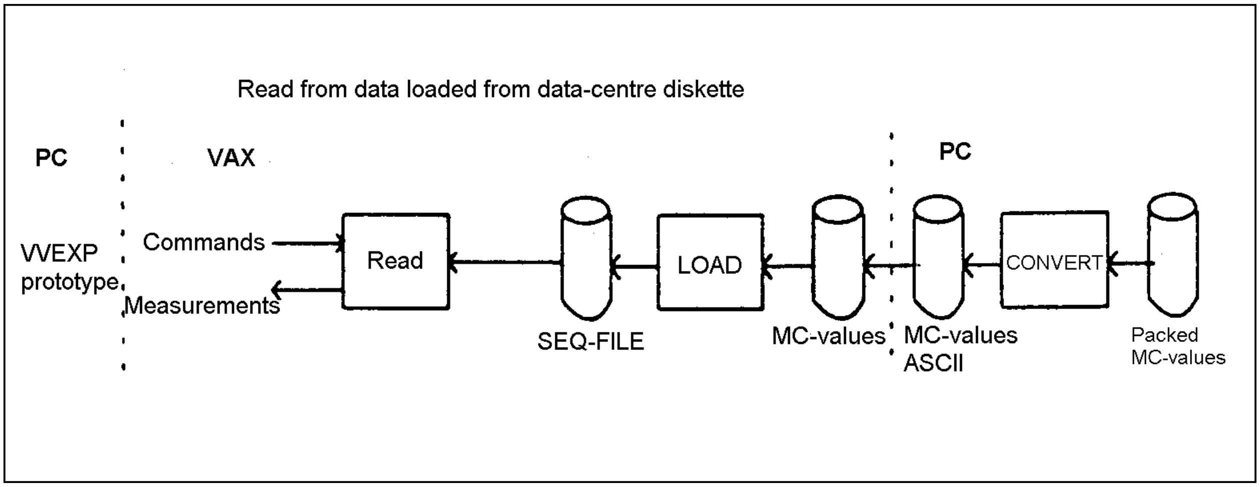


Fig. 2

Explanations for Fig. 2

PACKED MC-VALUES	Field station values in packed form for the Swedish Meteorological and Hydrological Institute (SMHI).
CONVERT	Converts from packed format.
MC-VALUES ASCII	Data centre RPU station values in ASCII-format.
MC-VALUES	Data centre RPU station values in VAX-text format.
LOAD	Loads all measurements from data centre MC-VALUES into the sequential file, SEQ-FILE. SEQ-FILE can contain an arbitrary number of records per RPU station.
READ	Communicates with knowledge-system in the PC according to stated protocol. On prompting, provides values from SEQ-FILE for the next RPU station in turn. At the end of file reading ends.

Description of RWIS - RDB

1. Introduction

The measurement values from RWIS are archived in RDB-databases at the computer centre for each respective region. The computers are accessible via a network (DECnet) and have names in the network which are composed of the symbol “VF” together with the region’s code for the administrative province (similar to county level of administration). The regional computer in Gävle, for example, is called “VFX”.

2. RWIS-database

The database with measurement values from the RWIS-stations has the name VVIS.RDB and the path is vvis_dbdir:[000000].

Example

```
Directory VFR::VVIS_DBDIR:[000000]

DOK.DIR;1        ORG_DB.DIR;1        TEST_DB.DIR;1        VVIS.RDB;1
VVIS.SNP;1       VVIS_DB_RESTORE.COM;1
```

In the database there are several tables (relations) which are each composed of several fields.

2.1 Relations

Indexes for relation ANVAENDARE *(USER)*

ANVAENDARE_PRIM	with field USERNAME No duplicates allowed	*User primary key*
ANVAENDARE_SEK1	with field ANV_GRUPP_KOD *(USER GROUP CODE)* Duplicates are allowed	*User secondary key*

Indexes for relation ANV_GRUPP (USER GROUP)

ANV_GRUPP_PRIM	with field ANV_GRUPP_KOD *(USER GROUP CODE)* No duplicates allowed	*User group primary key*

Indexes for relation LAENS_KONST *(“COUNTY” CONSTANTS)*

LAENS_KONST_PRIM	with field MSTN_ENHET *(REMOTE PROCESSING UNIT)* and field MAANAD *(MONTH)* and field DYGNS_TIMME *(HOUR OF DAY, 0-24)* and field DYGNS_TIMME_MINUT *(MINUTES PAST HOUR)* No duplicates allowed	*“County” Constants primary key*

Indexes for relation MAETNINGAR *(MEASUREMENTS)*

MAETNINGAR_PRIM	with field MSTN_ENHET *(REMOTE PROCESSING UNIT)* and field MSTN_KOD *(RPU CODE)* and field MAET_TID *(MEASUREMENT TIME)* and field RAD_TYP *(ROW TYPE)* No duplicates allowed description Primary key is MSTN_ENHET.MSTN_KOD.MAET_TID	*Measurements primary key*

Indexes for relation MC *(DATA CENTRE CONTAINING MEASUREMENTS)*

MC_PRIM	with field MC_ENHET *(DATA CENTRE UNIT)* No duplicates allowed	*Data centre primary key*

MSTN_PRIM	with field MSTN_ENHET *(REMOTE PROCESSING UNIT)* and field MSTN_KOD *(RPU CODE)* No duplicates allowed	*RPU primary key*
MSTN_SEK1	with field MSTN_ENHET *(REMOTE PROCESSING UNIT)* and field MSTN_KOD *(RPU CODE)* and field NED_BOERDS_GIV *(PRECIPITATION SENSOR)* No duplicates allowed	*RPU secondary key*
MSTN_SEK3	with field MSTN_ENHET *(REMOTE PROCESSING UNIT)* and field MSTN_KOD_FJAERR *(RPU CODE, REMOTE SENSOR)* Duplicates are allowed	*RPU tertiary key*

Indexes for relation PLATS_KONST *(LOCATION CONSTANTS)*

PLATS_KONST_PRIM	with field MSTN_ENHET *(REMOTE PROCESSING UNIT)* and field MSTN_KOD *(RPU CODE)* and field MAANAD *(MONTH)* and field DYGNS_TIMME *(HOUR OF DAY, 0-24)* and field DYGNS_TIMME_MINUT *(MINUTES PAST HOUR)* No duplicates allowed	*Location constants primary key*

Indexes for relation TAB_STATIONER *(STATION TABLE)*

TAB_STATIONER_PRIM	with field ANV_GRUPP_KOD *(USER GROUP CODE)* and field RAD_NR *(ROW NUMBER)* No duplicates allowed	*Station table primary key*
TAB_STATIONER_SEK1	with field MSTN_ENHET *(REMOTE PROCESSING UNIT)* and field MSTN_KOD *(RPU CODE)* Duplicates are allowed	*Station table secondary key*
TAB_STATIONER_SEK2	with field NOD *(NODE)* with field MSTN_ENHET *(REMOTE PROCESSING UNIT)* and field MSTN_KOD *(RPU CODE)* Duplicates are allowed	*Station table tertiary key*

2.1.1 Field descriptions

ANV_GRUPP_BEN	Field length for text is 25 Name of a user group, e.g. Borlänge Work District	*USER GROUP NAME*
ANV_GRUPP_KOD	Field length for text is 8 A group of users with information needs in common	*USER GROUP CODE*
DAGG_P	signed long word scale -1 Dewpoint	*DEWPOINT*
DYGNS_TIMME	signed word scale 0	*HOUR OF DAY (0-24)*
DYGNS_TIMME_MINUT	signed word scale 0	*MINUTES PAST HOUR*
ENHET	signed word scale 0 The unit where the data centre’s computers are located.	*UNIT*
FJAERR	signed long word scale -1 Pavement temperature, remote sensor	*REMOTE*

FJAERR_GIV	field length for text is 1 Flag to show if RPU has a remote sensor or not J = yes and N = no	*REMOTE SENSOR*
FRYSP	signed long word scale -1 Freezing-point on the pavement surface	*FREEZING-POINT*
FRYSP_GIV	field length for text is 1	*FREEZING-POINT SENSOR*
LU_FU	signed long word scale -1 Relative humidity	*RELATIVE HUMIDITY*
MAANAD	field length for text is 2	*MONTH*
MAET_TID	Date Date and time for a single measurement	*MEASUREMENT TIME*
MC_BEN	field length for text is 20 Name of the data centre	*DATA CENTRE NAME*
MSTN_BEN	field length for text is 20 Name of the remote processing unit (RPU)	*RPU NAME*
MSTN_FEL_KOD	text size is 4 RPU error status code	*RPU ERROR CODE*
MSTN_KOD	field length for text is 3 Together with ENHET *(UNIT)*, identifies the RPU	*RPU STATION CODE*
NDB	field length for text is 1 Precipitation where J = yes, precipitation at time of measurement N = no and * = recent precipitation	*PRECIPITATION*
NED_BOERDS_GIV	field length for text is 1 Flag for whether or not an RPU has a precipitation sensor J = yes and N = no	*PRECIPITATION SENSOR*
NOD	field length for text is 6	*NODE*
RAD_NR	signed word scale 0 Sorting sequence number for RPU during display of station table	*ROW NUMBER*
RAD_TYP	field length for text is 1	*ROW TYPE*
TID	signed long word scale -2	*TIME*
TLUFT	signed long word scale -1 Air temperature	*AIR TEMPERATURE*
TYTA	signed long word scale -1 Pavement surface temperature	*PAVEMENT TEMPERATURE*
TYTA_KONST	signed long word scale -3	*PAVEMENT TEMP CONSTANTS*
USERNAME	field length for text is 32 User name identifies the user to the machine	*USER NAME*
VARS	field length for text is 2 System messages	*SYSTEM MESSAGES*
VIMAX	signed word scale -1 Wind direction and strength in m/s, maximum value e.g. SW22.4	*WIND MAX*
VIMED	signed word scale -1 Wind direction and strength in m/s, average value e.g. SW22.4	*WIND AVERAGE*

VIRIK	field length for text is 2 Wind direction, e.g. SW = Southwest		*WIND DIRECTION*

2.3 Field description in the relation MAETNINGAR *(MEASUREMENTS)*

Fields for relation MAETNINGAR *(MEASUREMENTS)*

MSTN_KOD	field length for text is 3		*RPU STATION CODE*
TYTA	signed long word scale -1		*PAVEMENT TEMPERATURE*
FJAERR		only in X-“county” ***	*REMOTE*
FRYSP	signed long word scale -1		*FREEZING-POINT*
DAGGP	signed long word scale -1		*DEWPOINT*
TLUFT	signed long word scale -1		*AIR TEMPERATURE*
NDB	field length for text is 1		*PRECIPITATION*
VIMAX	signed long word scale -1		*WIND MAX*
VIMED	signed long word scale -2.41		*WIND AVERAGE*
VARS	text size is 2		*SYSTEM MESSAGES*
MSTN_ENHET	signed word scale 0 based on global field ENHET *(UNIT)*		*RPU STATION UNIT*
MAET_TID	Date		*MEASUREMENT TIME*
LU_FU	signed long word scale -1		*RELATIVE HUMIDITY*
VIRIK	text size is 2		*WIND DIRECTION*
MSTN_FEL_KOD	text size is 4		*RPU ERROR CODE*
RAD_TYP	text size is 1	not in X-“county” ***	*ROW TYPE*
DYGNS_TIMME	signed word scale 0	not in X-“county” ***	*HOUR OF DAY, 0-24*
DYGNS_TIMME_MINUT	signed word scale 0	not in X-“county” ***	*MINUTES PAST HOUR*

3. Example search in the RWIS-database with RDO

Commands from the user are in italics.

$*rdo*
RDO>*invoke database filename ‘vfr::vvus_dbdir:[000000]vvis.rdb’*
RDO>*start_transaction read_only*
RDO>*for m in maetningar (measurements)*
RDO cont>*print m.**
RDO cont>*end_for*
.
. here come the results of the search
.
RDO>*exit*
$

Example result:

MSTN_KOD	TYTA	FJAERR	FRYSP	DAGGP	TLUFT	NDB	VIMAX	VIMED	VARS	MSTN_ENHET	MAET_TID	LU_FU
RPU STATION CODE	*PAVE-MENT TEMP*	*REMOTE SENSOR*	*FREEZE-POINT*	*DEW-POINT*	*AIR TEMP*	*PRECIP*	*WIND MAX*	*WIND AVG*	*SYSTEM MESSAGE*	*RPU STATION UNIT*	*MEASUREMENT TIME*	*RELATIVE HUMIDITY*
11	1.1	1.2	1.3	1.4	1.5		1.6	1.7	-	21	12-NOV-1990 14:01:00.00	81.0
12	2.1	2.2	2.3	2.4	2.5	.	2.6	2.7	P-	22	12-NOV-1990 14:02:00.00	82.0

Rules for Nexpert Object - examples

```
(@RULE=       v_35
      (@LHS=
              (IsNot   (v_vaglag_nu)        ("torr"))      pavement condition now       dry
              (Is      (v_ndb_m)   ("sno_torr"))           precip. (measured)           dry snow
      )
      (@HYPO=          v_vaglag_m_bestemt)                 pavment condition (measured), defined
      (@RHS=
              (Do      ("sno_torr")  (v_vaglag_m)          dry snow        pavement condition (measured)

      )
)

(@RULE=       v_34
      (@LHS=
              (Is      (v_ndb_m             ("regn"))      precip. (measured)           rain
              (IsNot   (v_vaglag_nu)        ("torr"))      pavement condition now       dry
      )
      (@HYPO=          v_vaglag_m_bestemt)                 pavement condition (measured), defined
      (@RHS=
              (Do      ("vat")       (v_vaglag-m)          wet             pavement condition (measured)
      )
)

(@RULE=       v_33
      (@LHS=
              (Is      (v_ndb_m)            ("u_regn"))    precip. (measured)           freezing rain
              (IsNot   (v_vaglag_nu)        ("torr"))      pavement condition now       dry
      )
      (@HYPO=          v_vaglag_m_bestemt)                 pavement condition (measured), defined
      (@RHS=
              (Do      ("is_tunn")   (v_vaglag-m)          thin ice        pavement condition (measured)
      )
)

(@RULE=       v_32
      (@LHS=
              (Is      (v_vaglag_nu)        ("torr"))      pavement condition now       dry
              (Yes     (v_utfallning_m))                   deposition (measured)
      )
      (@HYPO=          v_vaglag_m_bestemt)                 pavement condition (measured), defined
      (@RHS=
              (Do      (v_utfallning_m_varde)          (v_vaglag-m)
      )                deposition (measured value)     pavement condition (measured)
)
```

Completed Processes - examples

In this version of VVEXP the expert-system finds all facts from a simulated Road Weather Information System (RWIS). In the version which will come into operation in Fall 1991 the values for forecast precipitation and forecast pavement condition are provided by the user. The existing system can be run in two modes, silent mode or talk mode. In silent mode the display only shows the user the recommendation provided by the system. In talk mode the user also sees the facts and partial results which are the basis for the recommendation.

Example of display screen - silent mode

VVEXP – Road salting V1.0
Using KB ../VVNEXP/VVEXPTST.CKB

Recommended treatment
2112 Vibodlångsjön Road E4
Salt with application 25 and plow

status
Waiting for new values from RWIS

Example of display screen - talk mode

VVEXP – Road salting V1.0
Using KB ../VVNEXP/VVEXPTST.CKB

Recommended treatment
2112 Vibodlångsjön Road E4
Either moistened salt (10 g/m*m) or brine (20 g/m*m)

facts
date = 1991-09-02
dew point (measured) = -2.0
dew point (forecast) = -1.0
RPU station error code = 0
Precipitation at station = yes
Precipitation forecast = wet snow
Location code = 2112
Time = 22:23
Air temperature = -2.0
Pavement temperature (measured) = -1.2
Pavement temperature (forecast) = -2.0
Pavement condition now = light frost

conclusions
action = action 103
action2 = unknown
precipitation (measured) = wet snow
pavement condition (measured) = wet snow
pavement condition (forecast) = wet snow

status
Waiting for new values from RWIS

[One line of missing text on original document. Trans.]...knowledge-base there is a log-file where facts, in-between results and recommendations are archived.

Example log-file

Field	Field Description	Field Contents		Field	Field Description	Field Contents
atg_text	action text	no action		atg_text2	action text 2	Unknown
atgard	action	either moistened salt		atgard2	action 2	Unknown
dat	date	19910902		dt_m	dewpoint (measured)	+2.0000
dt_p	dewpoint (forecast)	+3.0000		fjaerr	remote	-999.000
frys_temp	freezing-point	+2.2000		lu_fu	humidity	+78.0000
mstn_fel_kod	RPU error code	0		ndb_m	precipitation (meas.)	no
ndb_mstn	precip. @ station	no		ndb_p	precipitation forecast	rain
ortnamn	district name	Vidbolångsjön				
platsId	location ident.	2112		tid	time	1735
tlu	air temp	+2.0000		tyt_m	pavement temp (meas.)	+1.0000
tyt_p	pavement temp forecast	+0.5000		vaglag_m	pavement cond (meas.)	damp
vaglag_nu	pavement cond. now	dry		vaglag_p	pavement cond forecast	wet
vagnamn	road name	Road E4				
vars	message	- -		vimax	wind max	2
vimed	wind average	6		virik	wind direction	SE
atg_text	action text	either moistened salt		atg_text2	action text 2	Unknown
atgard	action	action 103		atgard2	action 2	Unknown
dat	date	1991-09-02		dt_m	dewpoint (measured)	-2.0000
dt_p	dewpoint (forecast)	-1.0000		fjaerr	remote	-999.0000
frys_temp	freezing-point	+2.2000		lu_fu	humidity	+78.0000
mstn_fel_kod	RPU error code	0		ndb_m	precipitation (meas.)	wet snow
ndb_mstn	precipitation	yes		ndb_p	precipitation forecast	no
ortnamn	district name	Vidbolångsjön				
platsId	location ident.	2112		tid	time	21:50
tlu	air temp	-2.0000		tyt_m	pavement temp (meas.)	-1.2000
tyt_p	pavement temp forecast	-2.0000		vaglag_m	pavement cond (meas.)	wet snow
vaglag_nu	pavement cond.	wet snow		vaglag_p	pavement cond forecast	wet snow
vagnamn	road name	Road E4				
vars	message	- -		vimax	wind max	2
vimed	wind average	6		virik	wind direction	SE
atg_text	action text	either moistened salt		atg_text2	action text 2	Unknown
atgard	action	action 105		atgard2	action 2	Unknown
dat	date	1991-09-02		dt_m	dewpoint (measured)	-1.0000
dt_p	dewpoint (forecast)	-0.5000		fjaerr	remote	-999.0000
frys_temp	freezing-point	+2.2000		lu_fu	humidity	+78.0000
mstn_fel_kod	RPU error code	0		ndb_m	precipitation (meas.)	no
ndb_mstn	precipitation	no		ndb_p	precipitation forecast	no
ortnamn	district name	Vidbolångsjön				
platsId	location ident.	2112		tid	time	17:36
tlu	air temp	+2.000		tyt_m	pavement temp (meas.)	-8.5000
tyt_p	pavement temp	-9.5000		vaglag_m	pavement cond (meas.)	heavy frost
vaglag_nu	pavement cond.	dry		vaglag_p	pavement cond forecast	heavy frost
vagnamn	road name	Road E4				
vars	message	- -		vimax	wind max	2
vimed	wind average	6		virik	wind direction	SE

User Guide - PC

Software and the knowledge-base for VVEXP are found in the directory \DAT\VVEXP. In the directory VVEXP there is a directory tree which contains source code, command files, executable files, and data files. The directory structure is shown in Fig. 1. [Fig. 1 was not provided for the translation project. Trans.]

Before running VVEXP, a driver for serial communication is installed and the server for Nexpert Object is started. The driver, which is a COM-file is started with the command COMBIOS and the server is started with the BAT-file NXPINST. COMBIOS is in the directory VVPGM and NXPINST is in the VVBAT directory. Then VVEXP is started with the BAT-file VVEXP in the directory VVMSC. The command file specifies which knowledge-base to use together with the parameters in effect for the serial communications. VVEXP tests that the signals at the specified serial port are according to RS232-C specifications. It is therefore necessary that the connection to the device, VAX-emulating PC (VAX-PC), is complete and that the communications program is running in VAX-PC.

Loading of the knowledge-base (KB) into main memory takes some minutes. When KB is loaded, the status window shows that VVEXP is waiting for data from the VAX-PC. Type values into the blanks in the VAX-PC window and send them to the PC. VVEXP then runs the inference-engine and presents a result. Processing takes a few minutes.

User Guide PC – VAX

Testing of the knowledge-base (KB) is eased through the user controlling which measurements are sent to VVEXP. This occurs through the PC (PC-VAX) emulating the VAX-system. For the PC-VAX there is a communications program which uses the same protocol as the VAX-system for communication with VVEXP. Those files which are used in the PC-VAX are found in the PC directory \VVEXP\PCVAX.

Before running the communications program (INTER), the driver (COMBIOS.COM) is run for the serial communications. INTER is a BAT-file which runs the program VVPROT.EXE. Serial communication parameters are specified in the BAT-file.

Modules in the Knowledge-base

The knowledge-base (KB) has been divided into modules. For each module there are files for rules, facts, and environment to test the module. Files which belong to a module all have the same prefix for the filename. The knowledge-base which is in the directory VVNEXP is in the file DIR.TXT.

```
: -----------------------------------------------------------------------------------
    File:        DIR.TXT
    Created      1991-04-04/ÅM Last change: 1991-06-09/ÅM
    Function:    Description of KB-files
: -----------------------------------------------------------------------------------
```

ÅM = Åke Malmberg

: -- standard name

*.TKB		KB text format for UNIX
*.KB		KB text format for DOS
*.CKB		KB in compiled format for DOS
VV_x_R.CKB		Merge of all in the modules x detailed rules and definitions
VVEXP_x.CKB		KB with all original modules up including module x and the rest dummy
LOAD_x.KB		KB with rules to load all original modules up including module x and rest dummy

: -- module 0

vv	ÅM	Common rules for start (VVEXP_HYPO)
vv_c	ÅM	Common characteristics and classes
vv_o	ÅM	Common objects for testing the entire system

: -- module 1

vv_y_o	ÅM	Object for testing pavement weather module	
vv_y_r	ÅM	Merged version of pavement weather module	
vv_y_rl	IN	Rules for pavement weather module	*IN = Inge Nordbø*
vv_y_rx	ÅM	Dummy rules	

: -- module 2

vv_l_r	ÅM	Merged version of atmospheric weather module
vv_l_rl	IN	Rules for atmospheric weather module
vv_l_rx	ÅM	Dummy rules

: -- module 3

vv_v_c	IN	Internal class in pavement condition	
vv_v_o	IN	Object for test of pavement condition	
vv_v_r	ÅM	Merged version of pavement condition module	[original said atmos. weather module. Trans.]
vv_v_rl	IN	Rules for pavement condition module	
vv_v_r2	IN		
vv_v_rx	ÅM	Dummy rules	

: --- module 4

vv_d_o	ÅM	Object for testing detection	
vv_d_r	ÅM	Merged version of detection module	
vv_d_r0	ÅM	Common rules for detection modules	
vv_d_rl	ÅM	Rules for detection module (detekt31)	
vv_d_r2	ÅM	Rules for detection module (detekt32)	
vv_d_r3	ÅM	Rules for detection module (detekt33)	
vv_d_r4	ÅM	Rules for detection module (detekt34)	
vv_d_rx	ÅM	Dummy rules	

: --- module 5

vv_f_r	ÅM	Merged version of event module	
vv_f_rl	IN	Rules for event module	
vv_f_rx	ÅM	Dummy rules	

: --- module 6

vv_m_r	ÅM	Merged version of RPU station module	*RPU = Remote Processing Unit*
vv_m_r0	ÅM	Rules for RPU station module	
vv_m_rl	ÅM	Rules for RPU station module	

: --- module 7

vv_r	ÅM	Rules for setting inference strategy and starting knowcess	*knowcess may mean KB access*

: --- tools

LOAD	Rules for loading production-KB
LOADTST	Rules for loading test-KB
LOAD_V	Rules for loading original modules including pavement condition module and rest of the dummy modules
LOAD_D	Rules for loading original modules including detection module and rest of the original modules

: --- KB

VVEXP.CKB	Production KB
VVEXPTST.CKB	Test KB
VVEXP_V.CKB	Original modules up including pavment condition module
VVEXP_D.CKB	Original modules up including detection module

Each module shall contain all local declarations.
Each module shall declare its starting hypothesis (e.g. d_hypo).

Systematic Grammar Network (SGN)

Contents

0. Introduction

Legend:	{	and	always all alternatives
	|	or	one or more alternatives
	[	xor	either or, never more alternatives

Each printout has a time stamp (Last changed) so that the reader can notice changes. For technical reasons the number (xx) appears in the printouts. This is related to ensuring that character strings are handled properly. The numbers have no bearing on applying the information.

1. Nexpert Object

1.1 Classes

```
File: KLASS    Last changed: 1991-03-27      16.24

root--  {RPU station-- {ident
        {              {position --   {start
        {              {              {end
        {              {              {start!
        {              {              {end!
        {              {
        {              {
        {              {name
        {
        {
        {value--  {dewpoint
        {         {date
        {         {remote
        {         {freezing-temp
        {         {relative humidity
        {         {RPU station error code
        {         {precipitation
        {         {station number
        {         {time
        {         {air temp
        {         {pavement temp
        {         {system message
        {         {wind, max.
        {         {wind, average
        {         {wind direction
        {
        {
        {road --  {ident
        {         {position
        {
        {
        {road section- {ident
        {              {road that section belongs to
        {              {crossing list
        {              {position!!
        {              {surface type
        {              {class of road
        {              {road district (ident)
        {
        {

        {report-  {ident
        {         {when
        {         {where
        {         {how
        {
        {
```

```
{crossing --   {ident
{              {position!!
{              {road list
{
{
{road district {ident
{              {name
{              {list with road sections
{
{
```

1.2 Objects

```
root--  [dummy
```

1.3 Modules

```
File:   MODULER              Last changed: 1991-06-22      15.18

root--  {pavement weather
        {atmospheric weather
        {pavement condition
        {detection
        {events
        {RPU station
```

2. Road Weather Information System (RWIS)

2.1 PC

2.2 VAX

```
File: VVIS                    Last changed: 1991-03-27      17.57

root --  {pc--   {codes (1)--   {Label                    XXXX     2311
         {       {              {Year                     XXXX     1991
         {       {              {Date                     mmdd     1221
         {       {              {time                     hhmm     1531
         {       {              {T-pavement               -XXx     -123           -9XX
         {       {              {T-pavement (remote)      -XXx     -123           -9XX
         {       {              {T-freeze-pt              -XX0     -100           -9XX
         {       {              {T-dewpoint               -XXx     -123           -9XX
         {       {              {T-air                    -XXx     -123           -9XX
         {       {              {Precip                   X
         {       {              {Humidity                 XX       85             -9
         {       {              {Wind dir                 XX       NV
         {       {              {Wind speed max           XXx      123            -99
         {       {              {Wind speed               XXx      123            -99
         {       {              {System message           XX       *p
         {       {              (Status                   -XXX     811/-100/0
         {       {              {End                      CR
         {       {
         {       {
         {       {err code (1)--  [status =  0 -> ok
         {       {                [*status   -100
         {       {                [*status   xxx
         {       {
         {       {
         {
         {
         {vax--  {codes (2)--   {row type -- [M - measured value
         {       {              {            [P - prognosticated (forecast) value
         {       {              {
         {       {              {
         {       {              {minutes past hour --     [45 <= t < 60 = 0
         {       {              {                         [0 <= t < 15 = 0
         {       {              {                         [15 <= t < 45 = 30
         {       {              {
         {       {              {
         {       {              {hour of day --[0 <= m < 30 = t
         {       {              {              [30 <= m < 60 = t+1
         {       {              {
         {       {              {
         {       {
         {       {
         {       {err code (2)--[RPU station error code - see pc.status
         {       {              [*RPU station error code = yyy
         {       {
         {       {
         {
         {

*status = -100 --      {error in a sensor
                       {error code for faulty sensor (e.g. pavement temp -996)

*status = xxx --       {modem error
                       {no measurements available from RPU station

*RPU station error code = yyy --{error at data centre
                                {no values available from data centre
```

2.3 Remote Processing Unit (RPU) Stations

```
File: MSTN                      Last changed: 1991-04-04  11.39

root --  {D-county -- {0401 -- {Korsbäcken              D = Södermanlands County
         {            {
         {            {
         {            {0413 -- {Västeråsen
         {            {
         {            {
         {
         {
         {F-county --{0601 --  {Gyllene Uttern          F = Jönköpings County
         {            {
         {            {
         {            {0618 -- {Hägna
         {            {
         {            {
         {            {0638 -- {Aneby
         {            {
         {            {
         {
         {
         {H-county --{0828 --  {Överum                  H = Kalmar County
         {            {
         {            {
         {            {0829 -- {Västra Ed
         {            {
         {            {
         {
         {
         {T-county --{1822 --  {Brattebo                T = Örebro County
         {            {
         {            {
         {            {1823 -- {Emma
         {            {
         {            {
         {
         {


File: MSTN-E                    Last changed: 1991-04-04  12.10

root --  {E-county -- (0523 -- {Kolmården               E = Östergötlands County
         {            {         {Work District 34 Norrköping
         {            {         {Highway E4
         {            {         {B-stn
         {            {         {3.2 km SW of Road 904
         {            {         {cold air location in forest
         {            {         {x= 6506215 y= 1527775
         {            {
         {            {
         {            {0524 -- {Åby
         {            {         {Work District 34 Norrköping
         {            {         {Road 55
         {            {         {B-stn
         {            {         {3.1 km N of Road 900
         {            {         {height of land in forest
         {            {         {x= 6510915 y= 1521025
         {            {
         {            {
         {            {0526 -- {Mjölby
         {            {         {Work District Mantorp
         {            {         {Road E4
         {            {         {B-stn
         {            {         {1 km E of Mjölby exit
         {            {         {cold air location in forested section
         {            {         {x= 6469625 y=1464140
```

```
{       {
{       {
{       {0527 --       {Linköping
{       {              {Work District 32 Gistad
{       {              {Highway E4
{       {              {A-stn
{       {              {2.2 km E of Road 1136
{       {              {cold air location, open
{       {              {x= 6478990 y= 1489130
{       {
{       {
{       {0528 --       {Lövstad
{       {              {Work District 32 Gistad
{       {              {Highway E4
{       {              {B-stn
{       {              {5 km NE of Norsholm
{       {              {cold air location, valley
{       {              {x= 6489870 y= 1513120
{       {
{       {
{       {0529 --       {Vadstena
{       {              {Work District 23 Mantorp
{       {              {Road 206
{       {              {A-stn
{       {              (2 km W of Fivelstad
{       {              {exposed location
{       {              {x= 6479800 y= 1451620
{       {
{       {
{       {0530 --       {Söderköping
{       {              {Work District 31 Ringarum
{       {              {Highway E66
{       {              {B-stn
{       {              {4 km S of Söderköping
{       {              {cold air location
{       {              {x= 6480405 y= 1532810
{       {
{       {
{       {0531 --       {Valdemarsvik
{       {              {Work District 31 Ringarum
{       {              {Highway E66
{       {              {B-stn
{       {              {3.3 km N of H-county boundary
{       {              {height of land
{       {              {x= 6446680 y= 1542950
{       {
{       {
{       {0533 --       {Rydnäs
{       {              {Work District 11 Österbymo
{       {              {Road 134
{       {              {B-stn
{       {              {0.3 km E of Road 529
{       {              {cold air location
{       {              {x= 6408445 y= 1461730
{       {
{       {
{       {0534 --       {Öringe
{       {              {Work District 12 Boxholm
{       {              {Road 32
{       {              {B-stn
{       {              {14 km N of F-county boundary
{       {              {height of land
{       {              {x= 6458915 y= 1457600
{       {
{       {
{       {0535 --       {Vadstugan
{       {              {Work District 13 Kisa
{       {              {Road 34
{       {              {B-stn
{       {              {6 km N of Road 135
{       {              {neutral location
{       {              {x= 6420790 y= 1493340
{       {
{       {
{       {
```

```
{       {0536 --       (Brokind
{       {              {Work District 13 Kisa
{       {              {Road 34
{       {              {B-stn
{       {              {4 km N of Brokind
{       {              {height of land
{       {              {x= 6457310 y= 1489050
{       {
{       {
{       {0537 --       {Väderstad
{       {              {Work District 21 Ödeshög
{       {              {Highway E4
{       {              {B-stn
{       {              {crossing Road 509
{       {              {cold air location in forested section
{       {              {x= 6465060 y= 1452635
{       {
{       {
{       {0538 --       {Medevi
{       {              {Work District 24 Borensberg
{       {              {Road 50
{       {              {B-stn
{       {              {1 km S of T-county boundary
{       {              {cold air drainage
{       {              {x= 6506525 y= 1451175
{       {
{       {
{       {0539 --       {Bankekind
{       {              {Work District 14 Åtvidaberg
{       {              {Road 35
{       {              {A-stn
{       {              {42 km NE H-county boundary
{       {              {cold air location, exposed
{       {              {x= 6472260 y= 1500390
{       {
{       {
{       {0540 --       {Hällestad
{       {              {Work District 33 Finnspång
{       {              {Road 51
{       {              {B-stn
{       {              {9 km E of  T-county boundary
{       {              {height of land in forest
{       {              {x= 6515925 y= 1483435
{       {
{       {
{       {0541 --       {Gullebo
{       {              {Work District 14 Åtvidaberg
{       {              {Road 35
{       {              {B-stn
{       {              {9 km N of H-county boundary
{       {              {height of land in forest
{       {              {x= 6448800 y= 1515155
{       {
{       {
{       {0542 --       {Östra Husby
{       {              {Work District 35 Östra Husby
{       {              {Road 209
{       {              {B-stn
{       {              {13.8 km E of Road 881
{       {              {small forested section
{       {              {x= 6494930 y= 1541150
{       {
{       {
{
{
```

```
File: MSTN_X                      Last changed: 1991-04-04  11.41

root --  {X-county -- {2101 -- {Gysinge                   X = Gävleborgs County
         {            {         {Road 67
         {            {         {A-stn
         {            {         {At Dalälven
         {            {         {bridge
         {            {
         {            {
         {            {2102 -- {Forsbacka
         {            {         {Road 80
         {            {         {B-stn
         {            {         {7 km east of Sandviken
         {            {         {bridge
         {            {
         {            {
         {            {2103 -- {Hille
         {            {         {Road 583
         {            {         {B-stn
         {            {         {6 km north of Gävle
         {            {         {exposed low-lying section
         {            {
         {            {
         {            {2104 -- {Skogsta
         {            {         {Highway E4/Road 758
         {            {         {A-stn
         {            {         {exposed low-lying section
         {            {
         {            {
         {            {2105 -- {Hoforsbacken
         {            {         {Road 80
         {            {         {B-stn
         {            {         {3 km north of Hofors
         {            {         {damp and shaded height of land
         {            {
         {            {
         {            {2106 -- {Högbacka
         {            {         {Highway E4
         {            {         {B-stn
         {            {         {low-lying near open water
         {            {         {x= 6766100 y= 1563900
         {            {
         {            {
         {            {2107 -- {Hamnäs
         {            {         {Road 83
         {            {         {B-stn
         {            {         {3 km S of Hamnäs at Blakans (River) outlet to Bergviken (Lake)
         {            {         {low point near water in shaded location
         {            {         {x= 6786300 y= 1552100
         {            {
         {            {
         {            {2108 -- {Ljusnan
         {            {         {Highway E4
         {            {         {B-stn
         {            {         {by Ljusnan
         {            {         {bridge
         {            {         {x= 6791400 y= 1565900
         {            {
         {            {
         {            {2109 -- {Norrala
         {            {         {Highway E4
         {            {         {B-stn
         {            {         {north of Norrala community
         {            {         {height of land
         {            {         {x= 6807200 y= 1561100
         {            {
         {            {
         {            {2110 -- {Lindefallet
         {            {         {Highway E4
         {            {         {B-stn
         {            {         {exposed low-lying section
         {            {         {x= 6819550 y= 1560600
         {            {
         {            {
```

```
{             {2111 --  {Njutånger
{             {         {Highway E4
{             {         {A-stn
{             {         {exposed low-lying section in vicinity of open water
{             {
{             {
{             {2112 --  {Vibodlångsjön
{             {         {Highway E4
{             {         {B-stn
{             {         {shaded location near open water
{             {
{             {
{             {2113 --  {Hammarbacken
{             {         {Highway E4
{             {         {B-stn
{             {         {4 km south of Harmånger
{             {         {shaded height of land
{             {
{             {
{             {2114 --  {Jättendal
{             {         {Highway E4
{             {         {A-stn
{             {         {Exposed low-lying section in vicinity of water
{             {
{             {
{             {2115 --  {Gryttjesjön
{             {         {Highway E4
{             {         {B-stn
{             {         {4 km north of Gnarp
{             {         {shaded height of land
{             {
{             {
{             {2116 --  {Djupdal
{             {         {Road 84
{             {         {B-stn
{             {         {bottom of valley
{             {
{             {
{             {2117 --  {Grurberget
{             {         {Road 546
{             {         {B-stn
{             {         {Rimsbro
{             {
{             {
{             {2118 --  {Snäre
{             {         {Road 84
{             {         {B-stn
{             {         {5 km east of Ljusdal
{             {
{             {
{             {2119 --  {Snasbäcken
{             {         {Road 84
{             {         {B-stn
{             {         {3 km west of Farila, west of bridge over Snasbäcken (stream)
{             {
{             {
{             {2120 --  {Edevägen
{             {         {Road 83
{             {         {A-stn
{             {         {4 km N Järvsö S bridge over Bodasjön (L.) outlet to Ljusnan R.
{             {         {exposed location
{             {
{             {
{             {2121 --  {Simeå
{             {         {Road 83
{             {         {B-stn
{             {         {100 m south of bridge
{             {         {cold air pool
{             {
{             {
{             {2122 --  {Rengsjö
{             {         {Road 82
{             {         {B-stn
{             {         {5 km W Rengsjö near Yxsjön
{             {         {height of land with wetland
{             {
{             {
```

```
{             {2123 --  {Hagsta
{             {         {Highway E4/Road 303
{             {         {B-stn
{             {         {1.5km south of Highway E4/Road 303
{             {
{             {
{
{
```

3. Road districts

3.1 Kisa

```
File: KISA                    Last changed: 1991-03-27      18.09

root --  {adjacent districts (1) --    {Österbymo District 11
         {                             {Boxholm District 12
         {                             {Mantorp District 23
         {                             {Åtvidaberg District 14
         {
         {
         {roads --    [B-salt --       {V34          V = Väg = Road
         {            [                              This is a list of road numbers.
         {            [
         {            [C-salt          {V134
         {            [                {V135
         {            [                {V674
         {            [                {v603
         {            [                {V588 (to V614)
         {            [
         {            [
         {
         {
         {use RWIS-stations --         {own --{Brokind 0536
         {                             {      {Vadstugan 053S
         {                             {
         {                             {                    Abbreviated Placenames
         {                             {other--{rydstn      Ryd station
         {                             {      {aneby        Aneby
         {                             {      {överu        Överum
         {                             {      {västr        Västraby
         {                             {      {gulle        Gullebo
         {                             {      {öring        Öringe
         {                             {      {banke        Bankestad
         {                             {      {linkö        Linköping
         {                             {
         {                             {
         {
         {
         {RWIS-computer ––    {Sörmlands RWIS-computer also serves Östergötland
         {
         {
         {use forecast regions ––      |E01
         {                             |E02
         {                             |E03
         {                             |E04
         {                             |EO5
         {
         {
         {salting --  {duration --     {2 trucks 50 km/h
         {            {                {V34
         {            {                {V134
         {            {                {V125
         {            {                {2 hours
         {            {
         {            {
         {
         {
```

```
{info --      {from --         |SMHI
{             {                |special report SMHI
{             {                |night-shift--{speaks directly to meteorologist
{             {                |             {speaks with all districts
{             {                |
{             {                |
{             {                |adjacent districts (2) --  |contractor on duty
{             {                |
{             {                |
{             {                |RWIS
{             {                |day-shift
{             {                |inspection --{before salting
{             {                |             {2 hours after salting
{             {                |
{             {                |
{             {                |own personnel salting
{             {
{             {
{             {to –-           |adjacent districts (3)
{             {                |night-shift
{             {                |current duty officer
{             {                |local radio (night-shift only)
{             {                |Headquarters in Borlänge --{pavement condition
{             {                |                           {night-shift only
{             {                |
{             {                |
{             {                |public --   {telephone inquiries
{             {                |
{             {                |
{             {
{             {
{
{
```

3.2 Söderala

```
File: SODERALA                Last changed: 1991-03-27      18.19

root --  {adjacent road districts -- {Bollnäs
         {                           {Valbo (Gävle)
         {                           {Forsa (Hudik)
         {                           {phone --    {when snowflakes fall
         {                           {            {slippery --     {*E4
         {                           {            {                 {other roads--{*”rock-hill”
         {                           {            {                 {              {*Hamnäs
         {                           {            {                 {
         {                           {            {                 {
         {                           {            {
         {                           {            {
         {                           {            {action (current uniform standard)
         {                           {            {unsafe (e.g. salting at -6C)
         {                           {
         {                           {
         {
         {
         {current info --    {weather info --   {TV long-range forecast --       {Monday
         {                    {                   {                                {Thursday
         {                    {                   {
         {                    {                   {
         {                    {                   {SMHI long-range forecast
         {                    {                   {RWIS
         {                    {                   {own control --   {drive --      {Mo Road 628
         {                    {                   {                 {              {Enne Rd 633.01
         {                    {                   {                 {              {Tröne Road 654
         {                    {                   {                 {
         {                    {                   {                 {
         {                    {                   {                 {slippery
         {                    {                   {                 {*immediate snow in Söderala
         {                    {                   {
         {                    {                   {
         {                    {                   {adjacent road districts
         {                    {                   {SMHI
         {                    {                   {local radio
         {                    {                   {other
         {                    {                   {weather reports --      {0300
         {                    {                   {                        {0900
         {                    {                   {                        {1500
         {                    {                   {                        {2100
         {                    {                   {
         {                    {                   {
         {                    {
         {                    {
         {                    {road info --    {adjacent road districts
         {                    {                {own control
         {                    {                {public phones
         {                    {                {other --    {own staff
         {                    {                {            {hired staff
         {                    {                {            {friends
         {                    {                {            {police
         {                    {                {            {transport companies
         {                    {                {            {taxi
         {                    {                {
         {                    {                {
         {                    {
         {                    {
         {
         {


*E4 --   {Alebacken (the hill with double lanes)
         {Ljusnan --  {river
         {            {RWIS
         {
         {
         {Högbacken --       {lakes
         {                    {RWIS
         {
```

```
*”rock-hill --         {V628
                       {steep hill


*Hamnäs --             {V83
                       {near water
                       {main road

*immediate snow in Söderala --      {probably snow in --   {Skogsbergen --        {V588
                                    {                      {                      {hill
                                    {                      {
                                    {                      {
                                    {                      {(Tröne-glösbo --      {V652
                                    {                      {                      {hill
                                    {                      {
                                    {                      {
                                    {                      {Storsjön –            {V564
                                    {                      {                      {hill
                                    {                      {
                                    {                      {
                                    {
                                    {
                                    {method: question
                                    {phone
                                    {action: plow
```

4. Symbols used by Swedish National Road Administration (SNRA)

```
File: VVBET                           Last changed: 1991-03-28      09.O5

root--  {reference --  [Rules for maintenance and operation
        {              [SNRA Publ 1990:51
        {
        {
        {winter road maintenance-standard classes -- [*main roads and primary county roads
        {                                            [*secondary and tertiary county roads
        {
        {



*main roads and primary county roads --       [Al   >= 16000 --     [pavement temp >= -8
                                              [                     [pavement temp <= -8
                                              [
                                              [
                                              [A2 8000-15999 --     [pavement temp >= -8
                                              [                     [pavement temp <= -8
                                              [
                                              [
                                              [B 2000-7999 --       [pavement temp >= -6
                                              [                     [pavement temp <= -6
                                              [
                                              [
                                              [C <= 1999 --         [pavement temp >= -3
                                              [                     [pavement temp <= -3
                                              [
                                              [


*secondary and tertiary county roads --       [A2   >= 16000 --     [pavement temp >= -8
                                              [                     [pavement temp <= -8
                                              [
                                              [
                                              [B 2000-15999 --      [pavement temp >= -6
                                              [                     [pavement temp <= -6
                                              [
                                              [
                                              [C 500-1999 --        [pavement temp >= -3
                                              [                     [pavement temp <= -3
                                              [
                                              [
                                              [D    <= 499
```

5. Meteorology

5.1 Symbols used by Swedish Meteorological and Hydrological Inst. (SMHI)

File: SMHIBET

```
root --  [wind --     [
         [            [0     < v <=  1        calm
         [            [1     < v <=  3        light
         [            [3     < v <=  8        moderate
         [            [8     < v <=  14       fresh
         [            [14    < v <= 25        severe
         [            [25    < v <= 32        storm
         [            [32    < v              hurricane
         [
         [
```

6. Controlling slippery conditions

6.1 Pavement condition

```
File: VAGLAG                     Last changed: 1991-06-22 14.57

root -- {delta(X) = dewpoint(X) - pavement temp(X)
        {deposition(X) --  [delta(X) > 0 --  [pavem temp(X) < 0 --  [delta(X)  >   2 ->  heavy frost
        {                  [                 [                      [delta(X)  <=  2 ->  light frost
        {                  [                 [
        {                  [                 [
        {                  [                 [pavem temp(X) >=0     [delta(X)  >   2 ->  wet
        {                  [                 [                      [delta(X)  <=  2 ->  moist
        {                  [                 [
        {                  [                 [
        {                  [
        {                  [
        {                  [delta(X) <= 0 -> none
        {
        {
        {pavem cond(m) (1) [no precip (11) --       [pavem cond(m)=dry -> deposition(0)          m = measured
        {                  [                        [pavem cond(m)=moist (112)
        {                  [                        [pavem cond(m)=wet (113)
        {                  [                        [pavem cond(m)=light frost (114)
        {                  [                        [pavem cond(m)=heavy frost (115)
        {                  [                        [pavem cond(m)=thin ice (116)
        {                  [                        [pavem cond(m)=thick ice (117)
        {                  [                        [pavem cond(m)=snow slush (118)
        {                  [                        [pavem cond(m)=wet snow (119)
        {                  [                        [pavem cond(m)=dry snow (11a)
        {                  [
        {                  [
        {                  [precip (12) --   [pavem cond(m)=dry -> deposition(0)
        {                  [                 [pavem cond(m) not dry --  [precip type(m)=rain          -> wet
        {                  [                 [                          [precip type(m)=freezing rain -> thin ice
        {                  [                 [                          [precip type(m)=dry snow      -> dry snow
        {                  [                 [                          [precip_type(m)=wet snow      -> wet snow
        {                  [                 [
        {                  [                 [
        {                  [
        {                  [
        {                                                                                   p = prognosticated
        {
        {pavem cond(p) (2) [pavem cond(m)=dry (21)--[precip(p)=yes (211 --    [rain           -> deposition(2)
        {                  [                        [                         [freezing rain  ->  ice
        {                  [                        [                         [wet snow
        {                  [                        [                         [dry snow
        {                  [                        [
        {                  [                        [
        {                  [                        [precip(p)=no -> deposition(2)
        {                  [
        {                  [
```

```
{                  [pavem cond(m)=moist (22) --  [precip(p)=yes (221) --  [regn
{                  [                             [                        [freezing rain -> ice
{                  [                             [                        [snow
{                  [                             [
{                  [                             [
{                  [                             [precip(p)=no (222) --   [pavem temp(p) <  0 -> ice
{                  [                             [                        [pavem temp(p) >= 0 -> moist/wet
{                  [                             [
{                  [                             [
{                  [
{                  [
{                  [pavem cond(m)=wet (23) --    [precip(p)=yes (231) --  [rain
{                  [                             [                        [freezing rain -> ice
{                  [                             [                        [snow
{                  [                             [
{                  [                             [
{                  [                             [precip(p)=no (232) --   [pavem temp(p) <  0 -> ice
{                  [                             [                        [pavem temp(p) >= 0 -> moist/wet
{                  [                             [
{                  [                             [
{                  [
{                  [
{                  [pavem cond(m)=light frost (24) --  [precip(p)=yes (241) --  [precip(p)=rain
{                  [                                   [                        [precip(p)=freezing rain -> ice
{                  [                                   [                        [precip(p)=snow
{                  [                                   [
{                  [                                   [
{                  [                                   [precip(p)=no (242) --   [pavem temp(p) <  0 -> frost
{                  [                                   [                        [pavem temp(p) >= 0 -> moist
{                  [                                   [
{                  [
{                  [
{                  [pavem cond(m)=heavy frost (25) --  [precip(p)=yes (251) --  [prec(p)=rain(2511)--[pave t(p)< 0 -> ice
{                  [                                   [                        [                     [pave t(p)>=0->moist
{                  [                                   [                        [
{                  [                                   [                        [
{                  [                                   [                        [precip(p)=freezing rain -> ice
{                  [                                   [                        [precip(p)=snow
{                  [                                   [
{                  [                                   [
{                  [                                   [precip(p)=no (252) --   [pavem temp(p) > 2 -> moist/wet
{                  [                                   [                        [pavem temp(p) 0/2 -> light frost
{                  [                                   [                        [pavem temp(p) <0  -> frost
{                  [                                   [
{                  [                                   [
{                  [
{                  [
```

```
{                [pavem cond(m)=thin ice (26)--  [precip(p)=yes (261) --  [prec(p)=rain (2611)--[pavem temp(p)>=0 ->moist
{                [                               [                        [                      [pavem temp(p) <0 ->ice
{                [                               [                        [
{                [                               [                        [
{                [                               [                        [precip(p)=freezing rain -> ice
{                [                               [                        [precip(p)=snow
{                [                               [
{                [                               [
{                [                               [precip(p)=no (262) --   [pavem temp(p) > 0 -> moist
{                [                               [                        [pavem temp(p) <=0 -> ice
{                [                               [
{                [                               [
{                [
{                [
{                [pavem cond(m)=thick ice (27)-- [precip(p)=yes (271) --  [precip(p)=rain            -> thick ice
{                [                               [                        [precip(p)=freezing rain   -> ice
{                [                               [                        [precip(p)=snow
{                [                               [
{                [                               [
{                [                               [precip(p)=no -> thick ice
{                [
{                [
{                [pavem cond(m)=snow slush (28)--[precip(p)=yes (281)--   [precip(p)=rain            -> wet
{                [                               [                        [precip(p)=freezing rain   -> snow slush
{                [                               [                        [precip(p)=snow            -> snow
{                [                               [
{                [                               [
{                [                               [precip(p)=no -> snow slush
{                [
{                [
{                [pavem cond(m)=wet snow (29) -- [precip(p)=yes (291) --  [precip(p)=rain            -> wet
{                [                               [                        [precip(p)=freezing rain   -> snow
{                [                               [                        [precip(p)=snow
{                [                               [
{                [                               [
{                [                               [precip(p)=no -> wet snow
{                [
{                [
{                [pavem cond(m)=dry snow (2a) -- [precip(p)=yes (2a1) --  [precip(p)=rain            -> wet snow
{                [                               [                        [precip(p)=freezing rain   -> dry snow
{                [                               [                        [precip(p)=snow            -> dry snow
{                [                               [
{                [                               [
{                [                               [precip(p)=no (2a2) --   [air temp(p) >  5          -> wet snow
{                [                               [                        [air temp(p) <= 5          -> dry snow
{                [                               [
{                [                               [
{                [
{                [
{
{
```

6.2 Detection

```
File: BESKRIV (DESCRIPTION)          Last changed: 1991-03-28      14.01

root --   {syntax -- {(p) = prognosticated value in 4 hours.
          {          {(m) = real-time value
          {          {pavem temp = pavement temperature
          {          {dewpoint = dew-point
          {          {precip = precipitation
          {          {freezing rain = super-cooled rain
          {
          {
          {nominal scale --    {precip --     [no
          {                    {              [yes --   {type --   [rain --  [super-cooled
          {                    {              [         {          [         [warm
          {                    {              [         {          [
          {                    {              [         {          [
          {                    {              [         {          [snow --  [wet
          {                    {              [         {          [         [dry
          {                    {              [         {          [
          {                    {              [         {          [
          {                    {              [         {
          {                    {              [         {
          {                    {              [         {intensity --  [light
          {                    {              [         {              [medium
          {                    {              [         {              [strong
          {                    {              [         {
          {                    {              [         {
          {                    {              [
          {                    {              [
          {                    {
          {                    {
          {                    {pavem cond -- [dry
          {                    {              [moist
          {                    {              [wet
          {                    {              [frost--  [light
          {                    {              [         [heavy
          {                    {              [
          {                    {              [
          {                    {              [ice --   [thin
          {                    {              [         [thick
          {                    {              [
          {                    {              [
          {                    {              [snow!--  [slush
          {                    {              [         [wet
          {                    {              [         [dry
          {                    {              [
          {                    {              [
          {                    {
          {                    {
          {
          {
          {variable --   {pavem temp(m)
          {              {pavem temp(p)
          {              {dewpoint(m)
          {              {dewpoint(p)
          {              {precip(m)
          {              {precip(p)
          {              {pavem cond(m)
          {              {pavem cond(p)
          {              {air temp(m)
          {
          {
```

```
File: DETEKT31                        Last changed: 1991-06-22      15.54

root --    [air temp(m) >= 10 -> act0   act = action
           [air temp(m) < 10 -- [precip(m)=yes --  [precip(p)=yes (1) --  [pavem cond(m)=dry (11) --  [pavem cond(p)=dry     -> act0
           [                    [                  [                      [                           [pavem cond(p)=moist   -> act0
           [                    [                  [                      [                           [pavem cond(p)=wet     -> act0
           [                    [                  [                      [                           [pavem cond(p)=light frost (114) --  [pavem temp(p)> 0 (never)
           [                    [                  [                      [                           [                                    [pavem temp(p) -2/0    -> act101
           [                    [                  [                      [                           [                                    [pavem temp(p) -4/-2   -> act102
           [                    [                  [                      [                           [                                    [pavem temp(p) -6/-4   -> act103
           [                    [                  [                      [                           [                                    [pavem temp(p) -8/-6   -> act104
           [                    [                  [                      [                           [                                    [pavem temp(p) -10/-8  -> act105
           [                    [                  [                      [                           [                                    [pavem temp(p) <-10    -> act0
           [                    [                  [                      [                           [
           [                    [                  [                      [                           [
           [                    [                  [                      [                           [pavem cond(p)=heavy frost (115) --  [pavem temp(p) > 0 (never)
           [                    [                  [                      [                           [                                    [pavem temp(p) -2/0    -> act102
           [                    [                  [                      [                           [                                    [pavem temp(p) -4/-2   -> act103
           [                    [                  [                      [                           [                                    [pavem temp(p) -6/-4   -> act104
           [                    [                  [                      [                           [                                    [pavem temp(p) -8/-6   -> act105
           [                    [                  [                      [                           [                                    [pavem temp(p) -10/-8  -> act106
           [                    [                  [                      [                           [                                    [pavem temp(p) <-10    -> act0
           [                    [                  [                      [                           [
           [                    [                  [                      [                           [
           [                    [                  [                      [                           [pavem cond(p)=thin ice (116) --     [pavem temp(p) > 0 (never)
           [                    [                  [                      [                           [                                    [pavem temp(p) -2/0    -> act101
           [                    [                  [                      [                           [                                    [pavem temp(p) -4/-2   -> act102
           [                    [                  [                      [                           [                                    [pavem temp(p) -6/-4   -> act103
           [                    [                  [                      [                           [                                    [pavem temp(p) -8/-6   -> act104
           [                    [                  [                      [                           [                                    [pavem temp(p) -10/-8  -> act105
           [                    [                  [                      [                           [                                    [pavem temp(p) <-10    -> act0
           [                    [                  [                      [                           [
           [                    [                  [                      [                           [
           [                    [                  [                      [                           [(pavem cond(p)=thick ice (117) --   [pavem temp(p) > 0 (never)
           [                    [                  [                      [                           [                                    [pavem temp(p) -2/0    -> act103
           [                    [                  [                      [                           [                                    [pavem temp(p) -4/-2   -> act104
           [                    [                  [                      [                           [                                    [pavem temp(p) -6/-4   -> act105
           [                    [                  [                      [                           [                                    [pavem temp(p) -8/-6   -> act106
           [                    [                  [                      [                           [                                    [pavem temp(p) -10/-8  -> act107
           [                    [                  [                      [                           [                                    [pavem temp(p) <-10    -> act0
           [                    [                  [                      [                           [
           [                    [                  [                      [                           [
           [                    [                  [                      [                           [pavem cond(p)=snow slush (never)
           [                    [                  [                      [                           [pavem cond(p)=wet snow (119) --     [pavem temp(p) > 0     -> act102
           [                    [                  [                      [                           [                                    [pavem temp(p) -2/0    -> act102
           [                    [                  [                      [                           [                                    [pavem temp(p) -4/-2   -> act103
           [                    [                  [                      [                           [                                    [pavem temp(p) -6/-4   -> act104
           [                    [                  [                      [                           [                                    [pavem temp(p) -8/-6   -> act105
           [                    [                  [                      [                           [                                    [pavem temp(p) -10/-8  -> act106
           [                    [                  [                      [                           [                                    [pavem temp(p) <-10    -> act0
           [                    [                  [                      [                           [
           [                    [                  [                      [                           [
```

```
[   [   [   [                             [pavem cond(p)=dry snow (11a) --    [pavem temp(p) > 0     -> act102
[   [   [   [                             [                                   [pavem temp(p) -2/0    -> act102
[   [   [   [                             [                                   [pavem temp(p) -4/-2   -> act0
[   [   [   [                             [                                   [pavem temp(p) -6/-4   -> act0
[   [   [   [                             [                                   [pavem temp(p) -8/-6   -> act0
[   [   [   [                             [                                   [pavem temp(p) -10/-8  -> act0
[   [   [   [                             [                                   [pavem temp(p) <-10    -> act0
[   [   [   [                             [
[   [   [   [                             [
[   [   [   [
[   [   [   [
[   [   [   [pavem cond(m)=moist (12) see pavem cond(m)=dry (11)
[   [   [   [pavem cond(m)=wet (13) see pavem cond(m)=dry (11)
[   [   [   [pavem cond(m)=light frost (14) --  [pavem temp(m) > 0 (never)
[   [   [   [                                   [pavem temp(m) -2/0     -> act101
[   [   [   [                                   [pavem temp(m) -4/-2    -> act102
[   [   [   [                                   [pavem temp(m) -6/-4    -> act102
[   [   [   [                                   [pavem temp(m) -8/-6    -> act103
[   [   [   [                                   [pavem temp(m) -10/-8   -> act105
[   [   [   [                                   [pavem temp(m) <-10     -> act0
[   [   [   [
[   [   [   [
[   [   [   [(pavem cond(m)=heavy frost (15) -- [pavem temp(m) > 0 (never)
[   [   [   [                                   [pavem temp(m) -2/0     -> act101
[   [   [   [                                   [pavem temp(m) -4/-2    -> act102
[   [   [   [                                   [pavem temp(m) -6/-4    -> act102
[   [   [   [                                   [pavem temp(m) -8/-6    -> act103
[   [   [   [                                   [pavem temp(m) -10/-8   -> act105
[   [   [   [                                   [pavem temp(m) <-10     -> act0
[   [   [   [
[   [   [   [
[   [   [   [pavem cond(m)=thin ice (16)  --    [pavem temp(m) > 0 (never)
[   [   [   [                                   [pavem temp(m) -2/0     -> act101
[   [   [   [                                   [pavem temp(m) -4/-2    -> act102
[   [   [   [                                   [pavem temp(m) -6/-4    -> act102
[   [   [   [                                   [pavem temp(m) -8/-6    -> act103
[   [   [   [                                   [pavem temp(m) -10/-8   -> act105
[   [   [   [                                   [pavem temp(m) <-10     -> act0
[   [   [   [
[   [   [   [
[   [   [   [pavem cond(m)=thick ice (17)  --   [pavem temp(m) > 0      -> act107
[   [   [   [                                   [pavem temp(m) -2/0     -> act107
[   [   [   [                                   [pavem temp(m) -4/-2    -> act108
[   [   [   [                                   [pavem temp(m) -6/-4    -> act108
[   [   [   [                                   [pavem temp(m) -8/-6    -> act109
[   [   [   [                                   [pavem temp(m) -10/-8   -> act109
[   [   [   [                                   [pavem temp(m) <-10     -> act200
[   [   [   [
[   [   [   [pavem cond(m)=snow slush (18) --   [pavem temp(m) > 0      -> act101
[   [   [   [                                   [pavem temp(m) -2/0     -> act102
[   [   [   [                                   [pavem temp(m) -4/-2    -> act103
[   [   [   [                                   [pavem temp(m) -6/-4    -> act104
[   [   [   [                                   [pavem temp(m) -8/-6    -> act105
[   [   [   [                                   [pavem temp(m) -10/-8   -> act106
[   [   [   [                                   [pavem temp(m) <-10     -> act300
[   [   [   [
```

```
[                    [                  [                     [
[                    [                  [                     [pavem cond(m)=wet snow (19)  --    [pavem temp(m) > 0      -> act102
[                    [                  [                     [                                   [pavem temp(m) -2/0     -> act103
[                    [                  [                     [                                   [pavem temp(m) -4/-2    -> act104
[                    [                  [                     [                                   [pavem temp(m) -6/-4    -> act105
[                    [                  [                     [                                   [pavem temp(m) -8/-6    -> act106
[                    [                  [                     [                                   [pavem temp(m) -10/-8   -> act107
[                    [                  [                     [                                   [pavem temp(m) <-10     -> act300
[                    [                  [                     [
[                    [                  [                     [pavem cond(m)=dry snow (1a) --     [pavem temp(m) > 0      -> act101+act300
[                    [                  [                     [                                   [pavem temp(m) -2/0     -> act102+act300
[                    [                  [                     [                                   [pavem temp(m) -4/-2    -> act300
[                    [                  [                     [                                   [pavem temp(m) -6/-4    -> act300
[                    [                  [                     [                                   [pavem temp(m) -8/-6    -> act300
[                    [                  [                     [                                   [pavem temp(m) -10/-8   -> act300
[                    [                  [                     [                                   [pavem temp(m) <-10     -> act300
[                    [                  [                     [
[                    [                  [                     [
[                    [                  [
[                    [                  [
[                    [                  [precip(p) - no
[                    [
[                    [
[                    [precip(m)=no
[
[
```

```
File: DETEKT32                          Last changed: 1991-06-22     15.57

root --    [air temp(m) >= 10 -> act0  act = action
           [air temp(m) < 10 -- [precip(m)=yes -- [precip(p) - yes
           [                    [                  [precip(p) - no (2)-- [pavem cond(m)=dry (never)
           [                    [                  [                     [pavem cond(m)=moist(22)-- [pavem cond(p)=dry     -> act0
           [                    [                  [                     [                           [pavem cond(p)=moist   -> act0
           [                    [                  [                     [                           [pavem cond(p)=wet     -> act0
           [                    [                  [                     [                           [pavem cond(p)=light frost (224) -- [pavem temp(p)> 0 (never)
           [                    [                  [                     [                           [                                   [pavem temp(p) -2/0    -> act101
           [                    [                  [                     [                           [                                   [pavem temp(p) -4/-2   -> act102
           [                    [                  [                     [                           [                                   [pavem temp(p) -6/-4   -> act103
           [                    [                  [                     [                           [                                   [pavem temp(p) -8/-6   -> act104
           [                    [                  [                     [                           [                                   [pavem temp(p) -10/-8  -> act105
           [                    [                  [                     [                           [                                   [pavem temp(p) <-10    -> act0
           [                    [                  [                     [                           [
           [                    [                  [                     [                           [
           [                    [                  [                     [                           [pavem cond(p)=heavy frost (225) -- [pavem temp(p) > 0 (never)
           [                    [                  [                     [                           [                                   [pavem temp(p) -2/0    -> act102
           [                    [                  [                     [                           [                                   [pavem temp(p) -4/-2   -> act103
           [                    [                  [                     [                           [                                   [pavem temp(p) -6/-4   -> act104
           [                    [                  [                     [                           [                                   [pavem temp(p) -8/-6   -> act105
           [                    [                  [                     [                           [                                   [pavem temp(p) -10/-8  -> act106
           [                    [                  [                     [                           [                                   [pavem temp(p) <-10    -> act0
           [                    [                  [                     [                           [
           [                    [                  [                     [                           [
           [                    [                  [                     [                           [pavem cond(p)=thin ice (226) --    [pavem temp(p) > 0 (never)
           [                    [                  [                     [                           [                                   [pavem temp(p) -2/0    -> act101
           [                    [                  [                     [                           [                                   [pavem temp(p) -4/-2   -> act102
           [                    [                  [                     [                           [                                   [pavem temp(p) -6/-4   -> act103
           [                    [                  [                     [                           [                                   [pavem temp(p) -8/-6   -> act104
           [                    [                  [                     [                           [                                   [pavem temp(p) -10/-8  -> act105
           [                    [                  [                     [                           [                                   [pavem temp(p) <-10    -> act0
           [                    [                  [                     [                           [
           [                    [                  [                     [                           [
           [                    [                  [                     [                           [(pavem cond(p)=thick ice (227) --  [pavem temp(p) > 0 (never)
           [                    [                  [                     [                           [                                   [pavem temp(p) -2/0    -> act102
           [                    [                  [                     [                           [                                   [pavem temp(p) -4/-2   -> act103
           [                    [                  [                     [                           [                                   [pavem temp(p) -6/-4   -> act104
           [                    [                  [                     [                           [                                   [pavem temp(p) -8/-6   -> act105
           [                    [                  [                     [                           [                                   [pavem temp(p) -10/-8  -> act106
           [                    [                  [                     [                           [                                   [pavem temp(p) <-10    -> act0
           [                    [                  [                     [                           [
           [                    [                  [                     [                           [
           [                    [                  [                     [                           [pavem cond(p)=snow slush (228) (never)
           [                    [                  [                     [                           [pavem cond(p)=wet snow (229)   (never)
           [                    [                  [                     [                           [pavem cond(p)=dry snow (22a)   (never)
           [                    [                  [                     [
           [                    [                  [                     [
           [                    [                  [                     [pavem cond(m)=wet (23)--   [pavem cond(p)=dry     -> act0
           [                    [                  [                     [                           [pavem cond(p)=moist   -> act0
           [                    [                  [                     [                           [pavem cond(p)=wet     -> act0
           [
```

```
[    [    [    [    [pavem cond(p)=light frost (234) --  [pavem temp(p)> 0 (never)
[    [    [    [    [                                    [pavem temp(p) -2/0    -> act101
[    [    [    [    [                                    [pavem temp(p) -4/-2   -> act102
[    [    [    [    [                                    [pavem temp(p) -6/-4   -> act103
[    [    [    [    [                                    [pavem temp(p) -8/-6   -> act104
[    [    [    [    [                                    [pavem temp(p) -10/-8  -> act105
[    [    [    [    [                                    [pavem temp(p) <-10    -> act0
[    [    [    [    [
[    [    [    [    [
[    [    [    [    [pavem cond(p)=heavy frost (235) --  [pavem temp(p) > 0 (never)
[    [    [    [    [                                    [pavem temp(p) -2/0    -> act102
[    [    [    [    [                                    [pavem temp(p) -4/-2   -> act103
[    [    [    [    [                                    [pavem temp(p) -6/-4   -> act104
[    [    [    [    [                                    [pavem temp(p) -8/-6   -> act105
[    [    [    [    [                                    [pavem temp(p) -10/-8  -> act106
[    [    [    [    [                                    [pavem temp(p) <-10    -> act0
[    [    [    [    [
[    [    [    [    [
[    [    [    [    [pavem cond(p)=thin ice (236) --     [pavem temp(p) > 0 (never)
[    [    [    [    [                                    [pavem temp(p) -2/0    -> act101
[    [    [    [    [                                    [pavem temp(p) -4/-2   -> act102
[    [    [    [    [                                    [pavem temp(p) -6/-4   -> act103
[    [    [    [    [                                    [pavem temp(p) -8/-6   -> act104
[    [    [    [    [                                    [pavem temp(p) -10/-8  -> act105
[    [    [    [    [                                    [pavem temp(p) <-10    -> act0
[    [    [    [    [
[    [    [    [    [
[    [    [    [    [(pavem cond(p)=thick ice (237) --   [pavem temp(p) > 0 (never)
[    [    [    [    [                                    [pavem temp(p) -2/0    -> act102
[    [    [    [    [                                    [pavem temp(p) -4/-2   -> act103
[    [    [    [    [                                    [pavem temp(p) -6/-4   -> act104
[    [    [    [    [                                    [pavem temp(p) -8/-6   -> act105
[    [    [    [    [                                    [pavem temp(p) -10/-8  -> act106
[    [    [    [    [                                    [pavem temp(p) <-10    -> act0
[    [    [    [    [
[    [    [    [    [
[    [    [    [    [pavem cond(p)=snow slush (never)
[    [    [    [    [pavem cond(p)=wet snow   (never)
[    [    [    [    [pavem cond(p)=dry snow   (never)
[    [    [    [
[    [    [    [
[    [    [    [pavem cond(m)=light frost(24)--    [pavem temp(m) > 0 (never)
[    [    [    [                                   [pavem temp(m) -2/0        -> act101
[    [    [    [                                   [pavem temp(m) -4/-2       -> act102
[    [    [    [                                   [pavem temp(m) -6/-4       -> act103
[    [    [    [                                   [pavem temp(m) -8/-6       -> act104
[    [    [    [                                   [pavem temp(m) -10/-8      -> act105
[    [    [    [                                   [pavem temp(m) <-10        -> act0
[    [    [    [
[    [    [    [
[    [    [    [pavem cond(m)=heavy frost(25)--    [pavem temp(m) > 0 (never)
[    [    [    [                                   [pavem temp(m) -2/0        -> act102
[    [    [    [                                   [pavem temp(m) -4/-2       -> act103
[    [    [    [                                   [pavem temp(m) -6/-4       -> act104
[    [    [    [                                   [pavem temp(m) -8/-6       -> act105
[    [    [    [                                   [pavem temp(m) -10/-8      -> act106
[    [    [    [                                   [pavem temp(m) <-10        -> act0
```

```
[          [          [          [
[          [          [          [
[          [          [          [pavem cond(m)=thin ice (26) --     [pavem temp(m) > 0 (never)
[          [          [          [                                   [pavem temp(m) -2/0        -> act101
[          [          [          [                                   [pavem temp(m) -4/-2       -> act102
[          [          [          [                                   [pavem temp(m) -6/-4       -> act102
[          [          [          [                                   [pavem temp(m) -8/-6       -> act103
[          [          [          [                                   [pavem temp(m) -10/-8      -> act105
[          [          [          [                                   [pavem temp(m) <-10        -> act0
[          [          [          [
[          [          [          [
[          [          [          [pavem cond(m)=thick ice (27) --    [pavem temp(m) > 0         -> act107
[          [          [          [                                   [pavem temp(m) -2/0        -> act107
[          [          [          [                                   [pavem temp(m) -4/-2       -> act108
[          [          [          [                                   [pavem temp(m) -6/-4       -> act108
[          [          [          [                                   [pavem temp(m) -8/-6       -> act109
[          [          [          [                                   [pavem temp(m) -10/-8      -> act109
[          [          [          [                                   [pavem temp(m) <-10        -> act200
[          [          [          [
[          [          [          [
[          [          [          [pavem cond(m)=snow slush (28) --   [pavem temp(m) > 0         -> act101
[          [          [          [                                   [pavem temp(m) -2/0        -> act102
[          [          [          [                                   [pavem temp(m) -4/-2       -> act103
[          [          [          [                                   [pavem temp(m) -6/-4       -> act104
[          [          [          [                                   [pavem temp(m) -8/-6       -> act105
[          [          [          [                                   [pavem temp(m) -10/-8      -> act106
[          [          [          [                                   [pavem temp(m) <-10        -> act300
[          [          [          [
[          [          [          [
[          [          [          [pavem cond(m)=wet snow (29) --     [pavem temp(m) > 0         -> act102
[          [          [          [                                   [pavem temp(m) -2/0        -> act103
[          [          [          [                                   [pavem temp(m) -4/-2       -> act104
[          [          [          [                                   [pavem temp(m) -6/-4       -> act105
[          [          [          [                                   [pavem temp(m) -8/-6       -> act106
[          [          [          [                                   [pavem temp(m) -10/-8      -> act107
[          [          [          [                                   [pavem temp(m) <-10        -> act300
[          [          [          [
[          [          [          [
[          [          [          [pavem cond(m)=dry snow (2a) --     [pavem temp(m) > 0         -> act101+act300
[          [          [          [                                   [pavem temp(m) -2/0        -> act102+act300
[          [          [          [                                   [pavem temp(m) -4/-2       -> act300
[          [          [          [                                   [pavem temp(m) -6/-4       -> act300
[          [          [          [                                   [pavem temp(m) -8/-6       -> act300
[          [          [          [                                   [pavem temp(m) -10/-8      -> act300
[          [          [          [                                   [pavem temp(m) <-10        -> act300
[          [          [          [
[          [          [          [
[          [          [
[          [          [
[          [
[          [
[          [precip(m)=no
[
[
```

```
File: DETEKT33                          Last changed: 1991-06-22      15.59

root --    [air temp(m) >= 10 -> act0   act = action
           [air temp(m) < 10 -- [precip(m)=yes
           [                    [precip(m)=no --   [precip(p)=yes --      [pavem cond=dry (31) --    [pavem cond(p)=moist   -> act0
           [                    [                  [                      [                          [pavem cond(p)=wet     -> act0
           [                    [                  [                      [                          [pavem cond(p)=light frost (313) --  [pavem temp(p)> 0 (never)
           [                    [                  [                      [                          [                                    [pavem temp(p) -2/0    -> act101
           [                    [                  [                      [                          [                                    [pavem temp(p) -4/-2   -> act101
           [                    [                  [                      [                          [                                    [pavem temp(p) -6/-4   -> act102
           [                    [                  [                      [                          [                                    [pavem temp(p) -8/-6   -> act103
           [                    [                  [                      [                          [                                    [pavem temp(p) -10/-8  -> act103
           [                    [                  [                      [                          [                                    [pavem temp(p) <-10    -> act0
           [                    [                  [                      [                          [
           [                    [                  [                      [                          [
           [                    [                  [                      [                          [pavem cond(p)=heavy frost (314) --  [pavem temp(p) > 0 (never)
           [                    [                  [                      [                          [                                    [pavem temp(p) -2/0    -> act101
           [                    [                  [                      [                          [                                    [pavem temp(p) -4/-2   -> act102
           [                    [                  [                      [                          [                                    [pavem temp(p) -6/-4   -> act103
           [                    [                  [                      [                          [                                    [pavem temp(p) -8/-6   -> act103
           [                    [                  [                      [                          [                                    [pavem temp(p) -10/-8  -> act104
           [                    [                  [                      [                          [                                    [pavem temp(p) <-10    -> act0
           [                    [                  [                      [                          [
           [                    [                  [                      [                          [
           [                    [                  [                      [                          [pavem cond(p)=thin ice (315) --     [pavem temp(p) > 0 (never)
           [                    [                  [                      [                          [                                    [pavem temp(p) -2/0    -> act101
           [                    [                  [                      [                          [                                    [pavem temp(p) -4/-2   -> act101
           [                    [                  [                      [                          [                                    [pavem temp(p) -6/-4   -> act102
           [                    [                  [                      [                          [                                    [pavem temp(p) -8/-6   -> act103
           [                    [                  [                      [                          [                                    [pavem temp(p) -10/-8  -> act103
           [                    [                  [                      [                          [                                    [pavem temp(p) <-10    -> act0
           [                    [                  [                      [                          [
           [                    [                  [                      [                          [
           [                    [                  [                      [                          [(pavem cond(p)=thick ice (316) --   [pavem temp(p) > 0 (never)
           [                    [                  [                      [                          [                                    [pavem temp(p) -2/0    -> act103
           [                    [                  [                      [                          [                                    [pavem temp(p) -4/-2   -> act103
           [                    [                  [                      [                          [                                    [pavem temp(p) -6/-4   -> act104
           [                    [                  [                      [                          [                                    [pavem temp(p) -8/-6   -> act105
           [                    [                  [                      [                          [                                    [pavem temp(p) -10/-8  -> act106
           [                    [                  [                      [                          [                                    [pavem temp(p) <-10    -> act106
           [                    [                  [                      [                          [
           [                    [                  [                      [                          [
           [                    [                  [                      [                          [pavem cond(p)=snow slush (never)
           [                    [                  [                      [                          [pavem cond(p)=wet snow (318) --     [pavem temp(p) > 0     -> act101
           [                    [                  [                      [                          [                                    [pavem temp(p) -2/0    -> act102
           [                    [                  [                      [                          [                                    [pavem temp(p) -4/-2   -> act103
           [                    [                  [                      [                          [                                    [pavem temp(p) -6/-4   -> act104
           [                    [                  [                      [                          [                                    [pavem temp(p) -8/-6   -> act105
           [                    [                  [                      [                          [                                    [pavem temp(p) -10/-8  -> act106
           [                    [                  [                      [                          [                                    [pavem temp(p) <-10    -> act0
           [                    [                  [                      [                          [
           [                    [                  [                      [                          [
```

```
[   [   [   [                              [pavem cond(p)=dry snow (319) --    [pavem temp(p) > 0     -> act101
[   [   [   [                              [                                   [pavem temp(p) -2/0    -> act102
[   [   [   [                              [                                   [pavem temp(p) -4/-2   -> act0
[   [   [   [                              [                                   [pavem temp(p) -6/-4   -> act0
[   [   [   [                              [                                   [pavem temp(p) -8/-6   -> act0
[   [   [   [                              [                                   [pavem temp(p) -10/-8  -> act0
[   [   [   [                              [                                   [pavem temp(p) <-10    -> act0
[   [   [   [                              [
[   [   [   [                              [
[   [   [   [
[   [   [   [
[   [   [   [pavem cond(m)=moist (32) see dry (31)
[   [   [   [pavem cond(m)=wet (33) see dry (31)
[   [   [   [pavem cond(m)=light frost (34) --  [pavem temp(m) > 0      -> act101
[   [   [   [                                   [pavem temp(m) -2/0     -> act101
[   [   [   [                                   [pavem temp(m) -4/-2    -> act102
[   [   [   [                                   [pavem temp(m) -6/-4    -> act102
[   [   [   [                                   [pavem temp(m) -8/-6    -> act103
[   [   [   [                                   [pavem temp(m) -10/-8   -> act103
[   [   [   [                                   [pavem temp(m) <-10     -> act105
[   [   [   [
[   [   [   [
[   [   [   [(pavem cond(m)=heavy frost (35) -- [pavem temp(m) > 0      -> act101
[   [   [   [                                   [pavem temp(m) -2/0     -> act102
[   [   [   [                                   [pavem temp(m) -4/-2    -> act103
[   [   [   [                                   [pavem temp(m) -6/-4    -> act104
[   [   [   [                                   [pavem temp(m) -8/-6    -> act105
[   [   [   [                                   [pavem temp(m) -10/-8   -> act106
[   [   [   [                                   [pavem temp(m) <-10     -> act200
[   [   [   [
[   [   [   [
[   [   [   [pavem cond(m)=thin ice (36)  --    [pavem temp(m) > 0      -> act107
[   [   [   [                                   [pavem temp(m) -2/0     -> act107
[   [   [   [                                   [pavem temp(m) -4/-2    -> act107
[   [   [   [                                   [pavem temp(m) -6/-4    -> act108
[   [   [   [                                   [pavem temp(m) -8/-6    -> act108
[   [   [   [                                   [pavem temp(m) -10/-8   -> act200
[   [   [   [                                   [pavem temp(m) <-10     -> act200
[   [   [   [
[   [   [   [
[   [   [   [pavem cond(m)=thick ice (37)  --   [pavem temp(m) > 0      -> act108
[   [   [   [                                   [pavem temp(m) -2/0     -> act108
[   [   [   [                                   [pavem temp(m) -4/-2    -> act108
[   [   [   [                                   [pavem temp(m) -6/-4    -> act109
[   [   [   [                                   [pavem temp(m) -8/-6    -> act109
[   [   [   [                                   [pavem temp(m) -10/-8   -> act200
[   [   [   [                                   [pavem temp(m) <-10     -> act200
[   [   [   [
[   [   [   [pavem cond(m)=snow slush (38) --   [pavem temp(m) > 0      -> act101+act300
[   [   [   [                                   [pavem temp(m) -2/0     -> act103+act300
[   [   [   [                                   [pavem temp(m) -4/-2    -> act105+act300
[   [   [   [                                   [pavem temp(m) -6/-4    -> act105+act300
[   [   [   [                                   [pavem temp(m) -8/-6    -> act107+act300
[   [   [   [                                   [pavem temp(m) -10/-8   -> act107+act300
[   [   [   [                                   [pavem temp(m) <-10     -> act300
[   [   [   [
```

```
[                    [                 [                      [
[                    [                 [                      [pavem cond(m)=wet snow (39)  --     [pavem temp(m) > 0      -> act101+act300
[                    [                 [                      [                                    [pavem temp(m) -2/0     -> act103+act300
[                    [                 [                      [                                    [pavem temp(m) -4/-2    -> act105+act300
[                    [                 [                      [                                    [pavem temp(m) -6/-4    -> act105+act300
[                    [                 [                      [                                    [pavem temp(m) -8/-6    -> act107+act300
[                    [                 [                      [                                    [pavem temp(m) -10/-8   -> act107+act300
[                    [                 [                      [                                    [pavem temp(m) <-10     -> act300
[                    [                 [                      [
[                    [                 [                      [pavem cond(m)=dry snow (3a) --      [pavem temp(m) > 0      -> act101+act300
[                    [                 [                      [                                    [pavem temp(m) -2/0     -> act103+act300
[                    [                 [                      [                                    [pavem temp(m) -4/-2    -> act105+act300
[                    [                 [                      [                                    [pavem temp(m) -6/-4    -> act105+act300
[                    [                 [                      [                                    [pavem temp(m) -8/-6    -> act107+act300
[                    [                 [                      [                                    [pavem temp(m) -10/-8   -> act107+act300
[                    [                 [                      [                                    [pavem temp(m) <-10     -> act300
[                    [                 [                      [
[                    [                 [                      [
[                    [                 [
[                    [                 [
[                    [                 [precip(p) = no
[                    [
[                    [
[
[
```

```
File: DETEKT34                          Last changed: 1991-06-22      16.01

root --    [air temp(m) >= 10 -> act0   act = action
           [air temp(m) < 10 -- [precip(m)=yes
           [                     [precip(m)=no --   [precip(p)=yes
           [                     [                  [precip(p)=no --      [pavem cond(m)=dry (41) --  [pavem cond(p)=dry    -> act0
           [                     [                  [                     [                           [pavem cond(p)=moist  -> act0*
           [                     [                  [                     [                           [pavem cond(p)=wet    -> act0*
           [                     [                  [                     [                           [pavem cond(p)=light frost (414) -- [pavem temp(p) -4/0   -> act101
           [                     [                  [                     [                           [                                   [pavem temp(p) -7/-4  -> act102
           [                     [                  [                     [                           [                                   [pavem temp(p) -10/-7 -> act103
           [                     [                  [                     [                           [                                   [pavem temp(p) <-10   -> act0
           [                     [                  [                     [                           [
           [                     [                  [                     [                           [
           [                     [                  [                     [                           [pavem cond(p)=heavy frost (415) -- [pavem temp(p) -2/0   -> act101
           [                     [                  [                     [                           [                                   [pavem temp(p) -4/-2  -> act102
           [                     [                  [                     [                           [                                   [pavem temp(p) -6/-4  -> act103
           [                     [                  [                     [                           [                                   [pavem temp(p) -8/-6  -> act104
           [                     [                  [                     [                           [                                   [pavem temp(p) -10/-8 -> act105
           [                     [                  [                     [                           [                                   [pavem temp(p) <-10   -> act0
           [                     [                  [                     [                           [
           [                     [                  [                     [                           [
           [                     [                  [                     [
           [                     [                  [                     [
           [                     [                  [                     [pavem cond(p)=moist(42)--  [pavem cond(p)=dry    -> act0
           [                     [                  [                     [                           [pavem cond(p)=moist  -> act0
           [                     [                  [                     [                           [pavem cond(p)=wet    -> act0
           [                     [                  [                     [                           [pavem cond(p)=light frost (424) -- [pavem temp(p) -4/0   -> act101
           [                     [                  [                     [                           [                                   [pavem temp(p) -7/-4  -> act102
           [                     [                  [                     [                           [                                   [pavem temp(p) -10/-7 -> act103
           [                     [                  [                     [                           [                                   [pavem temp(p) <-10   -> act0
           [                     [                  [                     [                           [
           [                     [                  [                     [                           [
           [                     [                  [                     [                           [(pavem cond(p)=heavy frost (425)-- [pavem temp(p) -2/ 0  -> act101
           [                     [                  [                     [                           [                                   [pavem temp(p) -4/-2  -> act102
           [                     [                  [                     [                           [                                   [pavem temp(p) -6/-4  -> act103
           [                     [                  [                     [                           [                                   [pavem temp(p) -8/-6  -> act104
           [                     [                  [                     [                           [                                   [pavem temp(p) -10/-8 -> act105
           [                     [                  [                     [                           [                                   [pavem temp(p) <-10   -> act0
           [                     [                  [                     [                           [
           [                     [                  [                     [                           [
           [                     [                  [                     [                           [pavem cond(p)=ice (426) --         [pavem temp(p) -4/0   -> act101
           [                     [                  [                     [                           [                                   [pavem temp(p) -7/-4  -> act102
           [                     [                  [                     [                           [                                   [pavem temp(p) -10/-7 -> act103
           [                     [                  [                     [                           [                                   [pavem temp(p) <-10   -> act0
           [                     [                  [                     [                           [
           [                     [                  [                     [                           [
           [                     [                  [                     [                           [pavem cond(p)=snow (never)
           [                     [                  [                     [
           [                     [                  [                     [
           [                     [                  [                     [pavem cond(m)=wet (43)--   [pavem cond(p)=dry    -> act0
           [                     [                  [                     [                           [pavem cond(p)=moist  -> act0
           [                     [                  [                     [                           [pavem cond(p)=wet    -> act0
```

```
[ [ [ [ [pavem cond(p)=light frost (435) -- [pavem temp(p) -2/0   -> act101
[ [ [ [ [                                  [pavem temp(p) -4/-2  -> act102
[ [ [ [ [                                  [pavem temp(p) -6/-4  -> act103
[ [ [ [ [                                  [pavem temp(p) -8/-6  -> act104
[ [ [ [ [                                  [pavem temp(p) -10/-8 -> act105
[ [ [ [ [                                  [pavem temp(p) <-10   -> act0
[ [ [ [ [
[ [ [ [ [
[ [ [ [ [pavem cond(p)=heavy frost (436) -- [pavem temp(p) -2/0   -> act102
[ [ [ [ [                                  [pavem temp(p) -4/-2  -> act103
[ [ [ [ [                                  [pavem temp(p) -6/-4  -> act104
[ [ [ [ [                                  [pavem temp(p) -8/-6  -> act105
[ [ [ [ [                                  [pavem temp(p) -10/-8 -> act106
[ [ [ [ [                                  [pavem temp(p) <-10   -> act0
[ [ [ [ [
[ [ [ [ [
[ [ [ [ [pavem cond(p)=ice (437) --         [pavem temp(p) -2/0   -> act102
[ [ [ [ [                                  [pavem temp(p) -4/-2  -> act103
[ [ [ [ [                                  [pavem temp(p) -6/-4  -> act104
[ [ [ [ [                                  [pavem temp(p) -8/-6  -> act105
[ [ [ [ [                                  [pavem temp(p) -10/-8 -> act106
[ [ [ [ [                                  [pavem temp(p) <-10   -> act0
[ [ [ [ [
[ [ [ [ [
[ [ [ [
[ [ [ [
[ [ [ [pavem cond(m)=light frost (44) --  [pavem temp(m) -4/0       -> act101
[ [ [ [                                   [pavem temp(m) -7/-4      -> act102
[ [ [ [                                   [pavem temp(m) -10/-7     -> act103
[ [ [ [                                   [[pavem temp(m) <-10      -> act200
[ [ [ [
[ [ [ [
[ [ [ [pavem cond(m)=heavy frost (45) --  [pavem temp(m) -2/0       -> act101
[ [ [ [                                   [pavem temp(m) -4/-2      -> act102
[ [ [ [                                   [pavem temp(m) -6/-4      -> act103
[ [ [ [                                   [pavem temp(m) -8/-6      -> act104
[ [ [ [                                   [pavem temp(m) -10/-8     -> act105
[ [ [ [                                   [pavem temp(m) <-10       -> act200
[ [ [ [
[ [ [ [
[ [ [ [pavem cond(m)=thin ice (46) --     [pavem temp(m) >0         -> act101
[ [ [ [                                   [pavem temp(m) -2/0       -> act102
[ [ [ [                                   [pavem temp(m) -4/-2      -> act103
[ [ [ [                                   [pavem temp(m) -6/-4      -> act104
[ [ [ [                                   [pavem temp(m) -8/-6      -> act105
[ [ [ [                                   [pavem temp(m) -10/-8     -> act106
[ [ [ [                                   [[pavem temp(m) <-10      -> act200
[ [ [ [
[ [ [ [
[ [ [ [pavem cond(m)=thick ice (47) --    [pavem temp(m) >0         -> act105
[ [ [ [                                   [pavem temp(m) -2/0       -> act107
[ [ [ [                                   [pavem temp(m) -4/-2      -> act107
[ [ [ [                                   [pavem temp(m) -6/-4      -> act108
[ [ [ [                                   [pavem temp(m) -8/-6      -> act108
[ [ [ [                                   [pavem temp(m) -10/-8     -> act200*
[ [ [ [                                   [pavem temp(m) <-10       -> act200*
[ [ [ [
```

```
[
[pavem cond(m)=snow slush (48) --   [pavem temp(m) > 0          -> act101+act300
[                                   [pavem temp(m) -2/0         -> act102+act300
[                                   [pavem temp(m) -4/-2        -> act103+act300
[                                   [pavem temp(m) -6/-4        -> act104+act300
[                                   [pavem temp(m) -8/-6        -> act105+act300
[                                   [pavem temp(m) -10/-8       -> act106+act300
[                                   [pavem temp(m) <-10         -> act300
[
[
[pavem cond(m)=wet snow (49) --     [pavem temp(m) > 0          -> act101+act300
[                                   [pavem temp(m) -2/0         -> act103+act300
[                                   [pavem temp(m) -4/-2        -> act104+act300
[                                   [pavem temp(m) -6/-4        -> act105+act300
[                                   [pavem temp(m) -8/-6        -> act106+act300
[                                   [pavem temp(m) -10/-8       -> act107+act300
[                                   [pavem temp(m) <-10         -> act300
[
[
[pavem cond(m)=dry snow (4a) --     [pavem temp(m) > 0          -> act101+act300
[                                   [pavem temp(m) -2/0         -> act103+act300
[                                   [pavem temp(m) -4/-2        -> act300
[                                   [pavem temp(m) -6/-4        -> act300
[                                   [pavem temp(m) -8/-6        -> act300
[                                   [pavem temp(m) -10/-8       -> act300
[                                   [pavem temp(m) <-10         -> act300
[
[
```

6.3 Treatments

```
File: ATGARD         (ACTION) Last changed: 1991-03-28 14.30

root --  [act0 -- [no action
         [
         [
         [actlOO -- [chemical anti-icing --  [act10l --    [moist salt -  5     g/m*m
         [          [                        [             [solution   - 10     g/m*m
         [          [                        [
         [          [                        [
         [          [                        [actl02 --    [moist salt - 7.5    g/m*m
         [          [                        [             [solution   - 15     g/m*m
         [          [                        [
         [          [                        [
         [          [                        [act103 --    [moist salt - 10     g/m*m
         [          [                        [             [solution   - 20     g/m*m
         [          [                        [
         [          [                        [
         [          [                        [actl04 --    [moist salt - 12.5   g/m*m
         [          [                        [             [solution   - 25     g/m*m
         [          [                        [
         [          [                        [
         [          [                        [actl05 --    [moist salt - 15     g/m*m
         [          [                        [             [solution   - 30     g/m*m
         [          [                        [
         [          [                        [
         [          [                        [actlO6 --    [moist salt - 17.5   g/m*m
         [          [                        [             [solution   - 35     g/m*m
         [          [                        [
         [          [                        [
         [          [                        [act107 --    [moist salt - 20     g/m*m
         [          [                        [             [solution   - 40     g/m*m
         [          [                        [
         [          [                        [
         [          [                        [actlO8 --    [moist salt - 25     g/m*m
         [          [                        [
         [          [                        [
         [          [                        [actl09 --    [moist salt - 30     g/m*m
         [          [                        [
         [          [                        [
         [          [                        [actllO --    [moist salt - 35     g/m*m
         [          [                        [
         [          [                        [
         [          [
         [          [
         [
         [
         [act2OO -- [mechanical anti-icing
         [
         [
         [act300 -- [plowing
         [
         [
```

7. Road network

7.1 Work districts

File: AO

```
root -- {E-county --   {11 --  {Österbymo
        {              {
        {              {
        {              {12 --  {Boxholm
        {              {
        {              {
        {              {13 --  {Kisa
        {              {
        {              {
        {              {14 --  {Åtvidaberg
        {              {
        {              {
        {              {21 --  {Ödeshög
        {              {
        {              {
        {              {23 --  {Mantorp
        {              {
        {              {
        {              {24 --  {Borgensberg
        {              {
        {              {
        {              {31 --  {Ringarum
        {              {
        {              {
        {              {32 --  {Gistad
        {              {
        {              {
        {              {33 --  {Finnspång
        {              {
        {              {
        {              {34 --  {Norrköping
        {              {
        {              {
        {              {35 --  {Ö Husby                Ö = East
        {              {
        {              {
        {
        {
        {X-county --   {Valbo
        {              {Kungsgården
        {              {Ockelbo
        {              {Söderala
        {              {Forsa
        {              {Gnarp
        {              {Delsbo
        {              {Ljusdal
        {              {Bollnäs
        {
        {
```

9. Miscellaneous

9.1 Characteristics

9.1.1 Chemical

```
File: KEMISK                   Last changed: 1991-03-28 09.52

root -- [salt -- [dry --  {apply --  {min   g/m*m
        [        [        {          {max   g/m*m
        [        [        {
        [        [        {salting 30 km/h
        [        [        {transport 50 km/h
        [        [        {effect --{vehicles -- [5 vehicles -> 30% remains on pavement
        [        [        {         {
        [        [        {         {
        [        [        {         {weather
        [        [        {
        [        [        {
        [        [
        [        [
        [        [moistened --  [water--  {mixture 25 l water/m3 salt      m3 = cubic metre
        [        [              [         {apply (1) --     {min    5   g/m*m
        [        [              [         {                 {mean   10  g/m*m
        [        [              [         {                 {max    20  g/m*m
        [        [              [         {
        [        [              [         {
        [        [              [         {salting 30 km/h
        [        [              [         {transport 50 km/h
        [        [              [         {effect (1) --    [*vehicle (1)
        [        [              [         {                 [*weather (1)
        [        [              [         {
        [        [              [
        [        [              [
        [        [              [NaCl--   {mixture         litre water/m3 litre NaCl
        [        [              [         {apply (2) --     {min  10 g/m*m
        [        [              [         {                 {mean    g/m*m value omitted in orig.
        [        [              [         {                 {max  20 g/m*m
        [        [              [         {
        [        [              [         {
        [        [              [         {salting 30 km/h
        [        [              [         {transport 50 km/h
        [        [              [         {effect (2) --    [*vehicle (2)
        [        [              [         {
        [        [              [         {
        [        [              [
        [        [              [
        [        [
        [        [
        [
        [
        [solution --      {equivalent to 4 times as much salt
        [                 {salting 30 km/h
        [                 {transport 50 km/h
        [                 {effect (3)--  {vehicles (3) -- [5 vehicles -> 90% remains on
        [                 {              {                                    pavement
        [                 {              {
        [                 {
        [                 {
        [                 {mixture 25 1 solution/m3 salt
        [                 {apply (3) --  [min
        [                 {              [mean
        [                 {              [max
        [                 {
        [                 {
        [
        [
```

```
*vehicles (1) --[5 vehicles -> 90% remains on pavement
```

[States effectiveness of treatment: 5 vehicles pass after treatment leaving more than 90% of treatment agent on pavement (Axelson, pers. comm., 1999). Trans.]

```
*weather (1) --   [much snow/rain -> two hours
                  [no precipitation -> several days


*vehicles (2) --[5 vehicles -> 90% remains on pavement
```

9.1.2 Mechanical

[Original did not contain this section even though it was listed on page A13-1. Trans.]

9.2 Time demands

```
File: TIDKRAV

root --[point of time -- [treatment shall be accomplished before rush-hour
        [
        [
```

9.3 Forecasts

```
File: PROGNOS                   Last changed: 1991-03-28   10.05

root --{smhi --   {draft smhi --{depends on weather above   smhi = Swedish Met. & Hydrol. Inst.
        {         {
        {         {
        {         {trial in --   {Östergötland
        {         {              {Bohuslän
        {         {
        {         {
        {         {updated from --     {SMHI Norrköping -- {staff works in shifts
        {         {                    {
        {         {                    {
        {         {
        {         {
        (         (forecast --   {planning-forecast (text)
        {         {              {variables
        {         {              {frequency (hours)         [0.5
        {         {              {                          [1.5
        {         {              {                          [3.5
        {         {              {
        {         {              {
        {         {              {90-95% confidence
        {         {
        {         {
        {         {communication -- {smhi's main computer - SNRA computer in Linköping
        {         {
        {         {
        {
        {
        {bergab--{draft bergab --     {depends on previous year's weather         bergab is a
        {         {                    {usual conditions                           private firm
        {         {
        {         {
        {         {interpretation bergab--{intersection of dew-point and pavement temp
        {         {                        {rain changing to snow-- {cold precipitation
        {         {                        {                         {dew-point falls
        {         {                        {                         {*air dries
        {         {                        {

*air dries --     [gap between air temperature and dew-point increases
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Royal Institute of Technology
University of Stockholm

Probabilistic reasoning: Local weather

by ÅKE MALMBERG*

translated by R. V. Wahlgren

1 INTRODUCTION

This paper discusses an attempt to forecast local weather situations. The method builds on networks for describing relationships between variables together with propagation of change in belief based on events that affect some of the variables. The method was applied to one station of the existing system of road weather information system (RWIS) stations in the Swedish road network.

2 RWIS

The Swedish National Road Administration (SNRA) has about 400 RWIS stations located in the road network. Each station gathers information about air and pavement temperature, dewpoint, relative humidity, precipitation, wind strength, and wind direction. In the future, the stations will be able to provide information about the actual freezing-point on the pavement. Measurements of dewpoint and pavement temperature are essential for detecting the formation of frost on the pavement. The RWIS stations can therefore forecast these variables up to four hours ahead.

Information is forwarded to a regional centre where it is analysed and presented to the individual road district contractors. The regional information system contains alarm points and has the capacity to contact the contractors who are on duty. The contractors use an ordinary television and a telephone to gather detailed information from the regional information system.

Two forecasting models are used for dewpoint and pavement temperature. The forecasting models come from Bergab [A private firm. Trans.] and the Swedish Meteorological and Hydrological Institute (SMHI). The model from Bergab uses an earlier executed climate mapping along the mentioned roads while the SMHI model relies on conventional forecasts for the global weather. The SMHI model is being used experimentally in Östergötland and Bohuslän while the Bergab model is used in the balance of the nation. Both models forecast the two temperatures for four hours but only for one station at a time.

3 VVEXP (Road weather expert-system)

Experiments are in progress to, with the aid of meteorological models, forecast and give warning of critical weather conditions. An example of this is the formation of black ice.

* Technical Institute in Östersund

[One line of missing text on original document. Trans.]
...with the knowledge-system applied to the variables and forecasts given above, earlier warnings during critical weather conditions can be received together with advice and instructions for suitable treatments. Calculation of salt amounts and timing so as to minimize salt quantity and maximize its effectiveness are examples of advice and instructions.

The knowledge-base can be thought of as divided into forecasting, detection, and treatment parts. Detection and treatment will not be dealt with further in this paper.

The forecast values for dewpoint and pavement temperature can, together with other variables from the RWIS station, be used to predict a situation where the risk of slipperiness on the pavement is large exactly within the road section where the station is located. For forecasting of local weather it is, however, desirable that forecasts from many stations be combined.

4 MODELS

Let the weather at *one* field station be described by the function

Weather(lufu, ndb, tluft, tyta, daggp, vimed, virik)

where the variables have the following meanings:

lufu	relative humidity
ndb	precipitation
tluft	air temperature
tyta	pavement temperature
daggp	dewpoint
vimed	wind speed, average
virik	wind direction

Let every station be represented by a variable V with subscript that gives the station's number (V_0 for the actual station). Furthermore the value's time sequence is given relative to the measurements already obtained.

For example, $V_1(2)$ indicates the forecast weather at station number one in two hours.

The premise for using probabilistic reasoning is based on the assumption that it is possible to localize typical weather situations. A weather system is further assumed to move with a speed and direction that depends on the wind conditions. Forecasts from other sources, for example SMHI can be applied to the model to strengthen confidence in the model's forecasts. The example in Fig. 4.0 shows a weather system at time 0 and the calculated situation four hours later.

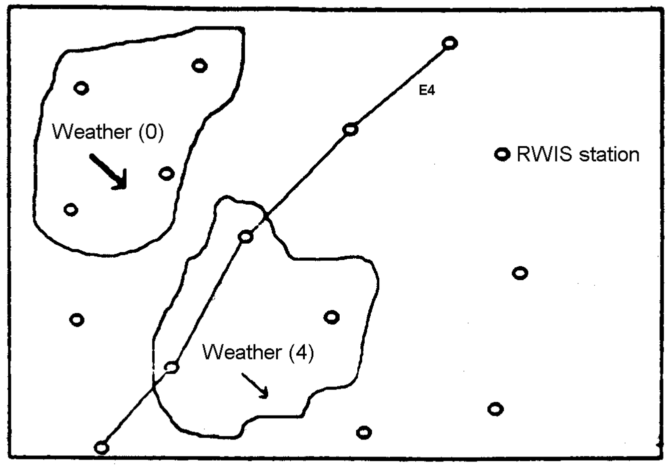

Fig. 4.0 *Weather system movement*

4.1 ONE RWIS STATION

Let the valuation of function V be (+, -) where + means slippery and - means not slippery. Slippery relates to that type of weather which gives some form of slipperiness to the pavement. Typical weather situations which cause the pavement to become slippery are snowfall, freezing rain and deposition of frost. Frost results when the dewpoint is higher than the pavement temperature and the pavement temperature is below the freezing-point. Assume that the weather at the RWIS station in question is not influenced by weather at the other stations.

Let $V_0(0)$ represent the weather at the immediate measurement point (point 0) while $V_0(T)$ represents the weather at the same measurement point in T hours.

Assume that there is a dependency between the weather now and the weather in T hours at the same point. This condition can be described by the probability $P(V_0(T)|V_0(0))$, that is to say, if we know the weather now we can state our belief in different weather situations in T hours. The below suggested model has the approach that the observed weather now is consistent with the weather situation in T hours at the same point. For calculations in the model it is therefore necessary to estimate $P(V_0(0)|V_0(T))$.

Bayes' formula gives:

$$P(V_0(0)|V_0(T)) = P(V_0(T)|V_0(0)) * \frac{P(V_0(0))}{P(V_0(T))}$$

In the example, times for forecast weather have been chosen to be two and four hours. Under the given constraints relationships between the variables can be represented by the structure in Fig. 4.1.

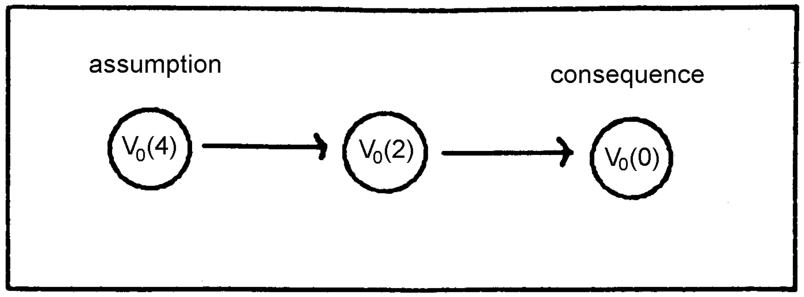

Fig. 4.1 *One RWIS station*

$V_0(0)$ is one observation (evidence). [“Evidence” is Pearl’s terminology. Trans.] The observation influences the confidence for the forecast $V_0(4)$. The weather for the station, calculated according to the function *Weather,* has an uncertainty. The uncertainty is reflected by the vector $8_{Vo(0)}$. The relationships between the nodes are given in the matrices $M_{Vo(0)*Vo(2)}$ and $M_{Vo(0)*Vo(4)}$. If, for example, the meteorologist/expert regards the probability that a weather pattern will persist is greater than that the weather will change, the diagonal of the matrix ([1:1], [2:2] should contain larger values than the other cells.

The approach involves producing a matrix (M_{xy}) for each and every connection between the nodes, that is, in the examples a matrix corresponds to each arrow between nodes. In the example in Fig. 4.1 only two matrices are called for which could be manually constructed by an expert/meteorologist. The method is, however, unusable in practice when the number of matrices increases. A possible technique could then be to work with historical data from actual measurement points. RWIS values from earlier measurements have been archived and can be used to estimate the desired relationships and the frequencies of various weather patterns.

Suppose that a forecast from SMHI gives a new estimate of $V_0(2)$. This gives a new 8-value for $V_0(2)$ and therefore a change in BEL ($V_0(4)$). [Pearl (page 152) used BEL to denote “...the dynamic values of the updated node probabilities...the overall belief accorded to proposition...by all evidence so far received. Trans.]

4.1.1 EXAMPLE 1

Model: $V_0(4) \rightarrow V_0(2) \rightarrow V_0(0)$

From weather observations <u>now</u> calculate the confidence in different weather patterns in four hours.

Assume the following:

$$\lambda_{V_0(0)} = \begin{bmatrix} 0.9 \\ 0.1 \end{bmatrix}$$ values indicate slipperiness

$$\pi_{V_0(4)} = \begin{bmatrix} 0.5 \\ 0.5 \end{bmatrix}$$

no knowlege about the weather in four hours

$$M_{V_0(0)|V_0(2)} = \begin{bmatrix} 0.8 & 0.2 \\ 0.2 & 0.8 \end{bmatrix}$$

$(V_0(0) = + \mid V_0(2) = +) = 0.8$, ... etc.

It is much more probable that the weather does not change (0.8) than that the weather changes (0.2)

$$M_{V_0(2)|V_0(4)} = \begin{bmatrix} 0.6 & 0.4 \\ 0.4 & 0.6 \end{bmatrix}$$

There is somewhat greater probability that the weather does not change (0.6) than the weather changing (0.4)

$$\lambda(x) = M_{y|x} * \lambda(y) \qquad \text{(Pearl)} \qquad (1)$$

Eq. (1) gives:

$$\lambda_{V_0(2)} = M_{V_0(0)|V_0(2)} * \lambda_{V_0(0)}$$

$$\lambda_{V_0(2)} = \begin{bmatrix} 0.8 & 0.2 \\ 0.2 & 0.8 \end{bmatrix} * \begin{bmatrix} 0.9 \\ 0.1 \end{bmatrix} = \begin{bmatrix} 0.74 \\ 0.26 \end{bmatrix}$$

$$\lambda_{V_0(4)} = M_{V_0(2)|V_0(4)} * \lambda_{V_0(2)}$$

$$\lambda_{V_0(4)} = \begin{bmatrix} 0.6 & 0.4 \\ 0.4 & 0.6 \end{bmatrix} * \begin{bmatrix} 0.74 \\ 0.26 \end{bmatrix} = \begin{bmatrix} 0.548 \\ 0.542 \end{bmatrix}$$

$$BEL(x) = \alpha * \pi(x) * \lambda(x) \qquad \text{(Pearl)} \qquad (2)$$

Eq. (2) gives

$$\mathrm{BEL}(V_0(4)) = \alpha * \pi_{V_0(4)} * \lambda_{V_0(4)} = \alpha * \begin{bmatrix} 0.5 \\ 0.5 \end{bmatrix} * \begin{bmatrix} 0.55 \\ 0.45 \end{bmatrix} = \begin{bmatrix} 0.55 \\ 0.45 \end{bmatrix}$$

Notice that the difference between the two elements of the vector is small which means that the calculation gave almost no knowledge of the forecast weather. The reason for this lies in the matrix $M_{Vo(2)|Vo(4)}$.

4.1.2 EXAMPLE 2

Model: $V_0(8) \rightarrow V_0(4) \rightarrow V_0(2) \rightarrow V_0(0)$

Same assumptions as in example 1 except for a forecast from SMHI which gives knowledge of probable weather in eight hours.

Assume the following:

$$M_{V_0(4)|V_0(8)} = \begin{bmatrix} 0.7 & 0.3 \\ 0.3 & 0.7 \end{bmatrix}$$

It is more probable that the weather does not change (0.7) than that the weather changes (0.3)

$$\pi_{V_0(8)} = \begin{bmatrix} 0.8 \\ 0.2 \end{bmatrix}$$ SMHI forecast probability of slipperiness is (0.8)

$$\pi(y) = \pi(x) * M_{y|x} \qquad \text{(Pearl)} \qquad (3)$$

Eq. (3) gives:

$$\pi_{V_0(4)} = \pi_{V_0(8)} * M_{V_0(4)|V_0(8)}$$

$$\pi_{V_0(4)} = \begin{bmatrix} 0.8 \\ 0.2 \end{bmatrix} * \begin{bmatrix} 0.7 & 0.3 \\ 0.3 & 0.7 \end{bmatrix} = \begin{bmatrix} 0.62 \\ 0.38 \end{bmatrix}$$

$$\mathrm{BEL}(V_0(4)) = \alpha * \pi_{V_0(4)} * \lambda_{V_0(4)} = \alpha * \begin{bmatrix} 0.62 \\ 0.38 \end{bmatrix} * \begin{bmatrix} 0.55 \\ 0.45 \end{bmatrix} = \alpha * \begin{bmatrix} 0.341 \\ 0.171 \end{bmatrix} = \begin{bmatrix} 0.67 \\ 0.33 \end{bmatrix}$$

Notice that the difference between the two elements in the vector is large which means that the calculation provided knowledge about the forecast weather. The reason for this was the knowledge provided by the SMHI forecast.

4.2 RING OF RWIS STATIONS

The reasoning above was based on a very limited example of two nodes. A more realistic model of reality describes the weather at location (V_0) in T hours as being dependent on the weather at surrounding locations (V_1 ...V_n) just now. By surrounding is meant locations which lie within such a distance that the weather at the measurement locations can influence the weather at location V_0 within T hours.

Let the value assigned to V be (n+,n-,ne+,ne-,e+,e-,se+,se-,s+,s-,sw+,sw-,w+,w-,nw+,nw-,calm+,calm-). The symbols stand for wind direction and weather situation where “+” means pavement is slippery and “-” means pavement is not slippery.

e.g. se+ means wind direction southeast with pavment slippery.

Assume further that the weather in two hours at a RWIS station depends on the weather at the station in question and the weather at the stations that lie within a radius that corresponds to the possible movement of weather systems during two hours.

Under the given restrictions, the relationships between the variables can be represented by the structure in Fig. 4.2.

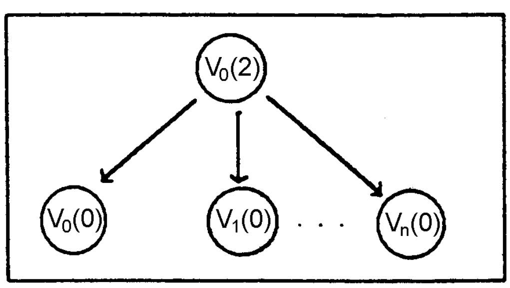

Fig. 4.2 *Ring of RWIS stations*

According to Pearl the belief for a forecast for $V_0(2)$ is calculated by first calculating $BEL(V_n(0))$ and thereafter propagating from $V_n(0)$ to $V_0(2)$. The propagation from $V_n(0)$ to $V_0(2)$ depends on the matrix $M_{Vn(0)|Vo(2)}$.

Propagation from $V_n(0)$ to $V_0(2)$is accomplished according to the theory of propagation in polytrees (Pearl, Eq. 4.49–4.53). [Belief propagation in causal polytrees (singly connected networks), Pearl, p. 175. Trans.]

4.3 SEVERAL LEVELS OF RWIS STATIONS

A more complete calculation of confidence for a weather forecast for a RWIS station can be accomplished if the model looks at several levels of stations. Which stations should be included is decided by how long in terms of time from V_0 that the weather at other stations is considered to influence the weather at

$V_0(T)$.

With this approach the structure for describing the relationships becomes complex. It forms multiple connections which presents complex but solvable calculations. For every relationship (arrow) a matrix needs to be constructed, manually or automatically.

Calculation volume increases exponentially with the number of node levels involved in the model. To forecast the weather within one region, calculations for each node need to be done as described above for one node.

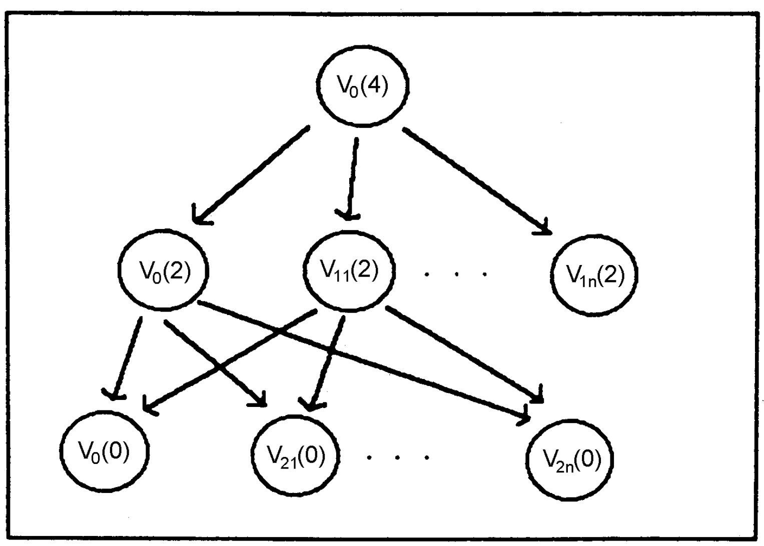

Fig. 4.3 *Several levels of RWIS stations.*

If the structure for several levels of RWIS stations forms polytrees, the propagation of $BEL(V_0(4))$ can be calculated. If the structure has loops Pearl mentions three methods of attacking the problem.

5 SUMMARY

The model of the relationships between the RWIS stations is in reality significantly more complex than the simplified models in 4.1, 4.2, and 4.3. In the models the measured values for each station were translated via a function into one value (=weather). A proper procedure could be to regard each measurement value as a variable in a model. Stations which will be regarded as influencing the weather at a location can be guided by $M_{y|x}$ which makes it possible theoretically to take all the stations into account. Distance, terrain and other factors which can influence the movement of local weather are reflected in those matrices ($M_{y|x}$) which are estimated from historical data. A structure describing a model with an arbitrary number of stations contains dependencies which results in a structure of very complex character. A suitable beginning could be to make a reasonable limitation on the number of variables/nodes. Grouping of variables and nodes could also be necessary to limit the volume of calculations.

To solve a system with an arbitrary number of stations requires a comprehensive study which lies outside the scope of this paper.

6 REFERENCE

Pearl, J. (1988) *Probabilistic reasoning in intelligent systems.* Morgan Kaufmann Publ.

APPENDIX E

SUMMARIES OF
ACTIONS ADVISED BY THE SNRA
DECISION SUPPORT SYSTEM

Prepared by:
Fleet Technology Ltd.
311 Legget Drive
Kanata, Ont.
K2K 1Z8

Prepared for:
Ministry of Transportation of Ontario (MTO)
1201 Wilson Ave.
Downsview, Ont.
M3M 1J8

Table 1 Action Table Summary by Case

Precipitation Currently Occurring ?	Precipitation Forecast To Occur ?	Current Pavement Condition	Forecast Pavement Condition	Table Following with Advised Actions
Yes	Yes	Dry	Various[1]	Table 2
Yes	Yes	Not dry[2]	Not important	Table 3
Yes	No	Various[3]		Table 4
No	Yes	Various[4]		Table 5
No	No	Various[5]		Table 6

Notes:

1. The forecast pavement conditions are: moist ; wet ; light frost ; heavy frost ; thin ice ; thick ice ; snow slush ; wet snow ; and dry snow.
2. The current pavement conditions included are: moist ; wet ; light frost ; heavy frost ; thin ice ; thick ice ; snow slush ; wet snow ; and dry snow.
3. The following pavement surface condition combinations are considered:

Current Condition	Forecast Condition
dry ; light frost ; heavy frost ; thin ice ; thick ice ; snow slush ; wet snow ; dry snow	not important
moist	dry ; moist ; wet ; light frost ; heavy frost ; thin ice ; thick ice ; snow slush ; wet snow ; dry snow
wet	dry ; moist ; wet ; light frost ; heavy frost ; thin ice ; thick ice ; snow slush ; wet snow ; dry snow

4. The following pavement surface condition combinations are considered:

Current Condition	Forecast Condition
moist ; wet ; light frost ; heavy frost ; thin ice ; thick ice ; snow slush ; wet snow ; dry snow	not important
dry	moist ; wet ; light frost ; heavy frost ; thin ice ; thick ice ; snow slush ; wet snow ; dry snow

5. The following pavement surface condition combinations are considered:

Current Condition	Forecast Condition
light frost ; heavy frost ; thin ice ; thick ice ; snow slush ; wet snow ; dry snow	not important
dry	dry ; moist ; wet ; light frost ; heavy frost
moist	dry ; moist ; wet ; light frost ; heavy frost ; ice ; snow cover
wet	dry ; moist ; wet ; light frost ; heavy frost ; ice

Table 2 Action Table[1] For:

- Precipitation Occurring Now & Forecasted To Occur As Well
- Pavement Currently Dry

Air Temp[2]	Precipitation		Pavement Condition		Current[3] Pavement Temp[2]	Action Advised	
	Current[3]	Forecast[3]	Current[3]	Forecast[3]		Moist Salt[7] (g/m^2)	Sol'n[7] (g/m^2)
>= + 10	not important - not included as specifiers					no action required	
<= + 10	occurring[4]	to occur[4]	dry	moist	not imp[8]	no action required	
<= + 10	occurring[4]	to occur[4]	dry	wet	not imp[8]	no action required	
<= + 10	occurring[4]	to occur[4]	dry	light frost	> 0	never[5]	
<= + 10	occurring[4]	to occur[4]	dry	light frost	-2/0[6]	5	10
<= + 10	occurring[4]	to occur[4]	dry	light frost	-4/-2[6]	7.5	15
<= + 10	occurring[4]	to occur[4]	dry	light frost	-6/-4[6]	10	20
<= + 10	occurring[4]	to occur[4]	dry	light frost	-8/-6[6]	12.5	25
<= + 10	occurring[4]	to occur[4]	dry	light frost	-10/-8[6]	15	30
<= + 10	occurring[4]	to occur[4]	dry	light frost	<-10	no action required	
<= + 10	occurring[4]	to occur[4]	dry	heavy frost	> 0	never[5]	
<= + 10	occurring[4]	to occur[4]	dry	heavy frost	-2/0[6]	7.5	15
<= + 10	occurring[4]	to occur[4]	dry	heavy frost	-4/-2[6]	10	20
<= + 10	occurring[4]	to occur[4]	dry	heavy frost	-6/-4[6]	12.5	25
<= + 10	occurring[4]	to occur[4]	dry	heavy frost	-8/-6[6]	15	30
<= + 10	occurring[4]	to occur[4]	dry	heavy frost	-10/-8[6]	17.5	35
<= + 10	occurring[4]	to occur[4]	dry	heavy frost	<-10	no action required	

<u>Notes:</u>

1. Taken from pages A13-20 to A13-32 of SNRA Translation.
2. Units not listed in SNRA Translation – presumed to be °C.
3. Current and forecast presumed to be "measured" and "prognosticated" respectively, as given in the SNRA Translation.
4. The SNRA Translation uses "yes". It is presumed that this indicates occurrence or forecast to occur.
5. The SNRA Translation uses "never". This is presumed to indicate that this case will never occur.
6. This code is taken directly from the SNRA Translation. It is presumed to indicate the minimum and maximum temperature of the applicable range.
7. The indicated application rates are taken from pg A13-33 of the SNRA translation. The material comprising "Solution" is not defined in the SNRA translation.
8. "not imp." – not important

Table 2 (cont'd) Action Table[1] For:

- Precipitation Occurring Now & Forecasted To Occur As Well
- Pavement Currently Dry

Air Temp[2]	Precipitation		Pavement Condition		Current[3] Pavement Temp[2]	Action Advised	
	Current[3]	Forecast[3]	Current[3]	Forecast[3]		Moist Salt[7] (g/m^2)	Sol'n[7] (g/m^2)
<= + 10	occurring[4]	to occur[4]	dry	thin ice	> 0	never[5]	
<= + 10	occurring[4]	to occur[4]	dry	thin ice	-2/0[6]	5	10
<= + 10	occurring[4]	to occur[4]	dry	thin ice	-4/-2[6]	7.5	15
<= + 10	occurring[4]	to occur[4]	dry	thin ice	-6/-4[6]	10	20
<= + 10	occurring[4]	to occur[4]	dry	thin ice	-8/-6[6]	12.5	25
<= + 10	occurring[4]	to occur[4]	dry	thin ice	-10/-8[6]	15	30
<= + 10	occurring[4]	to occur[4]	dry	thin ice	<-10	no action required	
<= + 10	occurring[4]	to occur[4]	dry	thick ice	> 0	never[5]	
<= + 10	occurring[4]	to occur[4]	dry	thick ice	-2/0[6]	10	20
<= + 10	occurring[4]	to occur[4]	dry	thick ice	-4/-2[6]	12.5	25
<= + 10	occurring[4]	to occur[4]	dry	thick ice	-6/-4[6]	15	30
<= + 10	occurring[4]	to occur[4]	dry	thick ice	-8/-6[6]	17.5	35
<= + 10	occurring[4]	to occur[4]	dry	thick ice	-10/-8[6]	20	40
<= + 10	occurring[4]	to occur[4]	dry	thick ice	<-10	no action required	
<= + 10	occurring[4]	to occur[4]	dry	snow slush	not imp.[8]	never[5]	
<= + 10	occurring[4]	to occur[4]	dry	wet snow	> 0	7.5	15
<= + 10	occurring[4]	to occur[4]	dry	wet snow	-2/0[6]	7.5	15
<= + 10	occurring[4]	to occur[4]	dry	wet snow	-4/-2[6]	10	20
<= + 10	occurring[4]	to occur[4]	dry	wet snow	-6/-4[6]	12.5	25
<= + 10	occurring[4]	to occur[4]	dry	wet snow	-8/-6[6]	15	30
<= + 10	occurring[4]	to occur[4]	dry	wet snow	-10/-8[6]	17.5	35
<= + 10	occurring[4]	to occur[4]	dry	wet snow	<-10	no action required	
<= + 10	occurring[4]	to occur[4]	dry	dry snow	> 0	7.5	15
<= + 10	occurring[4]	to occur[4]	dry	dry snow	-2/0[6]	7.5	15
<= + 10	occurring[4]	to occur[4]	dry	dry snow	-4/-2[6]	no action required	
<= + 10	occurring[4]	to occur[4]	dry	dry snow	-6/-4[6]	no action required	
<= + 10	occurring[4]	to occur[4]	dry	dry snow	-8/-6[6]	no action required	
<= + 10	occurring[4]	to occur[4]	dry	dry snow	-10/-8[6]	no action required	
<= + 10	occurring[4]	to occur[4]	dry	dry snow	<-10	no action required	

Notes:

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7. The indicated application rates are taken from pg A13-33 of the SNRA translation. The material comprising "Solution" is not defined in the SNRA translation.
8. "not imp." – not important

Table 3 Action Table[1] For:

- Precipitation Occurring Now & Forecasted To Occur As Well
- Pavement Currently Not Dry

Air Temp[2]	Precipitation		Pavement Condition		Current[3] Pavement Temp[2]	Action Advised	
	Current[3]	Forecast[3]	Current[3]	Forecast[3]		Moist Salt[7](g/m^2)	Sol'n[7] (g/m^2)
>= + 10	not important - not included as specifiers					no action required	
<= + 10	occurring[4]	to occur[4]	moist	not imp[8]	not imp[8]	no action required	
<= + 10	occurring[4]	to occur[4]	wet	not imp[8]	not imp[8]	no action required	
<= + 10	occurring[4]	to occur[4]	light frost	not imp[8]	> 0	never[5]	
<= + 10	occurring[4]	to occur[4]	light frost	not imp[8]	-2/0[6]	5	10
<= + 10	occurring[4]	to occur[4]	light frost	not imp[8]	-4/-2[6]	7.5	15
<= + 10	occurring[4]	to occur[4]	light frost	not imp[8]	-6/-4[6]	7.5	15
<= + 10	occurring[4]	to occur[4]	light frost	not imp[8]	-8/-6[6]	10	20
<= + 10	occurring[4]	to occur[4]	light frost	not imp[8]	-10/-8[6]	15	30
<= + 10	occurring[4]	to occur[4]	light frost	not imp[8]	<-10	no action required	
<= + 10	occurring[4]	to occur[4]	heavy frost	not imp[8]	> 0	never[5]	
<= + 10	occurring[4]	to occur[4]	heavy frost	not imp[8]	-2/0[6]	5	10
<= + 10	occurring[4]	to occur[4]	heavy frost	not imp[8]	-4/-2[6]	7.5	15
<= + 10	occurring[4]	to occur[4]	heavy frost	not imp[8]	-6/-4[6]	7.5	15
<= + 10	occurring[4]	to occur[4]	heavy frost	not imp[8]	-8/-6[6]	10	20
<= + 10	occurring[4]	to occur[4]	heavy frost	not imp[8]	-10/-8[6]	15	30
<= + 10	occurring[4]	to occur[4]	heavy frost	not imp[8]	<-10	no action required	
<= + 10	occurring[4]	to occur[4]	thin ice	not imp[8]	> 0	never[5]	
<= + 10	occurring[4]	to occur[4]	thin ice	not imp[8]	-2/0[6]	5	10
<= + 10	occurring[4]	to occur[4]	thin ice	not imp[8]	-4/-2[6]	7.5	15
<= + 10	occurring[4]	to occur[4]	thin ice	not imp[8]	-6/-4[6]	7.5	15
<= + 10	occurring[4]	to occur[4]	thin ice	not imp[8]	-8/-6[6]	10	20
<= + 10	occurring[4]	to occur[4]	thin ice	not imp[8]	-10/-8[6]	15	30
<= + 10	occurring[4]	to occur[4]	thin ice	not imp[8]	<-10	no action required	

Notes:

1. Taken from pages A13-20 to A13-32 of SNRA Translation.
2. Units not listed in SNRA Translation – presumed to be °C.
3. Current and forecast presumed to be “measured” and “prognosticated” respectively, as given in the SNRA Translation.
4. The SNRA Translation uses “yes”. This is presumed to mean occurrence or forecast to occur.
5. The SNRA Translation uses “never”. This is presumed to indicate that this case will never occur.
6. This code is taken directly from the SNRA Translation. It is presumed to indicate the minimum and maximum temperature of the applicable range.
7. The indicated application rates are taken from pg A13-33 of the SNRA translation. The material comprising “Solution” is not defined in the SNRA translation.
8. “not imp.” – not important
9. “n/a” – not advised to be used

Table 3 (cont'd) Action Table[1] For:

- Precipitation Occurring Now & Forecasted To Occur As Well
- Pavement Currently Not Dry

Air	Precipitation		Pavement Condition		Current[3]	Action Advised	
Temp[2]	Current[3]	Forecast[3]	Current[3]	Forecast[3]	Pavement Temp[2]	Moist Salt[7](g/m^2)	Sol'n[7] (g/m^2)
<= + 10	occurring[4]	to occur[4]	thick ice	not imp[8]	> 0	20	40
<= + 10	occurring[4]	to occur[4]	thick ice	not imp[8]	-2/0[6]	20	40
<= + 10	occurring[4]	to occur[4]	thick ice	not imp[8]	-4/-2[6]	25	n/a[9]
<= + 10	occurring[4]	to occur[4]	thick ice	not imp[8]	-6/-4[6]	25	n/a[9]
<= + 10	occurring[4]	to occur[4]	thick ice	not imp[8]	-8/-6[6]	30	n/a[9]
<= + 10	occurring[4]	to occur[4]	thick ice	not imp[8]	-10/-8[6]	30	n/a[9]
<= + 10	occurring[4]	to occur[4]	thick ice	not imp[8]	<-10	mechanical anti-icing	
<= + 10	occurring[4]	to occur[4]	snow slush	not imp[8]	> 0	5	10
<= + 10	occurring[4]	to occur[4]	snow slush	not imp[8]	-2/0[6]	7.5	15
<= + 10	occurring[4]	to occur[4]	snow slush	not imp[8]	-4/-2[6]	10	20
<= + 10	occurring[4]	to occur[4]	snow slush	not imp[8]	-6/-4[6]	12.5	25
<= + 10	occurring[4]	to occur[4]	snow slush	not imp[8]	-8/-6[6]	15	30
<= + 10	occurring[4]	to occur[4]	snow slush	not imp[8]	-10/-8[6]	17.5	35
<= + 10	occurring[4]	to occur[4]	snow slush	not imp[8]	<-10	plowing	
<= + 10	occurring[4]	to occur[4]	wet snow	not imp[8]	> 0	7.5	15
<= + 10	occurring[4]	to occur[4]	wet snow	not imp[8]	-2/0[6]	10	20
<= + 10	occurring[4]	to occur[4]	wet snow	not imp[8]	-4/-2[6]	12.5	25
<= + 10	occurring[4]	to occur[4]	wet snow	not imp[8]	-6/-4[6]	15	30
<= + 10	occurring[4]	to occur[4]	wet snow	not imp[8]	-8/-6[6]	17.5	35
<= + 10	occurring[4]	to occur[4]	wet snow	not imp[8]	-10/-8[6]	20	40
<= + 10	occurring[4]	to occur[4]	wet snow	not imp[8]	<-10	plowing	
<= + 10	occurring[4]	to occur[4]	dry snow	not imp[8]	> 0	5 & plowing	10 & plowing
<= + 10	occurring[4]	to occur[4]	dry snow	not imp[8]	-2/0[6]	7.5 & plowing	15 & plowing
<= + 10	occurring[4]	to occur[4]	dry snow	not imp[8]	-4/-2[6]	plowing	
<= + 10	occurring[4]	to occur[4]	dry snow	not imp[8]	-6/-4[6]	plowing	
<= + 10	occurring[4]	to occur[4]	dry snow	not imp[8]	-8/-6[6]	plowing	
<= + 10	occurring[4]	to occur[4]	dry snow	not imp[8]	-10/-8[6]	plowing	
<= + 10	occurring[4]	to occur[4]	dry snow	not imp[8]	<-10	plowing	

<u>Notes:</u>

1. Taken from pages A13-20 to A13-32 of SNRA Translation.
2. Units not listed in SNRA Translation – presumed to be °C.
3. Current and forecast presumed to be "measured" and "prognosticated" respectively, as given in SNRA Translation.
4. The SNRA Translation uses "yes". This is presumed to mean occurrence or forecast to occur.
5. The SNRA Translation uses "never". This is presumed to indicate that this case will never occur.
6. This code is taken directly from the SNRA Translation. It is presumed to indicate the minimum and maximum temperature of the applicable range.
7. The indicated application rates are taken from pg A13-33 of the SNRA translation. The material comprising "Solution" is not defined in the SNRA translation.
8. "not imp." – not important
9. "n/a" – not advised to be used

Table 4 Action Table[1] For:

- Precipitation Occurring Now But Not Forecasted To Continue
- Various Current and Forecasted Pavement Conditions

Air Temp[2]	Precipitation		Pavement Condition		Current[3] Pavement Temp[2]	Action Advised	
	Current[3]	Forecast[3]	Current[3]	Forecast[3]		Moist Salt[7] (g/m^2)	Sol'n[7] (g/m^2)
>= + 10	not important - not included as specifiers					no action required	
<= + 10	occurring[4]	not to occur[4]	dry	not imp[8]	not imp[8]	never[5]	
<= + 10	occurring[4]	not to occur[4]	moist	dry	not imp[8]	no action required	
<= + 10	occurring[4]	not to occur[4]	moist	moist	not imp[8]	no action required	
<= + 10	occurring[4]	not to occur[4]	moist	wet	not imp[8]	no action required	
<= + 10	occurring[4]	not to occur[4]	moist	light frost	> 0	never[5]	
<= + 10	occurring[4]	not to occur[4]	moist	light frost	-2/0[6]	5	10
<= + 10	occurring[4]	not to occur[4]	moist	light frost	-4/-2[6]	7.5	15
<= + 10	occurring[4]	not to occur[4]	moist	light frost	-6/-4[6]	10	20
<= + 10	occurring[4]	not to occur[4]	moist	light frost	-8/-6[6]	12.5	25
<= + 10	occurring[4]	not to occur[4]	moist	light frost	-10/-8[6]	15	30
<= + 10	occurring[4]	not to occur[4]	moist	light frost	<-10	no action required	
<= + 10	occurring[4]	not to occur[4]	moist	heavy frost	> 0	never[5]	
<= + 10	occurring[4]	not to occur[4]	moist	heavy frost	-2/0[6]	7.5	15
<= + 10	occurring[4]	not to occur[4]	moist	heavy frost	-4/-2[6]	10	20
<= + 10	occurring[4]	not to occur[4]	moist	heavy frost	-6/-4[6]	12.5	25
<= + 10	occurring[4]	not to occur[4]	moist	heavy frost	-8/-6[6]	15	30
<= + 10	occurring[4]	not to occur[4]	moist	heavy frost	-10/-8[6]	17.5	35
<= + 10	occurring[4]	not to occur[4]	moist	heavy frost	<-10	no action required	
<= + 10	occurring[4]	not to occur[4]	moist	thin ice	> 0	never[5]	
<= + 10	occurring[4]	not to occur[4]	moist	thin ice	-2/0[6]	5	10
<= + 10	occurring[4]	not to occur[4]	moist	thin ice	-4/-2[6]	7.5	15
<= + 10	occurring[4]	not to occur[4]	moist	thin ice	-6/-4[6]	10	20
<= + 10	occurring[4]	not to occur[4]	moist	thin ice	-8/-6[6]	12.5	25
<= + 10	occurring[4]	not to occur[4]	moist	thin ice	-10/-8[6]	15	30
<= + 10	occurring[4]	not to occur[4]	moist	thin ice	<-10	no action required	
<= + 10	occurring[4]	not to occur[4]	moist	thick ice	> 0	never[5]	
<= + 10	occurring[4]	not to occur[4]	moist	thick ice	-2/0[6]	7.5	15
<= + 10	occurring[4]	not to occur[4]	moist	thick ice	-4/-2[6]	10	20
<= + 10	occurring[4]	not to occur[4]	moist	thick ice	-6/-4[6]	12.5	25
<= + 10	occurring[4]	not to occur[4]	moist	thick ice	-8/-6[6]	15	30
<= + 10	occurring[4]	not to occur[4]	moist	thick ice	-10/-8[6]	17.5	35
<= + 10	occurring[4]	not to occur[4]	moist	thick ice	<-10	no action required	

1. Taken from pages A13-20 to A13-32 of SNRA Translation.
2. Units not listed in SNRA Translation – presumed to be °C.
3. Current and forecast presumed to be "measured" and "prognosticated" respectively, as given in the Translation.
4. The SNRA Translation uses "yes". It is presumed that this indicates occurrence or forecast to occur.
5. The SNRA Translation uses "never". This is presumed to indicate that this case will never occur.
6. This code is taken directly from the SNRA Translation. It is presumed to indicate the minimum and maximum temperature of the applicable range.
7. The indicated application rates are taken from pg A13-33 of the SNRA translation. The material comprising "Solution" is not defined in the SNRA translation.
8. "not imp." – not important

Table 4(cont'd) Action Table[1] For:

- Precipitation Occurring Now But Not Forecasted To Continue
- Various Current and Forecasted Pavement Conditions

Air Temp[2]	Precipitation Current[3]	Precipitation Forecast[3]	Pavement Condition Current[3]	Pavement Condition Forecast[3]	Current[3] Pavement Temp[2]	Action Advised Moist Salt[7] (g/m^2)	Action Advised Sol'n[7] (g/m^2)
<= + 10	occurring[4]	not to occur[4]	moist	snow slush	not imp[8]	never[5]	
<= + 10	occurring[4]	not to occur[4]	moist	wet snow	not imp[8]	never[5]	
<= + 10	occurring[4]	not to occur[4]	moist	dry snow	not imp[8]	never[5]	
<= + 10	occurring[4]	not to occur[4]	wet	dry	not imp[8]	no action required	
<= + 10	occurring[4]	not to occur[4]	wet	moist	not imp[8]	no action required	
<= + 10	occurring[4]	not to occur[4]	wet	wet	not imp[8]	no action required	
<= + 10	occurring[4]	not to occur[4]	wet	light frost	> 0	never[5]	
<= + 10	occurring[4]	not to occur[4]	wet	light frost	-2/0[6]	5	10
<= + 10	occurring[4]	not to occur[4]	wet	light frost	-4/-2[6]	7.5	15
<= + 10	occurring[4]	not to occur[4]	wet	light frost	-6/-4[6]	10	20
<= + 10	occurring[4]	not to occur[4]	wet	light frost	-8/-6[6]	12.5	25
<= + 10	occurring[4]	not to occur[4]	wet	light frost	-10/-8[6]	15	30
<= + 10	occurring[4]	not to occur[4]	wet	light frost	<-10	no action required	
<= + 10	occurring[4]	not to occur[4]	wet	heavy frost	> 0	never[5]	
<= + 10	occurring[4]	not to occur[4]	wet	heavy frost	-2/0[6]	7.5	15
<= + 10	occurring[4]	not to occur[4]	wet	heavy frost	-4/-2[6]	10	20
<= + 10	occurring[4]	not to occur[4]	wet	heavy frost	-6/-4[6]	12.5	25
<= + 10	occurring[4]	not to occur[4]	wet	heavy frost	-8/-6[6]	15	30
<= + 10	occurring[4]	not to occur[4]	wet	heavy frost	-10/-8[6]	17.5	35
<= + 10	occurring[4]	not to occur[4]	wet	heavy frost	<-10	no action required	
<= + 10	occurring[4]	not to occur[4]	wet	snow slush	not imp[8]	never[5]	
<= + 10	occurring[4]	not to occur[4]	wet	wet snow	not imp[8]	never[5]	
<= + 10	occurring[4]	not to occur[4]	wet	dry snow	not imp[8]	never[5]	
<= + 10	occurring[4]	not to occur[4]	wet	thin ice	> 0	never[5]	
<= + 10	occurring[4]	not to occur[4]	wet	thin ice	-2/0[6]	5	10
<= + 10	occurring[4]	not to occur[4]	wet	thin ice	-4/-2[6]	7.5	15
<= + 10	occurring[4]	not to occur[4]	wet	thin ice	-6/-4[6]	10	20
<= + 10	occurring[4]	not to occur[4]	wet	thin ice	-8/-6[6]	12.5	25
<= + 10	occurring[4]	not to occur[4]	wet	thin ice	-10/-8[6]	15	30
<= + 10	occurring[4]	not to occur[4]	wet	thin ice	<-10	no action required	

Notes:

1. Taken from pages A13-20 to A13-32 of SNRA Translation.
2. Units not listed in SNRA Translation – presumed to be °C.
3. Current and forecast presumed to be "measured" and "prognosticated" respectively, as given in the SNRA Translation.
4. The SNRA Translation uses "yes". It is presumed that this indicates occurrence or forecast to occur.
5. The SNRA Translation uses "never". This is presumed to indicate that this case will never occur.
6. This code is taken directly from the SNRA Translation. It is presumed to indicate the minimum and maximum temperature of the applicable range.
7. The indicated application rates are taken from pg A13-33 of the SNRA translation. The material comprising "Solution" is not defined in the SNRA translation.
8. "not imp." – not important

Table 4(cont'd) Action Table[1] For:

- Precipitation Occurring Now But Not Forecasted To Continue
- Various Current and Forecasted Pavement Conditions

Air	Precipitation		Pavement Condition		Current[3]	Action Advised	
Temp[2]	Current[3]	Forecast[3]	Current[3]	Forecast[3]	Pavement Temp[2]	Moist Salt[7](g/m^2)	Sol'n[7] (g/m^2)
<= + 10	occurring[4]	not to occur[4]	wet	thick ice	> 0	never[5]	
<= + 10	occurring[4]	not to occur[4]	wet	thick ice	-2/0[6]	7.5	15
<= + 10	occurring[4]	not to occur[4]	wet	thick ice	-4/-2[6]	10	20
<= + 10	occurring[4]	not to occur[4]	wet	thick ice	-6/-4[6]	12.5	25
<= + 10	occurring[4]	not to occur[4]	wet	thick ice	-8/-6[6]	15	30
<= + 10	occurring[4]	not to occur[4]	wet	thick ice	-10/-8[6]	17.5	35
<= + 10	occurring[4]	not to occur[4]	wet	thick ice	<-10	no action required	
<= + 10	occurring[4]	not to occur[4]	light frost	not imp[8]	> 0	never[5]	
<= + 10	occurring[4]	not to occur[4]	light frost	not imp[8]	-2/0[6]	5	10
<= + 10	occurring[4]	not to occur[4]	light frost	not imp[8]	-4/-2[6]	7.5	15
<= + 10	occurring[4]	not to occur[4]	light frost	not imp[8]	-6/-4[6]	10	20
<= + 10	occurring[4]	not to occur[4]	light frost	not imp[8]	-8/-6[6]	12.5	25
<= + 10	occurring[4]	not to occur[4]	light frost	not imp[8]	-10/-8[6]	15	30
<= + 10	occurring[4]	not to occur[4]	light frost	not imp[8]	<-10	no action required	
<= + 10	occurring[4]	not to occur[4]	heavy frost	not imp[8]	> 0	never[5]	
<= + 10	occurring[4]	not to occur[4]	heavy frost	not imp[8]	-2/0[6]	7.5	15
<= + 10	occurring[4]	not to occur[4]	heavy frost	not imp[8]	-4/-2[6]	10	20
<= + 10	occurring[4]	not to occur[4]	heavy frost	not imp[8]	-6/-4[6]	12.5	25
<= + 10	occurring[4]	not to occur[4]	heavy frost	not imp[8]	-8/-6[6]	15	30
<= + 10	occurring[4]	not to occur[4]	heavy frost	not imp[8]	-10/-8[6]	17.5	35
<= + 10	occurring[4]	not to occur[4]	heavy frost	not imp[8]	<-10	no action required	
<= + 10	occurring[4]	not to occur[4]	thin ice	not imp[8]	> 0	never[5]	
<= + 10	occurring[4]	not to occur[4]	thin ice	not imp[8]	-2/0[6]	5	10
<= + 10	occurring[4]	not to occur[4]	thin ice	not imp[8]	-4/-2[6]	7.5	15
<= + 10	occurring[4]	not to occur[4]	thin ice	not imp[8]	-6/-4[6]	10	20
<= + 10	occurring[4]	not to occur[4]	thin ice	not imp[8]	-8/-6[6]	12.5	25
<= + 10	occurring[4]	not to occur[4]	thin ice	not imp[8]	-10/-8[6]	15	30
<= + 10	occurring[4]	not to occur[4]	thin ice	not imp[8]	<-10	no action required	

Notes:

1. Taken from pages A13-20 to A13-32 of SNRA Translation.
2. Units not listed in SNRA Translation – presumed to be °C.
3. Current and forecast presumed to be "measured" and "prognosticated" respectively, as given in the SNRA Translation.
4. The SNRA Translation uses "yes". It is presumed that this indicates occurrence or forecast to occur.
5. The SNRA Translation uses "never". This is presumed to indicate that this case will never occur.
6. This code is taken directly from the SNRA Translation. It is presumed to indicate the minimum and maximum temperature of the applicable range.
7. The indicated application rates are taken from pg A13-33 of the SNRA translation. The material comprising "Solution" is not defined in the SNRA translation.
8. "not imp." – not important

Table 4(cont'd) Action Table[1] For:

- Precipitation Occurring Now But Not Forecasted To Continue
- Various Current and Forecasted Pavement Conditions

Air Temp[2]	Precipitation		Pavement Condition		Current[3] Pavement Temp[2]	Action Advised	
	Current[3]	Forecast[3]	Current[3]	Forecast[3]		Moist Salt[7](g/m^2)	Sol'n[7] (g/m^2)
<= + 10	occurring[4]	not to occur[4]	thick ice	not imp[8]	> 0	20	40
<= + 10	occurring[4]	not to occur[4]	thick ice	not imp[8]	-2/0[6]	20	40
<= + 10	occurring[4]	not to occur[4]	thick ice	not imp[8]	-4/-2[6]	25	n/a[9]
<= + 10	occurring[4]	not to occur[4]	thick ice	not imp[8]	-6/-4[6]	25	n/a[9]
<= + 10	occurring[4]	not to occur[4]	thick ice	not imp[8]	-8/-6[6]	30	n/a[9]
<= + 10	occurring[4]	not to occur[4]	thick ice	not imp[8]	-10/-8[6]	30	n/a[9]
<= + 10	occurring[4]	not to occur[4]	thick ice	not imp[8]	<-10	mechanical anti-icing	
<= + 10	occurring[4]	not to occur[4]	snow slush	not imp[8]	> 0	5	10
<= + 10	occurring[4]	not to occur[4]	snow slush	not imp[8]	-2/0[6]	7.5	15
<= + 10	occurring[4]	not to occur[4]	snow slush	not imp[8]	-4/-2[6]	10	20
<= + 10	occurring[4]	not to occur[4]	snow slush	not imp[8]	-6/-4[6]	12.5	25
<= + 10	occurring[4]	not to occur[4]	snow slush	not imp[8]	-8/-6[6]	15	30
<= + 10	occurring[4]	not to occur[4]	snow slush	not imp[8]	-10/-8[6]	17.5	35
<= + 10	occurring[4]	not to occur[4]	snow slush	not imp[8]	<-10	plowing	
<= + 10	occurring[4]	not to occur[4]	wet snow	not imp[8]	> 0	7.5	15
<= + 10	occurring[4]	not to occur[4]	wet snow	not imp[8]	-2/0[6]	10	15
<= + 10	occurring[4]	not to occur[4]	wet snow	not imp[8]	-4/-2[6]	12.5	25
<= + 10	occurring[4]	not to occur[4]	wet snow	not imp[8]	-6/-4[6]	15	30
<= + 10	occurring[4]	not to occur[4]	wet snow	not imp[8]	-8/-6[6]	17.5	35
<= + 10	occurring[4]	not to occur[4]	wet snow	not imp[8]	-10/-8[6]	20	40
<= + 10	occurring[4]	not to occur[4]	wet snow	not imp[8]	<-10	plowing	
<= + 10	occurring[4]	not to occur[4]	dry snow	not imp[8]	> 0	5 & plowing	10 & plowing
<= + 10	occurring[4]	not to occur[4]	dry snow	not imp[8]	-2/0[6]	7.5 & plowing	15 & plowing
<= + 10	occurring[4]	not to occur[4]	dry snow	not imp[8]	-4/-2[6]	plowing	
<= + 10	occurring[4]	not to occur[4]	dry snow	not imp[8]	-6/-4[6]	plowing	
<= + 10	occurring[4]	not to occur[4]	dry snow	not imp[8]	-8/-6[6]	plowing	
<= + 10	occurring[4]	not to occur[4]	dry snow	not imp[8]	-10/-8[6]	plowing	
<= + 10	occurring[4]	not to occur[4]	dry snow	not imp[8]	<-10	plowing	

Notes:

1. Taken from pages A13-20 to A13-32 of SNRA Translation.
2. Units not listed in SNRA Translation – presumed to be °C.
3. Current and forecast presumed to be "measured" and "prognosticated" respectively, as given in the SNRA Translation.
4. The SNRA Translation uses "yes". It is presumed that this indicates occurrence or forecast to occur.
5. The SNRA Translation uses "never". This is presumed to indicate that this case will never occur.
6. This code is taken directly from the SNRA Translation. It is presumed to indicate the minimum and maximum temperature of the applicable range.
7. The indicated application rates are taken from pg A13-33 of the SNRA translation. The material comprising "Solution" is not defined in the SNRA translation.
8. "not imp." – not important

Table 5 Action Table[1] For:

- No Precipitation Currently But Forecasted To Occur
- Various Current and Forecasted Pavement Conditions

Air Temp[2]	Precipitation		Pavement Condition		Current[3]	Action Advised	
	Current[3]	Forecast[3]	Current[3]	Forecast[3]	Pavement Temp[2]	Moist Salt[7] (g/m^2)	Sol'n[7] (g/m^2)
<= + 10	not occurring[4]	to occur[4]	dry	moist	not imp[8]	no action required	
<= + 10	not occurring[4]	to occur[4]	dry	wet	not imp[8]	no action required	
<= + 10	not occurring[4]	to occur[4]	dry	light frost	> 0	never[5]	
<= + 10	not occurring[4]	to occur[4]	dry	light frost	-2/0[6]	5	10
<= + 10	not occurring[4]	to occur[4]	dry	light frost	-4/-2[6]	5	10
<= + 10	not occurring[4]	to occur[4]	dry	light frost	-6/-4[6]	7.5	15
<= + 10	not occurring[4]	to occur[4]	dry	light frost	-8/-6[6]	10	20
<= + 10	not occurring[4]	to occur[4]	dry	light frost	-10/-8[6]	10	20
<= + 10	not occurring[4]	to occur[4]	dry	light frost	<-10	no action required	
<= + 10	not occurring[4]	to occur[4]	dry	heavy frost	> 0	never[5]	
<= + 10	not occurring[4]	to occur[4]	dry	heavy frost	-2/0[6]	5	10
<= + 10	not occurring[4]	to occur[4]	dry	heavy frost	-4/-2[6]	7.5	15
<= + 10	not occurring[4]	to occur[4]	dry	heavy frost	-6/-4[6]	10	20
<= + 10	not occurring[4]	to occur[4]	dry	heavy frost	-8/-6[6]	10	20
<= + 10	not occurring[4]	to occur[4]	dry	heavy frost	-10/-8[6]	12.5	25
<= + 10	not occurring[4]	to occur[4]	dry	heavy frost	<-10	no action required	
<= + 10	not occurring[4]	to occur[4]	dry	thin ice	> 0	never[5]	
<= + 10	not occurring[4]	to occur[4]	dry	thin ice	-2/0[6]	5	10
<= + 10	not occurring[4]	to occur[4]	dry	thin ice	-4/-2[6]	5	10
<= + 10	not occurring[4]	to occur[4]	dry	thin ice	-6/-4[6]	7.5	15
<= + 10	not occurring[4]	to occur[4]	dry	thin ice	-8/-6[6]	10	20
<= + 10	not occurring[4]	to occur[4]	dry	thin ice	-10/-8[6]	10	20
<= + 10	not occurring[4]	to occur[4]	dry	thin ice	<-10	no action required	
<= + 10	not occurring[4]	to occur[4]	dry	snow slush	not imp[8]	never[5]	
<= + 10	not occurring[4]	to occur[4]	dry	thick ice	> 0	never[5]	
<= + 10	not occurring[4]	to occur[4]	dry	thick ice	-2/0[6]	10	20
<= + 10	not occurring[4]	to occur[4]	dry	thick ice	-4/-2[6]	10	20
<= + 10	not occurring[4]	to occur[4]	dry	thick ice	-6/-4[6]	12.5	25
<= + 10	not occurring[4]	to occur[4]	dry	thick ice	-8/-6[6]	15	30
<= + 10	not occurring[4]	to occur[4]	dry	thick ice	-10/-8[6]	17.5	35
<= + 10	not occurring[4]	to occur[4]	dry	thick ice	<-10	17.5	35

Notes:

1. Taken from pages A13-20 to A13-32 of SNRA Translation.
2. Units not listed in SNRA Translation – presumed to be °C.
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7. The indicated application rates are taken from pg A13-33 of the SNRA translation. The material comprising “Solution” is not defined in the SNRA translation.
8. “not imp.” – not important

Table 5 (cont'd) Action Table[1] For:

- No Precipitation Currently But Forecasted To Occur
- Various Current and Forecasted Pavement Conditions

Air Temp[2]	Precipitation		Pavement Condition		Current[3] Pavement Temp[2]	Action Advised	
	Current[3]	Forecast[3]	Current[3]	Forecast[3]		Moist Salt[7] (g/m^2)	Sol'n[7] (g/m^2)
<= + 10	not occurring[4]	to occur[4]	dry	wet snow	> 0	5	10
<= + 10	not occurring[4]	to occur[4]	dry	wet snow	-2/0[6]	7.5	15
<= + 10	not occurring[4]	to occur[4]	dry	wet snow	-4/-2[6]	10	20
<= + 10	not occurring[4]	to occur[4]	dry	wet snow	-6/-4[6]	12.5	25
<= + 10	not occurring[4]	to occur[4]	dry	wet snow	-8/-6[6]	15	30
<= + 10	not occurring[4]	to occur[4]	dry	wet snow	-10/-8[6]	17.5	35
<= + 10	not occurring[4]	to occur[4]	dry	wet snow	<-10	no action required	
<= + 10	not occurring[4]	to occur[4]	dry	dry snow	> 0	5	10
<= + 10	not occurring[4]	to occur[4]	dry	dry snow	-2/0[6]	7.5	15
<= + 10	not occurring[4]	to occur[4]	dry	dry snow	-4/-2[6]	no action required	
<= + 10	not occurring[4]	to occur[4]	dry	dry snow	-6/-4[6]	no action required	
<= + 10	not occurring[4]	to occur[4]	dry	dry snow	-8/-6[6]	no action required	
<= + 10	not occurring[4]	to occur[4]	dry	dry snow	-10/-8[6]	no action required	
<= + 10	not occurring[4]	to occur[4]	dry	dry snow	<-10	no action required	
<= + 10	not occurring[4]	to occur[4]	moist	not imp[8]	not imp[8]	no action required	
<= + 10	not occurring[4]	to occur[4]	wet	not imp[8]	not imp[8]	no action required	
<= + 10	not occurring[4]	to occur[4]	light frost	not imp[8]	> 0	5	10
<= + 10	not occurring[4]	to occur[4]	light frost	not imp[8]	-2/0[6]	5	10
<= + 10	not occurring[4]	to occur[4]	light frost	not imp[8]	-4/-2[6]	7.5	15
<= + 10	not occurring[4]	to occur[4]	light frost	not imp[8]	-6/-4[6]	7.5	15
<= + 10	not occurring[4]	to occur[4]	light frost	not imp[8]	-8/-6[6]	10	20
<= + 10	not occurring[4]	to occur[4]	light frost	not imp[8]	-10/-8[6]	10	20
<= + 10	not occurring[4]	to occur[4]	light frost	not imp[8]	<-10	15	30
<= + 10	not occurring[4]	to occur[4]	heavy frost	not imp[8]	> 0	5	10
<= + 10	not occurring[4]	to occur[4]	heavy frost	not imp[8]	-2/0[6]	7.5	15
<= + 10	not occurring[4]	to occur[4]	heavy frost	not imp[8]	-4/-2[6]	10	20
<= + 10	not occurring[4]	to occur[4]	heavy frost	not imp[8]	-6/-4[6]	12.5	25
<= + 10	not occurring[4]	to occur[4]	heavy frost	not imp[8]	-8/-6[6]	15	30
<= + 10	not occurring[4]	to occur[4]	heavy frost	not imp[8]	-10/-8[6]	17.5	35
<= + 10	not occurring[4]	to occur[4]	heavy frost	not imp[8]	<-10	mechanical anti-icing	

Notes:

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Table 5 (cont'd) Action Table[1] For:

- No Precipitation Currently But Forecasted To Occur
- Various Current and Forecasted Pavement Conditions

Air Temp[2]	Precipitation		Pavement Condition		Current[3]	Action Advised	
	Current[3]	Forecast[3]	Current[3]	Forecast[3]	Pavement Temp[2]	Moist Salt[7](g/m^2)	Sol'n[7] (g/m^2)
<= + 10	not occurring[4]	to occur[4]	thin ice	not imp[8]	> 0	20	40
<= + 10	not occurring[4]	to occur[4]	thin ice	not imp[8]	-2/0[6]	20	40
<= + 10	not occurring[4]	to occur[4]	thin ice	not imp[8]	-4/-2[6]	20	40
<= + 10	not occurring[4]	to occur[4]	thin ice	not imp[8]	-6/-4[6]	25	n/a[9]
<= + 10	not occurring[4]	to occur[4]	thin ice	not imp[8]	-8/-6[6]	25	n/a[9]
<= + 10	not occurring[4]	to occur[4]	thin ice	not imp[8]	-10/-8[6]	mechanical anti-icing	
<= + 10	not occurring[4]	to occur[4]	thin ice	not imp[8]	<-10	mechanical anti-icing	
<= + 10	not occurring[4]	to occur[4]	thick ice	not imp[8]	> 0	25	n/a[9]
<= + 10	not occurring[4]	to occur[4]	thick ice	not imp[8]	-2/0[6]	25	n/a[9]
<= + 10	not occurring[4]	to occur[4]	thick ice	not imp[8]	-4/-2[6]	25	n/a[9]
<= + 10	not occurring[4]	to occur[4]	thick ice	not imp[8]	-6/-4[6]	30	n/a[9]
<= + 10	not occurring[4]	to occur[4]	thick ice	not imp[8]	-8/-6[6]	30	n/a[9]
<= + 10	not occurring[4]	to occur[4]	thick ice	not imp[8]	-10/-8[6]	mechanical anti-icing	
<= + 10	not occurring[4]	to occur[4]	thick ice	not imp[8]	<-10	mechanical anti-icing	
<= + 10	not occurring[4]	to occur[4]	snow slush	not imp[8]	> 0	5 & plowing	10 & plowing
<= + 10	not occurring[4]	to occur[4]	snow slush	not imp[8]	-2/0[6]	10 & plowing	20 & plowing
<= + 10	not occurring[4]	to occur[4]	snow slush	not imp[8]	-4/-2[6]	15 & plowing	30 & plowing
<= + 10	not occurring[4]	to occur[4]	snow slush	not imp[8]	-6/-4[6]	15 & plowing	30 & plowing
<= + 10	not occurring[4]	to occur[4]	snow slush	not imp[8]	-8/-6[6]	20 & plowing	40 & plowing
<= + 10	not occurring[4]	to occur[4]	snow slush	not imp[8]	-10/-8[6]	20 & plowing	40 & plowing
<= + 10	not occurring[4]	to occur[4]	snow slush	not imp[8]	<-10	plowing	

Notes:

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Table 5 (cont'd) Action Table[1] For:

- No Precipitation Currently But Forecasted To Occur
- Various Current and Forecasted Pavement Conditions

Air Temp[2]	Precipitation		Pavement Condition		Current[3] Pave. Temp[2]	Action Advised	
	Current[3]	Forecast[3]	Current[3]	Forecast[3]		Moist Salt[7](g/m^2)	Sol'n[7] (g/m^2)
<= + 10	not occurring[4]	to occur[4]	wet snow	not imp[8]	> 0	5 & plowing	10 & plowing
<= + 10	not occurring[4]	to occur[4]	wet snow	not imp[8]	-2/0[6]	10 & plowing	20 & plowing
<= + 10	not occurring[4]	to occur[4]	wet snow	not imp[8]	-4/-2[6]	15 & plowing	30 & plowing
<= + 10	not occurring[4]	to occur[4]	wet snow	not imp[8]	-6/-4[6]	15 & plowing	30 & plowing
<= + 10	not occurring[4]	to occur[4]	wet snow	not imp[8]	-8/-6[6]	20 & plowing	40 & plowing
<= + 10	not occurring[4]	to occur[4]	wet snow	not imp[8]	-10/-8[6]	20 & plowing	40 & plowing
<= + 10	not occurring[4]	to occur[4]	wet snow	not imp[8]	<-10	plowing	
<= + 10	not occurring[4]	to occur[4]	dry snow	not imp[8]	> 0	5 & plowing	10 & plowing
<= + 10	not occurring[4]	to occur[4]	dry snow	not imp[8]	-2/0[6]	10 & plowing	20 & plowing
<= + 10	not occurring[4]	to occur[4]	dry snow	not imp[8]	-4/-2[6]	15 & plowing	30 & plowing
<= + 10	not occurring[4]	to occur[4]	dry snow	not imp[8]	-6/-4[6]	15 & plowing	30 & plowing
<= + 10	not occurring[4]	to occur[4]	dry snow	not imp[8]	-8/-6[6]	20 & plowing	40 & plowing
<= + 10	not occurring[4]	to occur[4]	dry snow	not imp[8]	-10/-8[6]	20 & plowing	40 & plowing
<= + 10	not occurring[4]	to occur[4]	dry snow	not imp[8]	<-10	plowing	

Notes:

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8. "not imp." – not important
9. "n/a" – not advised to be used

Table 6 Action Table[1] For:

- No Precipitation Currently & No Precipitation Forecasted To Occur
- Various Current and Forecasted Pavement Conditions

Air	Precipitation		Pavement Condition		Current[3]	Action Advised	
Temp[2]	Current[3]	Forecast[3]	Current[3]	Forecast[3]	Pavement Temp[2]	Moist Salt[7] (g/m^2)	Sol'n[7] (g/m^2)
<= + 10	not occurring[4]	not to occur[4]	dry	dry	not imp[8]	no action required	
<= + 10	not occurring[4]	not to occur[4]	dry	moist	not imp[8]	no action required	
<= + 10	not occurring[4]	not to occur[4]	dry	wet	not imp[8]	no action required	
<= + 10	not occurring[4]	not to occur[4]	dry	light frost	-4/0[6]	5	10
<= + 10	not occurring[4]	not to occur[4]	dry	light frost	-7/-4[6]	7.5	15
<= + 10	not occurring[4]	not to occur[4]	dry	light frost	-10/-7[6]	10	20
<= + 10	not occurring[4]	not to occur[4]	dry	light frost	< -10	no action required	
<= + 10	not occurring[4]	to occur[4]	dry	heavy frost	-2/0[6]	5	10
<= + 10	not occurring[4]	to occur[4]	dry	heavy frost	-4/-2[6]	7.5	15
<= + 10	not occurring[4]	to occur[4]	dry	heavy frost	-6/-4[6]	10	20
<= + 10	not occurring[4]	to occur[4]	dry	heavy frost	-8/-6[6]	12.5	25
<= + 10	not occurring[4]	to occur[4]	dry	heavy frost	-10/-8[6]	15	30
<= + 10	not occurring[4]	to occur[4]	dry	heavy frost	<-10	no action required	
<= + 10	not occurring[4]	not to occur[4]	moist	dry	not imp[8]	no action required	
<= + 10	not occurring[4]	not to occur[4]	moist	moist	not imp[8]	no action required	
<= + 10	not occurring[4]	not to occur[4]	moist	wet	not imp[8]	no action required	
<= + 10	not occurring[4]	not to occur[4]	moist	light frost	-4/0[6]	5	10
<= + 10	not occurring[4]	not to occur[4]	moist	light frost	-7/-4[6]	7.5	15
<= + 10	not occurring[4]	not to occur[4]	moist	light frost	-10/-7[6]	10	20
<= + 10	not occurring[4]	not to occur[4]	moist	light frost	< -10	no action required	
<= + 10	not occurring[4]	to occur[4]	moist	heavy frost	-2/0[6]	5	10
<= + 10	not occurring[4]	to occur[4]	moist	heavy frost	-4/-2[6]	7.5	15
<= + 10	not occurring[4]	to occur[4]	moist	heavy frost	-6/-4[6]	10	20
<= + 10	not occurring[4]	to occur[4]	moist	heavy frost	-8/-6[6]	12.5	25
<= + 10	not occurring[4]	to occur[4]	moist	heavy frost	-10/-8[6]	15	30
<= + 10	not occurring[4]	to occur[4]	moist	heavy frost	<-10	no action required	

Notes:

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Table 6 (cont'd) Action Table[1] For:

- No Precipitation Currently & No Precipitation Forecasted To Occur
- Various Current and Forecasted Pavement Conditions

Air Temp[2]	Precipitation		Pavement Condition		Current[3] Pavement Temp[2]	Action Advised	
	Current[3]	Forecast[3]	Current[3]	Forecast[3]		Moist Salt[7] (g/m²)	Sol'n[7] (g/m²)
<= + 10	not occurring[4]	not to occur[4]	moist	ice	-4/0[6]	5	10
<= + 10	not occurring[4]	not to occur[4]	moist	ice	-7/-4[6]	7.5	15
<= + 10	not occurring[4]	not to occur[4]	moist	ice	-10/-7[6]	10	20
<= + 10	not occurring[4]	not to occur[4]	moist	ice	< -10	no action required	
<= + 10	not occurring[4]	not to occur[4]	moist	snow cover	< -10	never[5]	
<= + 10	not occurring[4]	not to occur[4]	wet	dry	not imp[8]	no action required	
<= + 10	not occurring[4]	not to occur[4]	wet	moist	not imp[8]	no action required	
<= + 10	not occurring[4]	not to occur[4]	wet	wet	not imp[8]	no action required	
<= + 10	not occurring[4]	to occur[4]	wet	light frost	-2/0[6]	5	10
<= + 10	not occurring[4]	to occur[4]	wet	light frost	-4/-2[6]	7.5	15
<= + 10	not occurring[4]	to occur[4]	wet	light frost	-6/-4[6]	10	20
<= + 10	not occurring[4]	to occur[4]	wet	light frost	-8/-6[6]	12.5	25
<= + 10	not occurring[4]	to occur[4]	wet	light frost	-10/-8[6]	15	30
<= + 10	not occurring[4]	to occur[4]	wet	light frost	<-10	no action required	
<= + 10	not occurring[4]	to occur[4]	wet	heavy frost	-2/0[6]	7.5	15
<= + 10	not occurring[4]	to occur[4]	wet	heavy frost	-4/-2[6]	10	20
<= + 10	not occurring[4]	to occur[4]	wet	heavy frost	-6/-4[6]	12.5	25
<= + 10	not occurring[4]	to occur[4]	wet	heavy frost	-8/-6[6]	15	30
<= + 10	not occurring[4]	to occur[4]	wet	heavy frost	-10/-8[6]	17.5	35
<= + 10	not occurring[4]	to occur[4]	wet	heavy frost	<-10	no action required	
<= + 10	not occurring[4]	to occur[4]	wet	ice	-2/0[6]	7.5	15
<= + 10	not occurring[4]	to occur[4]	wet	ice	-4/-2[6]	10	20
<= + 10	not occurring[4]	to occur[4]	wet	ice	-6/-4[6]	12.5	25
<= + 10	not occurring[4]	to occur[4]	wet	ice	-8/-6[6]	15	30
<= + 10	not occurring[4]	to occur[4]	wet	ice	-10/-8[6]	17.5	35
<= + 10	not occurring[4]	to occur[4]	wet	ice	<-10	no action required	

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Table 6 (cont'd) Action Table[1] For:

- No Precipitation Currently & No Precipitation Forecasted To Occur
- Various Current and Forecasted Pavement Conditions

Air Temp[2]	Precipitation Current[3]	Precipitation Forecast[3]	Pavement Condition Current[3]	Pavement Condition Forecast[3]	Current[3] Pavement Temp[2]	Action Advised Moist Salt[7] (g/m²)	Action Advised Sol'n[7] (g/m²)
<= + 10	not occurring[4]	not to occur[4]	light frost	not imp[8]	-4/0[6]	5	10
<= + 10	not occurring[4]	not to occur[4]	light frost	not imp[8]	-7/-4[6]	7.5	15
<= + 10	not occurring[4]	not to occur[4]	light frost	not imp[8]	-10/-7[6]	10	20
<= + 10	not occurring[4]	not to occur[4]	light frost	not imp[8]	<-10	mechanical anti-icing	
<= + 10	not occurring[4]	not to occur[4]	heavy frost	not imp[8]	-2/0[6]	5	10
<= + 10	not occurring[4]	not to occur[4]	heavy frost	not imp[8]	-4/-2[6]	7.5	15
<= + 10	not occurring[4]	not to occur[4]	heavy frost	not imp[8]	-6/-4[6]	10	20
<= + 10	not occurring[4]	not to occur[4]	heavy frost	not imp[8]	-8/-6[6]	12.5	25
<= + 10	not occurring[4]	not to occur[4]	heavy frost	not imp[8]	-10/-8[6]	15	30
<= + 10	not occurring[4]	not to occur[4]	heavy frost	not imp[8]	<-10	mechanical anti-icing	
<= + 10	not occurring[4]	not to occur[4]	thin ice	not imp[8]	>0	5	10
<= + 10	not occurring[4]	not to occur[4]	thin ice	not imp[8]	-2/0[6]	7.5	15
<= + 10	not occurring[4]	not to occur[4]	thin ice	not imp[8]	-4/-2[6]	10	20
<= + 10	not occurring[4]	not to occur[4]	thin ice	not imp[8]	-6/-4[6]	12.5	25
<= + 10	not occurring[4]	not to occur[4]	thin ice	not imp[8]	-8/-6[6]	15	30
<= + 10	not occurring[4]	not to occur[4]	thin ice	not imp[8]	-10/-8[6]	17.5	35
<= + 10	not occurring[4]	not to occur[4]	thin ice	not imp[8]	<-10	mechanical anti-icing	
<= + 10	not occurring[4]	not to occur[4]	thick ice	not imp[8]	>0	15	30
<= + 10	not occurring[4]	not to occur[4]	thick ice	not imp[8]	-2/0[6]	20	40
<= + 10	not occurring[4]	not to occur[4]	thick ice	not imp[8]	-4/-2[6]	20	40
<= + 10	not occurring[4]	not to occur[4]	thick ice	not imp[8]	-6/-4[6]	25	n/a[9]
<= + 10	not occurring[4]	not to occur[4]	thick ice	not imp[8]	-8/-6[6]	25	n/a[9]
<= + 10	not occurring[4]	not to occur[4]	thick ice	not imp[8]	-10/-8[6]	mechanical anti-icing	
<= + 10	not occurring[4]	not to occur[4]	thick ice	not imp[8]	<-10	mechanical anti-icing	

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5. The SNRA Translation uses "never". This is presumed to mean that this will never occur.
6. This code is taken directly from the SNRA Translation. It is presumed to indicate the minimum and maximum temperature of the applicable range.
7. The indicated application rates are taken from pg A13-33 of the SNRA translation. The material comprising "Solution" is not defined in the SNRA translation.
8. "not imp." – not important
9. "n/a" – not advised to be used

Table 6 (cont'd) Action Table[1] For:

- No Precipitation Currently & No Precipitation Forecasted To Occur
- Various Current and Forecasted Pavement Conditions

Air Temp[2]	Precipitation		Pavement Condition		Current[3] Pavement Temp[2]	Action Advised	
	Current[3]	Forecast[3]	Current[3]	Forecast[3]		Moist Salt[7] (g/m^2)	Sol'n[7] (g/m^2)
<= + 10	not occurring[4]	not to occur[4]	snow slush	not imp[8]	> 0	5 & plowing	10 & plowing
<= + 10	not occurring[4]	not to occur[4]	snow slush	not imp[8]	-2/0[6]	7.5 & plowing	15 & plowing
<= + 10	not occurring[4]	not to occur[4]	snow slush	not imp[8]	-4/-2[6]	10 & plowing	20 & plowing
<= + 10	not occurring[4]	not to occur[4]	snow slush	not imp[8]	-6/-4[6]	12.5 & plowing	25 & plowing
<= + 10	not occurring[4]	not to occur[4]	snow slush	not imp[8]	-8/-6[6]	15 & plowing	30 & plowing
<= + 10	not occurring[4]	not to occur[4]	snow slush	not imp[8]	-10/-8[6]	17.5 & plowing	35 & plowing
<= + 10	not occurring[4]	not to occur[4]	snow slush	not imp[8]	<-10	plowing	
<= + 10	not occurring[4]	not to occur[4]	wet snow	not imp[8]	> 0	5 & plowing	10 & plowing
<= + 10	not occurring[4]	not to occur[4]	wet snow	not imp[8]	-2/0[6]	10 & plowing	20 & plowing
<= + 10	not occurring[4]	not to occur[4]	wet snow	not imp[8]	-4/-2[6]	12.5 & plowing	25 & plowing
<= + 10	not occurring[4]	not to occur[4]	wet snow	not imp[8]	-6/-4[6]	15 & plowing	30 & plowing
<= + 10	not occurring[4]	not to occur[4]	wet snow	not imp[8]	-8/-6[6]	17.5 & plowing	35 & plowing
<= + 10	not occurring[4]	not to occur[4]	wet snow	not imp[8]	-10/-8[6]	20 & plowing	40 & plowing
<= + 10	not occurring[4]	not to occur[4]	wet snow	not imp[8]	<-10	plowing	
<= + 10	not occurring[4]	not to occur[4]	dry snow	not imp[8]	> 0	5 & plowing	10 & plowing
<= + 10	not occurring[4]	not to occur[4]	dry snow	not imp[8]	-2/0[6]	10 & plowing	20 & plowing
<= + 10	not occurring[4]	not to occur[4]	dry snow	not imp[8]	-4/-2[6]	plowing	
<= + 10	not occurring[4]	not to occur[4]	dry snow	not imp[8]	-6/-4[6]	plowing	
<= + 10	not occurring[4]	not to occur[4]	dry snow	not imp[8]	-8/-6[6]	plowing	
<= + 10	not occurring[4]	not to occur[4]	dry snow	not imp[8]	-10/-8[6]	plowing	
<= + 10	not occurring[4]	not to occur[4]	dry snow	not imp[8]	<-10	plowing	

1. Taken from pages A13-20 to A13-32 of SNRA Translation.
2. Units not listed in SNRA Translation – presumed to be °C.
3. Current and forecast presumed to be "measured" and "prognosticated" respectively, as given in the Translation.
4. The SNRA Translation uses "yes". This is presumed to mean occurrence or forecast to occur.
5. The SNRA Translation uses "never". This is presumed to mean that this will never occur.
6. This code is taken directly from the SNRA Translation. It is presumed to indicate the minimum and maximum temperature of the applicable range.
7. The indicated application rates are taken from pg A13-33 of the SNRA translation. The material comprising "Solution" is not defined in the SNRA translation.
8. "not imp." – not important
9. "n/a" – not advised to be used

Table 7 Winter Road Maintenance Standard Classes[1]

Road Class	Traffic Volume ?[2]	Pavement Temp (°C ?)[3]
Main roads and primary county roads	>= 16000	Pavement temp >= -8, or Pavement temp >= -8
	8000 to 15,999	Pavement temp >= -8, or Pavement temp >= -8
	2000 to 7,999	Pavement temp >= -6, or Pavement temp >= -6
	<= 1,999	Pavement temp >= -3, or Pavement temp >= -3
Secondary roads and tertiary county roads	>= 16000	Pavement temp >= -8, or Pavement temp >= -8
	2000 to 15,999	Pavement temp >= -6, or Pavement temp >= -6
	500 to 1,999	Pavement temp >= -3, or Pavement temp >= -3
	<= 500	Not included as a specifier

Notes:

1. Taken from page A13-15 of SNRA Translation.
2. Not specified in SNRA Translation. Values listed presumed to be traffic volume.
3. Units not specified in SNRA Translation. Values listed presumed to be °C.

Attachment No. 2 :
Operating Notes Regarding The DART (De -icing and Abrasives Road Treatment) Program

1. About DART : The DART program is written in Microsoft Access (version 2.0), and was developed to run using a Windows 3.1 operating system. The individual displays in the DART program are sized to fill a 640 x 480 screen, and these notes are applicable to monitors with that resolution. Users with greater screen resolution will see some bla nk area horizontally and more vertical information. However, the program is functionally identical, regardless of the screen resolution.

2. Overview Of ProLyram Capabilities And Structure The program has two main functions and operating modes, as summar ized below

Program Function	Operating Mode	
	"Current"	"Historical"
I - Provision Of Recommendations - advises regarding appropriate road treatment actions for various weather events and conditions. The programmed weather events, and the recommended actions for each, are described under separate cover, as Attachment 1.		
2 - Logging - records actions taken and results obtained	4	

New records are generated in the "current" mode, either with respect to the recommended actions for a given weather event and set of conditions , or for the actions taken for a given case. The "historical" mode allows the user to review previous records.

To help the user distinguish these two operating modes, the DART program has a teal-coloured background in the "historical" mode, and a dark blue background in the "current" mode.

When the DART program is first run, it defaults to the "Recommendation Provision" function and the "current" mode of operation. The other modes of operation are activated from this point in the program as follows

To review recommendations made for other records: Press the "View Records" button at the bottom of the screen
To switch to the Logging Function Press the "Actions Log" button at the bottom of the screen.
To review the Actions Log for other events Select the date of interest from the pull-down menu, and then the Record ID of interest, from the pull-down menu. This can also be done by entering the "historical" operating mode (by pressing "Show Records"), and then by pressing the "Actions Log" button.

3.0 Operating The Program To Provide Recommendations

3.1 Input Data - The required input data are indicated on the computer screen, and are entered manually. There are two main types of input data, as follows

(a) Mandatory data - These data are essential for the program to provide a recommendation.

(b) Ancillary data - The provision to enter these data is included to allow a record to be documented more fully. However, they are not required for the program to provide a recommendation.

Other notes regarding data inputs are listed below

(a) to provide some error-trapping, values can only be inputted over program-specified ranges.

(b) current time - double-clicking the current time box will cause the current (i.e., computer) time to be filled in there. If desired, other values can be inputted directly or by editing the inputted time.

(c) forecast time - double-clicking the forecast time box will cause the current (i.e., computer) time plus one (1) hour to be filled in there. If desired, other values can be inputted directly or by editing the inputted time. Because the program is intended to provide short-term recommendations only, the forecast time must be within four (4) hours of the current time to obtain a recommendation.

(d) inputting "wet" or "dry" snow - the selection can be changed by clicking the one that is not selected, if the other case is already selected. Double-clicking the selected value will cause both input boxes to become blank.

3.2 To Obtain A Recommendation (regarding appropriate actions) - Press the "Advise" button at the bottom of the screen.

3.3) Returning To The "Data Input" Screen From The "Advise" Screen - press the "Back To Top" button at the bottom of the page.

3.4 To Create And Store A New Record - New records can only be created when the program is operated in the "current" mode to provide recommendations. The user is given the option to store a record (by means of pop-out box that asks the user to make this decision) when this part of the program is exited. This occurs if :

(a) the "View Records" button is pressed , or
(b) the "Actions Log" button is pressed , or
(c) the "Exit" button is pressed.

Also, the current record will be saved, creating a new record in the database, if the user clicks the "Add Record" button at the top right-hand comer of the screen. In this case, the record is automatically created without a pop-out box appearing that asks the user to make this decision.

3.5 Obtaining Hard-Copv Outputs - This is done by pressing the "Print" button at the bottom of the page. This switches the user to Windows 3. 1, and printing is achieved by making the appropriate choices in the menus provided by Windows. This produces tabular summaries, as shown in Appendix A. The DART program produces five tables (i.e., Mandatory Data 1 & 2, Ancillary Data, Initial Actions Advised, and the Subsequent Actions Advised) that summarize all information for all records.

4.0 Operating The Program To Log The Actions Taken And The Results Obtained

4.1 Filling Out The Actions Log - Actions are added to the log by first selecting an action from the indicated pop-out box, and then pressing "Add Action" Each potential action has a number
of parameters specifically associated with it (e.g., application rate, etc.) that can be input by the user by means of the pop-out box to the right of the Actions Log on the screen. The indicated

Actions are added to the Log in reverse chronological order (i.e, the one most recently inputted appears at the top of the list). The individual actions are assigned the time and date in the computer when they are inputted. This time and date information can be edited if necessary.

The actions can be sorted into chronological order by pressing the "Re-Sort" button.

4.2 Storing The Actions LoQ. - The Actions Log is automatically stored with the record that is open at the time.

4.3 Switching To The "Recommendation" Function From The "Logging" Function - press the "Show Records" button at the bottom of the page. This returns the user to the "historical" mode of operation. To obtain a new recommendation, and/or enter a new record, press the "Add Records" button at the top right hand comer of the screen.

4.4 Obtaining Hard-Copv Outputs - This is done by pressing the "Print" button that shows on the screen in this mode. This switches the user to Windows 3. 1, and printing is achieved by making the appropriate choices in the menus provided by Windows. This produces Actions Log summaries, as shown in Appendix B. It should be noted that the format used for the Actions Log Summary was selected to be as general as possible (to simplify programming efforts), and consequently, not all of the parameters included on the summary report are applicable in all cases. Inapplicable fields are left blank on the Action Log report.

5.0 Conventions Regarding, Event Definition And Record-Keeping Events are identified by date, and the corresponding Record IDs for that date (i.e., event) are grouped with it. Many Record IDs can be generated for a given date. This approach was selected because it was thought that the program might be run several times during a given event or storm.

To view the records that are applicable to a given date (i.e., event) in the "historical" mode, the user must first select the appropriate date, using the date pull-down menu at the top of the Input screen. This selection causes only the Record IDs that are associated with that date to be visible when the Record ID pull-down box (at the top of the screen) is opened. Then, the Record ID of interest is selected from the Record ID pull-down menu.

Attachment No. I

Technical Basis Of The DART (De-icing and Abrasives Road Treatment)

1. Overview Of ProLyram Basis And Logic The recommendations given by the DART program are primarily based on those given in Ketcham et al, 1996, who prepared tables summarizing the recommended actions for the following weather events

(a) a light snow storm.
(b) a light snowstorm with period(s) of moderate or heavy snow.
(c) a moderate or heavy snow storm.
(d) a frost or back ice occurrence.
(e) a freezing rain storm.
(f) a sleet storm.

For reference, the tables prepared by Ketcham et al, 1996 are copied with this attachment as Appendix A. Appendix A also contains information provided by Ketcham et al, 1996 to define the above weather events.

To assist the implementation of Ketcham et al, 1996's recommendations in the DART program, tables were prepared by FTL that list Ketcham et al, 1996' s recommendations in expanded form. These are included in Appendix B.

2. **Revisions And Modifications To Ketcham et al. 1996's Tables** The logic in the DART program includes a number of revisions, modifications, and extensions that were made to Ketcham et al, 1996's tables, as follows

(a) the "gaps" in Ketcham et al, 1996's tables were filled. For example, all of their recommendations refer to the case where the road temperature is forecast to remain in a given range. No advisements are given for the case where the road temperature will change form one range to another (e.g., from -6 to -8'C for the light snow case - see tables in Appendix A). For this type of case, the DART program selects the recommendation for the Initial Action from the first temperature, and the advisement for the Subsequent Action from the second road temperature.

(b) the requirement for Plowing actions was based on whether or not at least 2.5 cm of snow has currently accumulated on the. road, based on the MTO's current guidelines. As a result, the DART program differs from Ketcham et al, 1996's tables as follows

- Initial Action - For all weather events that involve snow, Ketcham et al, 1996's tables advise that plowing is not required, unless the road temperature is cold, in which case they advise plowing "as required" (Appendix A). The DART program maintains this logic if the current snow accumulation on , the road is less than 2.5 cm. If the snow accumulation is greater than or equal. to 2.5 cm for any -event, involving snow, the DART program advises that plowing is required.

- Subsequent Action - The DART program has the same recommendations as Ketcham et al, 1996's tables for all weather events that involve snow. For these cases, the DART program recommends plowing "as required" based on whether or not this is advised by Ketcham et al, 1996's tables.

(c) Frost or black ice - the logic for the occurrence of a frost or black ice event, as well as the recommended actions, was revised as summarized in Appendix C to eliminate inconsistencies.

(d) Sleet - the "sleet" event described in Ketcham et al, 1996 was re-termed a "ram-snow mixture" event, as Environment Canada would use this term for this type of event.

(e) Abrasives - an application rate of 500 kg/21ane*km is suggested for abrasives.

(f) Units for application rates - Ketcham et al, 1996's tables were revised to provide recommendations with respect to the following units

- dry salt . kg/2 lane * km
- brine litres/2 lane*km (assuming a solution concentration of 23%, and thus solution density of 1. 19 kg/litter)
- pre-wetted salt two values are given. The first value is the percentage of brine to be added by weight on an overall basis, and it is based on a pre-wetting rate of 45 1 of brine per 1000 kg of dry salt , the second value is the amount of dry salt in kg/21ane*km.
- abrasives kg/21ane*km

3.0 Definition Of "Heavy" and "Light" Snow On The Mandatory Input Screen - The actions advised by Ketcham et al. 1996 for a "light snow storm with period(s) of moderate or heavy snow" event depend upon whether the snow is "light" or "heavier" See Appendix A. "Light" snow is considered to be snow that is falling at less than 12 mm (1/2 in) per hour (Appendix A, and Ketcham et al, 1996), "Heavier" snow is considered to be s now that is falling at more than 12 mm. (1/2 in) per hour (S. Ketcham, US Army Cold Regions Research and Engineering Laboratory, personal communication).

4.0 Reference

Ketcham, S., Minsk, D., Blackburn, R., and Fleege, E., 1996, Manual Of Practice For A n Effective Anti-Icing Program A Guide For Highway Maintenance Personnel, US DOT report FHWA-RD-95-202.

APPENDIX A

WINTER MAINTENANCE OPERATIONS RECOMMENDED BY KETCHAM ET AL, 1996

(after Ketcham et al, 1996)

APPENDIX C. OPERATIONS GUIDE FOR MAINTENANCE FIELD PERSONNEL

CA INTRODUCTION

This appendix is a guide to highway anti-icing operations for maintenance field personnel. Its purpose is to suggest maintenance actions for *preventing* the formation or development of packed and bonded snow or bonded ice during a variety of winter weather events. It is intended to complement the decision-making and management practices of a systematic anti-icing program so that roads can be efficiently maintained in the best possible condition.

The guidance is based upon the results of four years of anti-icing field testing conducted by 15 State highway agencies and supported by the Strategic Highway Research Program (SHRP) and the Federal Highway Administration (FHWA). It has been augmented with practices developed outside the U.S., where necessary, for completeness. The recommendations are subject to refinement as U.S. highway agencies gain additional experience with anti-icing operations. Final decisions for their implementation rests with management personnel.

C.2 GUIDANCE FOR ANTI-ICING OPERATIONS

Guidance for anti-icing operations is presented in Tables 8 to 13 for six distinctive winter weather events. The six events are:

- Light Snow Storm
- Light Snow Storm with Period(s) of Moderate or Heavy Snow
- Moderate or Heavy Snow Storm
- Frost or Black Ice
- Freezing Rain Storm
- Sleet Storm

The tables suggest the appropriate maintenance action to take during an initial or subsequent (follow-up) anti-icing operation for a given precipitation or icing event. Each action is defined for a range of pavement temperatures and an associated temperature trend. For some events the operation is dependent not only on the pavement temperature and trend, but also upon the pavement surface or the traffic condition at the time of the action. Most of the maintenance actions involve the application of a chemical in either a dry solid, liquid, or prewetted solid form. Application rates ("spread rates") are given for each chemical form where appropriate. These are suggested values and should be adjusted, if necessary to achieve increased effectiveness or efficiency, for local conditions. *The rates givenfor liquid chemicals are the equivalent dry chemical rates.* Application rates in volumetric units such as L/lane-km (or gal/lane-mi) must be calculated from these dry chemical rates for each chemical and concentration.

Comments and notes are given in each table where appropriate to further guide the maintenance field personnel in their anti-icing operations.

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C.3 GLOSSARY OF TERMS

Black ice. Popular term for a very thin coating of clear, bubble-free, homogeneous ice which forms on a pavement with a temperature at or slightly above O*C (32'F) when the temperature of the air in contact with the ground is below the freezing-point of water and small slightly supercooled water droplets deposit on the surface and coalesce (flow together) before freezing.

Dry chemical spread rate. The chemical application rate. For solid applications it is simply the weight of the chemical applied per lane kilometer (or mile). For liquid applications it is the weight of the dry chemical in solution applied per lane kilometer (or mile).

Freezing rain. Supercooled droplets of liquid precipitation failing on a surface whose temperature is below or slightly above freezing, resulting in a hard, slick, generally thick coating of ice commonly called glaze or clear ice. Non-supercooled raindrops falling on a surface whose temperature is well below freezing will also result in glaze.

Frost Also called hoarfrost. Ice crystals in the form of scales, needles, feathers or fans deposited on surfaces cooled by radiation or by other processes. The deposit may be composed of drops of dew frozen after deposition and of ice formed directly from water vapor at a temperature below OOC (320F) (sublimation).

Light snow. Snow failing at the rate of less than 12 mm (1/2 in) per hour, visibility is not affected adversely.

Liquid chemical. A chemical solution -, the weight of the dry chemical m solution applied per lane kilometer (or mile) is the chemical application rate - the "dry chemical spread rate 99 used in this appendix.

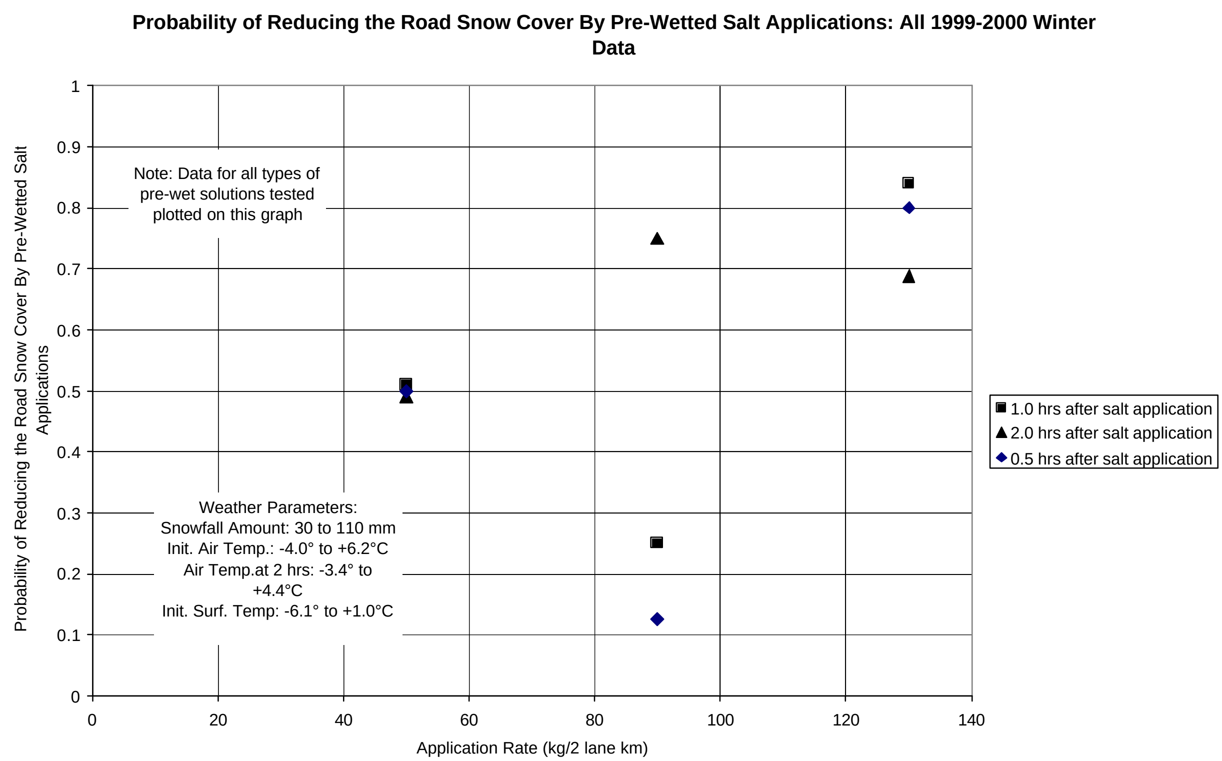
Moderate or heavy snow. Snow failing at a rate of 12 mm (1/2 in) per hour or greater; visibility may be reduced.

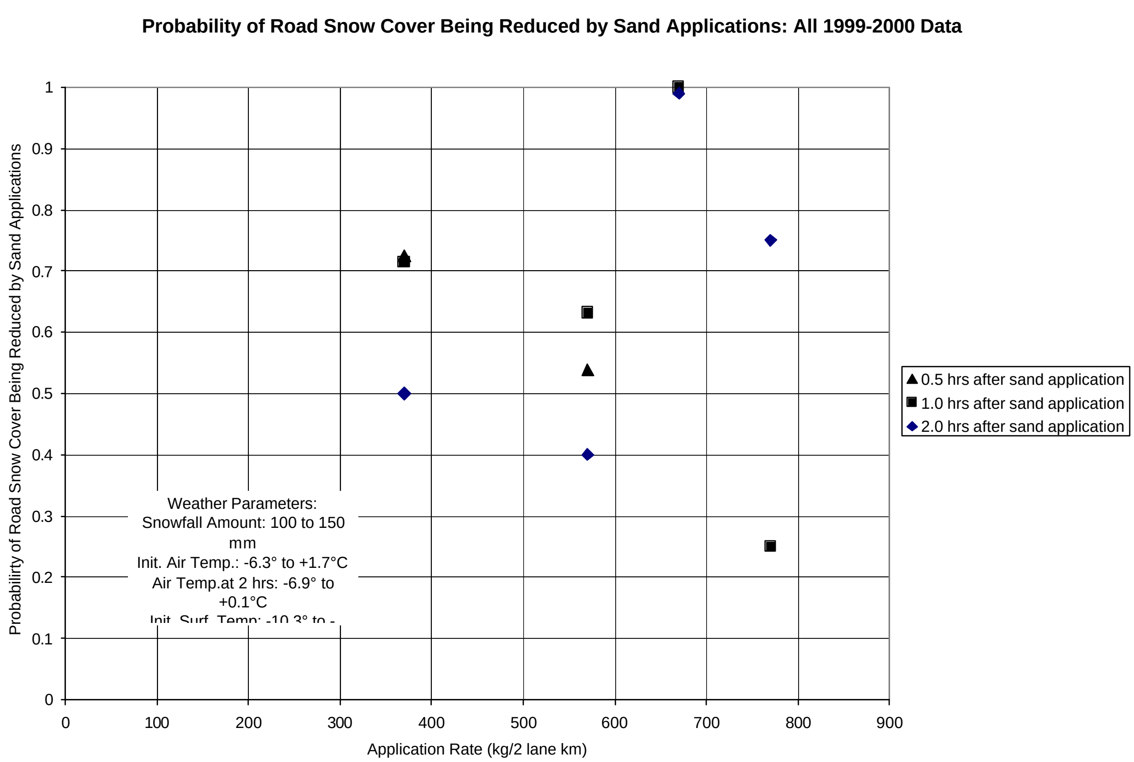
Sleet A mixture of rain and of snow which has been partially melted by failing through an atmosphere with a temperature slightly above freezing.

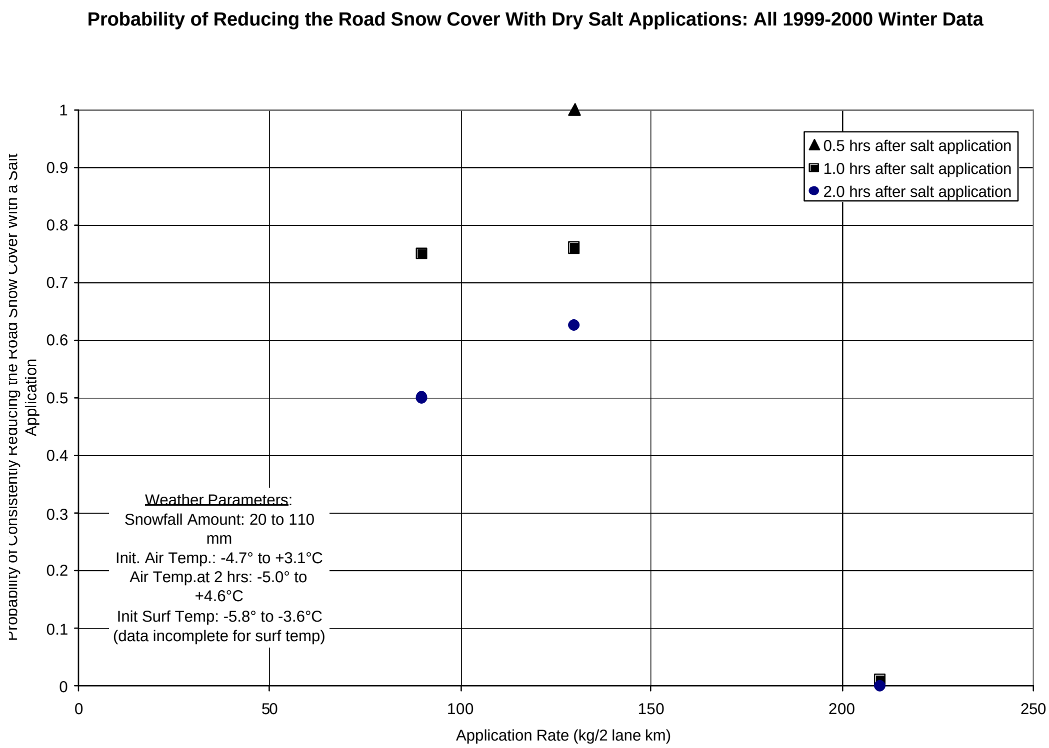
Slush. Accumulation of snow which lies on an impervious base and is saturated with water in excess of its freely drained capacity. It will not support any weight when stepped or driven on but will "squish" until the base support is reached.

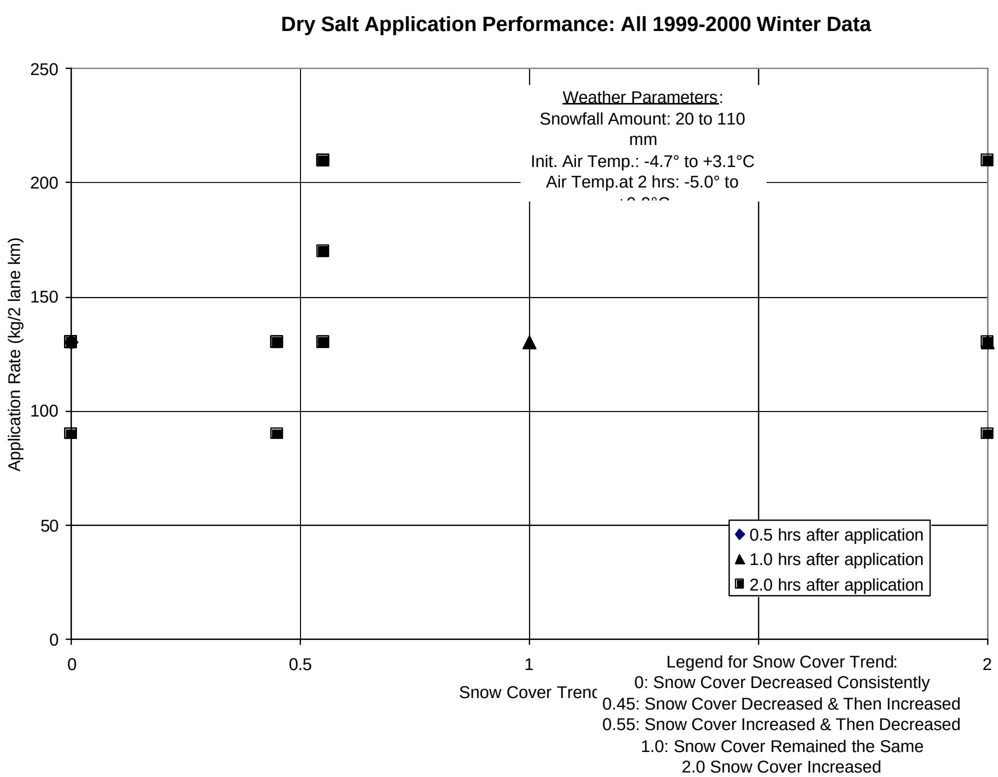
-

APPENDIX C. MTO EVALUATION OF DART APPLICATION RECOMMENDATIONS






Probability of Reducing the Road Snow Cover With Dry Salt Applications: All 1999-2000 Winter Data
Probability of Consistently Reducing the Road Snow Cover with a Salt Application
Application Rate (kg/2 lane km)
0.5 hrs after salt application
1.0 hrs after salt application
2.0 hrs after salt application
Weather Parameters:
Snowfall Amount: 20 to 110 mm
Init. Air Temp.: -4.7° to +3.1°C
Air Temp.at 2 hrs: -5.0° to +4.6°C
Init Surf Temp: -5.8° to -3.6°C
(data incomplete for surf temp)


Dry Salt Application Performance: All 1999-2000 Winter Data
Application Rate (kg/2 lane km)
Snow Cover Trend
Weather Parameters:
Snowfall Amount: 20 to 110 mm
Init. Air Temp.: -4.7° to +3.1°C
Air Temp.at 2 hrs: -5.0° to
0.5 hrs after application
1.0 hrs after application
2.0 hrs after application
Legend for Snow Cover Trend:
0: Snow Cover Decreased Consistently
0.45: Snow Cover Decreased & Then Increased
0.55: Snow Cover Increased & Then Decreased
1.0: Snow Cover Remained the Same
2.0 Snow Cover Increased

APPENDIX D. Feasibility of Integrating DART with RWIS

COMPARISON: DART INPUT REQUIREMENTS VS RWIS SYSTEM OUTPUTS

G. Comfort

Submitted to:
Attn: M. Perchanok
Ministry of Transportation of Ontario (MTO)
1202 Wilson Avenue
Downsview, Ont.
M3M 1J8

Submitted by:
Fleet Technology Limited
311 Legget Drive
Kanata, Ontario
K2K 1Z8

April, 2000

TABLE OF CONTENTS

1.0 <u>Inputs Required for the DART Program And Project Objective</u>

1.1 <u>Background and Objective</u>

Fleet Technology Limited (FTL) produced the DART 100 (Deicing and Abrasives Road Treatment) program in 1997 for the Ministry of Transportation of Ontario (MTO). The DART 100 program provided recommendations regarding suitable winter maintenance operations for various environmental conditions (Comfort, 1997).

The recommendations in the DART 100 program were primarily based on those given in Ketcham et al, 1996, who prepared tables summarizing the recommended actions for various cases. The DART 100 program also contained a number of revisions, extensions and modifications to Ketcham et al, 1996's recommendations. These were done by FTL and the MTO to fill gaps in Ketcham et, 1996's tables, and to take account of specific MTO practices.

The DART 100 program has since been modified by the MTO who eventually produced the DART 300 program, which is the most current version. However, major changes were not made with respect to the inputs required for the DART program.

In a parallel development, the use of Road Weather Information Systems (RWIS) has been steadily increasing over the past several years.

The objective of this study was to compare the outputs available from various RWISs with the inputs required for the DART program. The study also included a preliminary investigation of the most suitable way(s) of integrating DART with RWISs.

1.2 <u>Inputs Required for the DART Program</u>

The DART 300 program recommends winter maintenance actions based on:

- the Weather Event, or Type of Precipitation: the possible choices are:
  - (a) Freezing Rain
  - (b) Light Snow
  - (c) Moderate to Heavy Snow
  - (d) Frost or Black Ice
  - (e) Rain-Snow Mixture
- the Current Pavement Temperature and Forecast Pavement Temperature (note 1)
- the Current Dew Point and Forecast Dew Point (note 1)
- the Current Snow Accumulation on the Road (in cm)
- the Pavement Condition: Possible Choices: Dry
Wet
Slush
Light Snow Cover
Packed Snow

- the Traffic: Possible Choices: Heavy (>10,000/day)
  Moderate (2400-10,000/day)
  Light (<2400/day)
- the Snow Type: Possible Choices: Light (note 2)
  Heavy (note 2)

Notes:

1. Required forecast period - The DART program is only intended to provide advisories for time periods of up to four (4) hours in the future from a user-specified time. The user-specified time can be the current time, or it can be some time in the future.

2. “Light” vs “Heavy” Snow - “Light” snow is considered to be snow that is falling at less than 12 mm (0.5 inches) per hour. “Heavy” snow is considered to be snow that is falling at more than 12 mm (0.5 inches) per hour.

2.0 RWIS Manufacturers Contacted

The RWIS manufacturers contacted are summarized in Table 1.

Table 1 RWIS Manufacturers Contacted

RWIS Manufacturer	Person Contacted	Contact Information	Information Received ?
Surface Systems Incorporated (SSI)	Mark Greer	Tel:1-800-325-7226 1-314-569-1002 Fax:1-314-569-3567 Website: www.surface.com	No – information taken from: (a) their website (b) visit with P. Delannoy of Environment Canada who issue forecasts for road authorities
Vaisala Oyj	Panu Partanen	Tel: +358 9 894 91 Fax: +358 9 894 9227 Email:panu.partanen@vaisala.com Website: www.vaisala.com	Yes
Coastal Environmental Systems	Rick Banks	Tel:1-206-682-6048 Fax:1-206-682-5658 Website: www.coastal.org	No – information taken from their website
Lufft	Sam Aebi	Tel:1-514-990-9940 1-800-363-6224 Email: saebi@traftech2000.com Website: www.lufft.de	Yes
Findlay-Irvine	Colin Irvine	Tel: + 44 (0) 1968 672111 Fax: + 44 (0) 1968 672596 Website: www.findlayirvine.com/sensors.htm	Yes

3.0 **Detailed Comparison: RWIS Outputs Versus DART Input Requirements**

3.1 Surface Systems Incorporated

The information in this section was obtained by visiting the SSI website as well as by visiting Mr. Paul Delannoy (of Environment Canada) who produce forecasts for various road authorities in Canada using SSI RWIS outputs as one of their main input data sources.

- Definition of the weather event, or type of precipitation: this is not outputted directly in the format required for DART, although this could be obtained from analyses of the forecasts produced, which cover a time period of 12 to 24 hours, depending on the time of day being considered.

- Current and forecast pavement temperature: the current pavement temperature is measured. The pavement temperature is forecast for the next 12 to 24 hours, depending on the time of day being considered.

- Current and forecast dew point: the current dew point temperature is calculated. The dew point temperature is forecast for the next 12 to 24 hours, depending on the time of day being considered.

- Snow accumulation (in cm) – this is not an output of the SSI System. Environment Canada provides forecasts of snow accumulation versus time.

- Pavement condition – the SSI system provides part of the required information. The SSI system defines whether the pavement is either dry or wet, and ; the salinity of the solution.

- Traffic - this is not an output of the SSI System.

- Light vs Heavy Snow (which is defined based on the snowfall rate) – this is not an output of the SSI System. This information can be obtained from the forecasted trend of snowfall accumulation versus time.

- Integrating DART with RWIS Systems - It was generally felt that DART should be introduced gradually. The status quo (in which the users select actions based on their judgement and the forecast information) should be maintained. The recommendations from DART should be provided as an extra piece of information that the users can use as they wish. This will lead to better acceptance of, and further development of DART.

  Environment Canada (EC) now offers users three methods in which RWIS information and forecasts can be delivered as follows:

  (a) in hard copy, which can be sent by fax.

(b) through a user's network. This is one way in which information is currently provided to the MTO. In this case, EC polls the RWIS stations, stores this information in a SQL database, and then does a forecast. The forecast is then downloaded onto three MTO servers. Patrol yards obtain information by accessing the server. This method only works currently with SSI RWIS systems and it requires Scan for Windows to run.

A different system would have to be set up if other RWIS systems (e.g., Vaisala, Lufft, etc) were to be used.

(c) by posting RWIS information and forecasts on an EC, password-protected, web page that is accessible through the Internet. The MTO is also using this delivery method. In this case, EC obtains the RWIS information from the stations and produces forecasts. The user is able to obtain the information and forecasts by accessing their web page.

Option (c) is the most universal method for integrating DART because this delivery method is independent of the RWIS type (e.g., SSI vs Vaisalla vs Lufft, etc).

- Other information provided by Environment Canada's forecasts – this includes:

(a) more detailed information regarding precipitation and pavement condition- the categories are: dry, rain, snow, freezing rain, blowing snow, mist, fog, drizzle, and black ice.

(b) forecasted pavement temperature – this is provided every 20 minutes for the next 12 to 24 hours, depending on the time of day being considered. This exceeds the present DART requirements, which advises actions based on: (i) the current pavement temperature in relation to set values (e.g., 0°C), and (ii) whether the trend is falling, steady or rising in the user-specified time period (which can not exceed 4 hours).

(c) wind speed and direction – forecasted values are provided every 3 hours for the next 12 to 24 hours, depending on the time of day being considered. The wind speed and direction do not affect the actions advised by the DART program.

(d) air temperature and "wind chill" temperature – forecasted values are provided every 3 hours for the next 12 to 24 hours, depending on the time of day being considered. These parameters do not affect the actions advised by the DART program.

(e) Sky condition (height of clouds, and amount, in octas, of lowest cloud layer) - forecasted values are provided every 3 hours for the next 12 to 24 hours, depending on the time of day being considered. These parameters do not affect the actions advised by the DART program.

(f)

Table 1 Comparison: EC Output vs DART Requirements

Output from Environment Canada		DART Requirements
Parameter	Frequency	
Precip. & pavement condition – dry, rain, snow, freezing rain, blowing snow, mist, fog, drizzle, black ice	Every 20 minutes for next 12 to 24 hrs[1]	Definition of the Type of Weather Event • light snow • light snow but heavy at times • moderate to heavy snow • frost or black ice • freezing rain • sleet
Assessment w/r to DART's Requirements: The EC output is not directly applicable but this could be solved relatively simply. The EC output would allow a wider range of events to be considered by DART.		
Pavement temp.	Every 20 minutes for next 12 to 24 hrs[1]	Pavement temp w/r to set values (e.g., 0°, etc) & whether the trend is falling, steady, or rising
Assessment w/r to DART's Requirements: The EC output provides more information than is currently used by DART. The EC output is not directly applicable although this could be solved relatively simply.		
Wind speed & direction	Every 3 hrs for next 12 to 24 hrs	Not used
Assessment w/r to DART's Requirements: This EC output is not required by DART at present.		
Air Temp & Wind Chill "Temperature"	Every 3 hrs for next 12 to 24 hrs[1]	Not used
Assessment w/r to DART's Requirements: This EC output is not required by DART at present.		
Dew Point & Rel. Humidity – provides indication whether black ice is likely or not based on comparisons between air temp., pavement temp., and dew point	Every 3 hrs for next 12 to 24 hrs[1]	Dew point used to establish if frost and black ice are possible: • Current dew pt affects initial action • Forecast dew pt affects subsequent action
Assessment w/r to DART's Requirements: This EC output is required by DART and could be integrated simply into DART.		
Sky condition • height–low, med, or high • cover (in octas) of lowest cloud layer	Every 3 hrs for next 12 to 24 hrs[1]	Not used
Assessment w/r to DART's Requirements: This EC output is not required by DART at present.		
Not part of EC's output but the RWIS system defines whether the pavement is: (a) dry or wet, and ; (b) the salinity of the solution		Current Pavement Condition – dry, wet, slush, light snow cover
Assessment w/r to DART's Requirements: This DART requirement is not fully satisfied.		
Forecast snow accumulation vs time	Every 3 hrs for next 12 to 24 hrs[1]	Snowfall rate – defines "heavy" vs "light" snow
Assessment w/r to DART's Requirements: The information is available to fulfill this DART requirement but it is not provided in a directly usable form now.		

Notes:

1. The time period covered by the forecast depends on the time of day being considered.

3.2 Vaisala Oyj

- Definition of the Weather event, or type of precipitation: the required information is not outputted directly. However, it can be obtained by combining the following data that are outputted by Vaisala's ROSA (Vaisala trademark for Road and Runway Surface Analyzer) station:

  (a) precipitation amount in the following classes – no rain, light rain, moderate rain, heavy rain, light snow, moderate snow, and heavy snow.
  (b) precipitation type – rain, sleet, or snow
  (c) road surface condition – dry, moist, moist & chemical, wet, wet & chemical, frost, snow, and ice (including black ice).

- Current and forecast pavement temperature: the current pavement temperature is outputted by the Vaisala System.

  The ROSA weather station does not provide the forecast pavement temperature. However, in Vaisala's IceCast data collection software, it is possible to add a NowCast module, which provides automated surface temperature forecasts. The standard NowCast forecasting time span is 3 hours.

- Current and forecast dewpoint: same comments as above for pavement temperature

- Snow accumulation (in cm) – this is not an output of the Vaisala System. Vaisala commented that although it would be possible to measure the snowfall amount and the actual snow depth on the side of the road, direct measurements of snow depth on the road, where traffic flows occur, would be difficult.

- Pavement condition – the ROSA/IceCast System provides part of the required information. It identifies the following conditions: dry, moist, moist & chemical, wet, wet & chemical, frost, snow and ice (including black ice).

  Vaisala noted that the ROSA/IceCast system provides more detailed information than is required for DART in some cases. On the other hand, they also noted that the ROSA/IceCast system does not differentiate between light or packed snow, and it does not identify slush. In the case of a slush surface condition, the ROSA/IceCast system would report "snow".

- Traffic - this is not an output of the Vaisala System.

  However, Vaisala stated that they have included traffic counting in past projects that they have conducted. In those cases, the traffic counting was handled separately from their ROSA/IceCast system.

- Light vs Heavy Snow (which is defined based on the snowfall rate) – this is an output of the Vaisala System. The ROSA system (equipped with their PWD11 detector) outputs the following precipitation classes: no rain, light rain, moderate rain, heavy rain, light snow, moderate snow, and heavy snow.

- Integrating DART and RWIS systems – In the context of their system, Vaisala suggested that the integration be done at the IceCast data collection level. Vaisala's IceCast software is responsible for collecting the meteorological data from the ROSA weather stations. The Ice Cast system could then output an ASCII text file which includes the measurement data. This data file would then be fed into the DART program. Vaisala enclosed an example of such a data file with their reply to the survey conducted.

  With respect to the traffic volume data required for DART, Vaisala commented that it would be preferable to collect the traffic data separately. This was suggested because in many cases, traffic counting is done at fixed sites, which are not optimal for road weather measurements.

3.3 Lufft

- Definition of the Weather event, or type of precipitation: with the exception of a warning for black ice, this is not outputted by the Traffic Technology/Lufft System.

- Current and forecast pavement temperature: this is outputted by the Traffic Technology/Lufft System

- Current and forecast dewpoint: the system provides the calculated as well as the forecasted dew point.

- Snow accumulation (in cm) – this is not an output of the Traffic Technology/Lufft System. The amount of snow can be measured on the road surface via the road sensor only.

- Pavement condition – the Traffic Technology/Lufft System provides part of the required information. The standard indicators are: dry, damp, and wet road, as well as snow or ice. There are 200 different levels of wetness that are indicated. The road sensor is capable of distinguishing dry from wet snow.

- Traffic - this is not an output of the Traffic Technology/Lufft System. However, Lufft stated that a third party counter could easily be connected to their series 200 dataloggers.

- Light vs Heavy Snow (which is defined based on the snowfall rate) – this is not an output of the Traffic Technology/Lufft System, and the Lufft ARWIS does not have a sensor capable of distinguishing between light and heavy snow. However, Lufft stated that the series 200 datalogger will allow connection to third party sensors providing this type of information.

3.4 Coastal Environmental Systems

- Definition of the Weather event, or type of precipitation: this is not outputted directly although this can be obtained through 24-hour forecasts.

- Current and forecast pavement temperature: the current pavement temperature is measured by the system. Forecasts are required to obtain the forecast pavement temperature.

- Current and forecast dewpoint: this is not clear from the information on their website. It is expected (by FTL) that the system would provide the calculated dewpoint, and that forecasts would be required to obtain the forecast dew point.

- Snow accumulation (in cm) – this does not appear to be an output of the Coastal Environmental System.

- Pavement condition – the Coastal Environmental System provides part of the required information. It can identify the following pavement surface conditions and information:

  (a) dry pavement
  (b) wet pavement
  (c) moist pavement
  (d) wet but not frozen pavement below 0°C
  (e) snowy or icy pavement, at or below 0°C
  (f) dew-covered pavement
  (g) frost-covered pavement
  (h) solution freeze-point , from –20.6° to 0°C (-5° to 32°F)
  (i) chemical concentration of de-icing chemical, from 0 to 100%.
  (j) percentage of ice present on pavement, from 0% to 100%.

- Traffic - this is not an output of the Coastal Environmental System.

- Light vs Heavy Snow (which is defined based on the snowfall rate) – this is not an output of the Coastal Environmental System. However, it is expected that this information could be obtained from 24-hour forecasts.

3.5 Findlay-Irvine

- Definition of the weather event, or type of precipitation: This is not outputted directly although this can be obtained through the 24 hour forecasts that are generated through use of United Kingdom (UK) forecasting authorities using data gathered from the Findlay-Irvine system.

- Time period for the forecasts – the Findlay-Irvine system does not presently have access to “nowcasts” (i.e., up to 4 hours ahead) but that this could be obtained with some additional work.

- Current pavement temperature and dew point: these are outputted by the Findlay-Irvine system.
- Forecast pavement temperature and dew point: these are available as they are part of the information generated in the 24-hour forecasts (above).
- Snow accumulation (in cm) – The Findlay-Irvine system can estimate the amount of snow that has fallen using the present weather sensor. However, it can not provide information to define the accumulation of snow lying on the pavement.
- Pavement condition – The Findlay-Irvine system only provides part of the required information. It will report the surface condition as being dry, wet, or icy, or it will provide a de-icing chemical content level. If snow is present, the system will report the surface condition as icy.
- Traffic – this is not an output of the Findlay-Irvine system at present although this could be integrated with some additional work.
- Light vs Heavy Snow (which is defined based on the snowfall rate) – this is a measured output from the present weather sensor.

4.0 Conclusions and Recommendations

4.1 Summary Results

A survey has been carried out to compare the outputs available from various RWISs with the inputs required for the DART program. The following conclusions can be drawn:

(a) defining the weather event, or type of precipitation - none of the RWISs provide the required output directly. However, this discrepancy could be resolved relatively simply. Furthermore, the information available from RWISs, in combination with weather forecasts, would allow a wider range of cases to be considered by DART.

(b) defining the current and forecast pavement temperature – these are provided by RWISs in combination with forecasts.

(c) defining the current and forecast dew point – these are provided by RWISs in combination with forecasts.

(d) defining the pavement surface condition – none of the RWISs provided all of the required information although they all provide part of it. None of the RWISs could identify slush, or packed snow.

(e) defining the traffic volume - this is not part of current RWIS systems. However, it was generally felt that this capability could be added relatively simply. One RWIS manufacturer cautioned that it might be advisable to collect this information separately because often, traffic counters are not located in optimal locations for RWIS systems.

(f) defining the snow accumulation on the road – this information is not available from any of the RWIS systems although some provide forecasts of snow accumulation vs time, or measurements made at other locations. One RWIS manufacturer cautioned that relevant data (obtained on roads where traffic flows occur) would be very difficult to obtain.

(g) defining the snow type (i.e., “heavy” versus “light” based on the snowfall rate) – this was not available from all systems. However, it was generally felt that this capability could be added with relatively little effort.

(h) integrating DART with RWIS systems – this has only been investigated in a preliminary manner. It appears that it would be possible to accomplish this automatically, and one RWIS manufacturer provided a sample input data file that might be used as an input. More work is required before definitive statements can be made.

One information provider suggested that DART should be introduced gradually. The status quo (in which the users select actions based on their judgement and the forecast information) should be maintained. The recommendations from DART should be provided as an extra piece of information that the users can use as they wish. This will lead to better acceptance of, and further development of DART.

4.2 Recommendations

The significance of the information gaps noted in section 4.1 should be evaluated by assessing their effect on the actions advised by DART. As well, the DART algorithms should be reviewed in relation to any additional information that is available from RWIS systems to assess whether improved reliability could be obtained by including these parameters.

It is noted that other work (e.g., the MTO’s Maintenance 2001 Project) is currently ongoing to verify and further develop advisories for winter maintenance actions, and this should be taken into account as well in assessing the significance of the noted information gaps.

5.0 References

[1] Comfort, G., 1997, De-Icing and Abrasives Road Treatment Computer Program: Operating Notes and Technical Basis, Fleet Technology Ltd. report 4626 submitted to the MTO.

[2] Ketcham, S.L., Minsk, D.L., Blackburn, R., and Fleege, E., 1996, Manual of Practice for an Effective Anti-Icing Program: A Guide for Highway Winter Maintenance Personnel, Report FHWA-RD-95-202.

Decision Support System for Winter Maintenance: The DART Database

Aurora Project Team: Max Perchanok, Ontario Ministry of Transportation
Curt Pape, Minnesota DoT
Lee Smithson, Iowa DoT
Dan Eriksson, Swedish National Road Authority
Tim Bullock/PaulDeLannoy, Environment Canada
Alfred Uzokwe, Pennsylvania DoT

Report Author: Max Perchanok, Ontario Ministry of Transportation

Prepared by the Maintenance 2001 Project, Ontario Ministry of Transportation, for the AURORA Consortium, Project 1997-03, Decision Support System for Winter Maintenance

November 5, 2002

FINAL REPORT

Table of Contents

Appendices

1. Introduction

Snow and ice removal methods on highways in North American are changing from re-active ploughing and of spreading large quantities of rock salt following snow accumulation, to application of smaller quantities of salt in anticipation of snowfall or frost. Pre-application is expected to prevent accumulation under low snowfall conditions and to improve the effectiveness of ploughing under heavier snowfall.

Rock salt is quickly dispersed from bare pavement surfaces by traffic and dissolves slowly when applied on snow. Road maintenance practice in Scandinavia and recently in North America suggest that dispersal is reduced and solution rate is increased if rock salt is pre-wetted with a small quantity of liquid de-icer or is applied as a brine.

Road operating agencies which use pre-wetting or Direct Liquid Application (DLA), have developed application guidelines particular to a type of winter weather, traffic and, standards of snow removal. Computer-based systems such as the De-icing/Anti-icing Response Treatment (DART) program or the Maintenance Decision Support System (MDSS) have been developed to implement those guidelines. However, the transfer of guidelines from place to place requires an understanding of the relationship between performance of different chemical types, application rates, spreading methods, environmental conditions and road maintenance standards which is not incorporated in existing systems.

This study was undertaken to develop a database that can be used to quantify and compare the effectiveness of snow removal using alternative chemicals and methods under specified environmental conditions.

2. Methods

2.1 General Approach

The overall approach was to measure differences in the rate of snow removal under known environmental conditions and maintenance operations. The measurements were conducted on consecutive sections of highway maintenance routes, each of which had a fixed observation site.

A set of chemical application protocols was developed which specified the chemical type, application rate and spread pattern to be used in each road section during a given weather and snow cover condition. The protocols were designed to compare the effects of one variable (chemical, application rate or method) under comparable environmental and traffic conditions.

The effectiveness of snow removal following each material application was measured and categorized to permit comparison of each method tested.

2.2 Field Site

Test areas were selected to provide frequent exposure to the range of winter weather conditions experienced in Ontario, consistent conditions across a maintenance route and, a traffic level which is safe for test operations under inclement weather conditions.

Two maintenance routes were used; one from fall 1997 until spring 1999 (former Highway 26, now County Road 26) and one from fall 1999 until the present (Highway 21) (Appendix A). Both routes are located in the Great Lakes-St. Lawrence climatic region of southwestern Ontario, Canada (Hare and Thomas, 1974). This is a continental climate modified by the Great Lakes, with normal winter snow accumulation of 2.8 m, occurring on 75 to 80 days and, mean daily temperature (MDT) below $0^{o}C$ for the period December through March. The coldest month is January with MDT of $-7^{o}C$ (AES, 1980; 1991). Both routes are in the lee of Lake Huron and Georgian Bay and are subject to frequent lake-effect snowfall and, to drifting snow for several days following precipitation. They traverse a region of rolling farmlands and woodlots including open terrain which is exposed to drifting snow and sunlight and, forested terrain which is sheltered from wind and sun.

The highways have one lane of asphalt pavement in each direction, winter average daily traffic in the range 2,000 to 6,000 vehicles and Service Class 2, which requires ploughing when snow depth reaches 20 mm and, recovery of bare pavement within eight hours after a storm (MTO, 2002).

The maintenance routes were divided into sections 2 to 5 km in length for purposes of varying the material application and monitoring the surface conditions (Appendix A). A luminaire, video surveillance camera and VCR or digital image recording device were located on a roadside utility pole near the centre of each test section and a measurement grid was marked on the pavement under each camera.

2.3 Snow Removal and Test Protocols

All test operations were conducted as part of the normal winter maintenance operations while highways were open to traffic. Test protocols were developed prior to each winter season defining the chemicals, application rates and methods that should be used in each test section during specified road-weather conditions. Protocols varied from year to year and an example is provided in Appendix B.

The test area was normally ploughed prior to chemical application and then at one to two hour intervals. Chemicals or winter sand was sometimes re-applied if the surface was not cleared within a two hour period. Each chemical or sand application in each test section is considered an independent test event. Each pass of the plough and spreader across each test section was recorded either manually or with an Automated Vehicle Location (AVL) system. The records for each test section include the time and direction of ploughing and spreading, vehicle speed, chemical type and application rate.

2.4 Weather and Road Surface Conditions

One or two Road Weather Information System (RWIS) stations were operated at an observation site on both maintenance routes. They automatically measured and recorded air, road surface and subsurface temperature, wind speed and direction, humidity and, precipitation.

The surveillance camera in each test section photographed the pavement surface from shoulder to shoulder, recording with date and time annotation at 10-minute intervals through each test event..

Snow cover was estimated from the video images for each of three, 1.3 m square sectors across each lane. Snow cover fraction, estimated in tenths from 0 to 1.0, was defined as the area in each square in which pavement was not visible. Independent estimates of snow covered area from the same video images showed that estimates were reliable within +/- 1 tenth. The snow cover was entered as a line on a spreadsheet to provide a time series associated with each chemical application at each test section.

2.5 Data Reduction

Data were collated to provide a time series of snow cover at each test site, starting at the time of the spreader pass. Time series were plotted with annotations showing each plough and spreader pass (Figure 1).

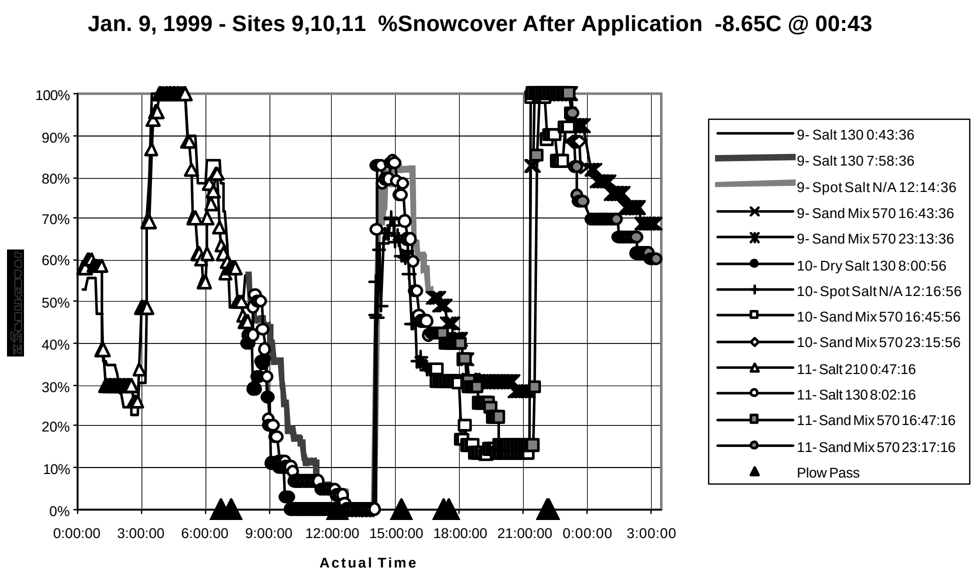


Figure 1. Time series of snow cover for Sites 9, 10 and 11, January 9, 1999

The plotted data were used to estimate or classify the effectiveness of each material application using three objective criteria; melting rate, trend in snow cover and, success in reducing snow cover (Appendix C).

Melting rate was defined as the change in width of snow cover across the pavement over the time period starting at material application and ending when snow cover was reduced to 25% of the pavement width or, the next material application, whichever occurred first. The criterion of 25% was used rather than completely bare pavement because non-travelled portions of the pavement such as shoulder edges frequently retain snow for many hours after the driving surface is cleared to a safe level. Melting rate is a continuous variable that can be used to develop predictive models.

Trend in snow cover was classified using a numeric code that describes the increase or decrease in snow cover over a specified time period (0.5, 1 or 2 hours) following material application.

Effect of material application was classified as either successful or unsuccessful in reducing snow cover over a specified time period (0.5, 1 or 2 hours) following material application.

The two classification systems, each with 3 time criteria, were developed to provide results that are comparable with a variety of winter maintenance standards. For example, analysis using the Effect criterion over a 0.5 hour period gives results for dry rock salt applied at 130 kg/2-lane km which are consistent with winter maintenance standards in the Province of Ontario.

The Melting Rate, Trend and Effect were estimated and tabulated with the initial snow cover, other environmental conditions and, operations data for each test event.

2.6 Analysis

An analysis was conducted to demonstrate an application of the database. It was sorted into categories of light and heavy snowfall and three ranges of surface temperature. Effect was used as a success criterion by tabulating the percent of cases having Effect code 1 under each environmental category (Appendix E).

3. Results

The database contains 786 records, each describing the environmental and road surface conditions, the type, rate and method of a de-icing chemical or winter sand application and, the effectiveness of the application in clearing snow from the pavement (Appendix D).

A sample analysis shows that salt application rates can be reduced under equivalent environmental conditions when it is pre-wet with a liquid de-icer (Appendix E).

4. Discussion

Direct comparison of the effectiveness of maintenance treatments requires similar snow and environmental conditions and, different maintenance actions in adjacent test sections at the same time. Local weather, traffic or other conditions may preclude direct comparison of results in adjacent sections at the same time and therefore, the data should be sorted to compare test events from different time periods in which similar conditions are experienced.

Snow depth and compaction, wind and sunlight conditions were not included in the regular measurement program and are not include in the database but may be accounted for through other factors such as time of day, site exposure, snowfall rate and precipitation. Variation in snow depth between sites is limited by Ontario Class 2 Highway Service Standards, which require ploughing when depth reaches 20 mm.

5. Conclusions

The relative effectiveness of alternative chemicals, application rates and application methods for highway snow removal can be analysed and evaluated using the DART database.

6. References

Hare, F.K, and M. K. Thomas, 1974. Climate Canada, Wiley Publishers of Canada Limited, Toronto.

MTO, 2002. Maintenance Special Provisions, Area Maintenance Contracts. Maintenance Office, Ontario Ministry of Transportation, St. Catharines, Ontario.

7. Acknowledgements

The DART database was acquired as part of the Maintenance 2001 project, conducted co-operatively between the Maintenance Office, Southwest Region Office and, Owen Sound District Office, Ontario Ministry of Transportation (MTO), between 1995 and 2001. The project was sponsored by the Director, Construction and Operations Branch and, the Assistance Deputy Minister, Operations Division, MTO.

Data were collected and tabulated by MTO staff, by students under contract from the Universities of Guelph and Waterloo and, by contractors.

8. Appendices Summary:

A. Test Sections and Surveillance Camera Sites
B. Sample Test Protocol
C. Variable Definitions
D. DART Database
E. Example Analysis of Reduction in Salt Application Rate with Pre-wetting

APPENDIX A. DART Database Data Collection Sites

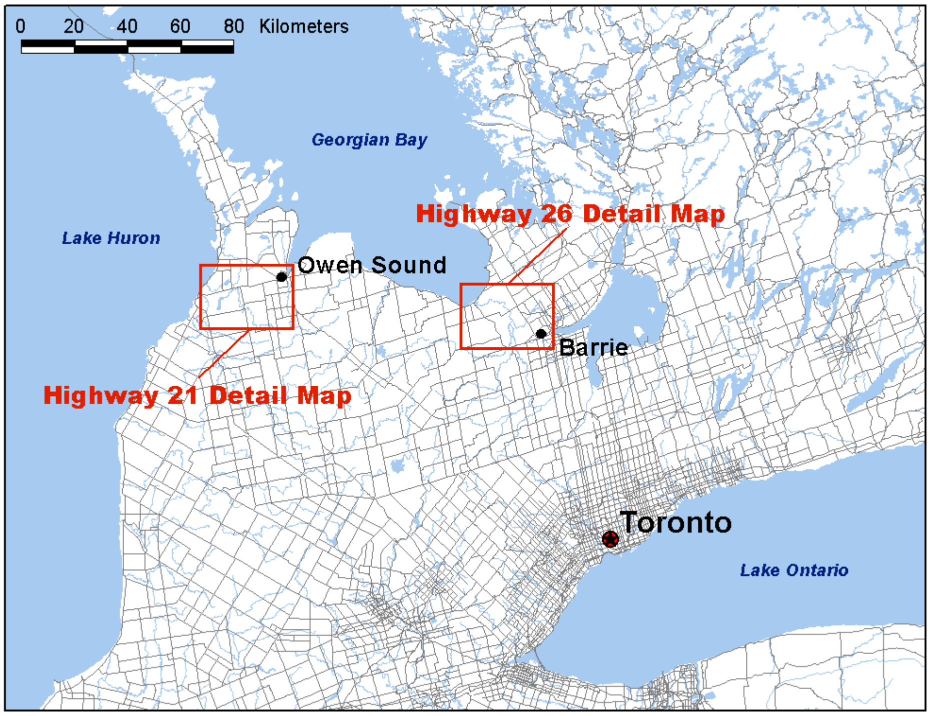


Figure 1: Data Collection Areas on Highway 21, Owen Sound and Highway 26, Barrie, Ontario, Canada

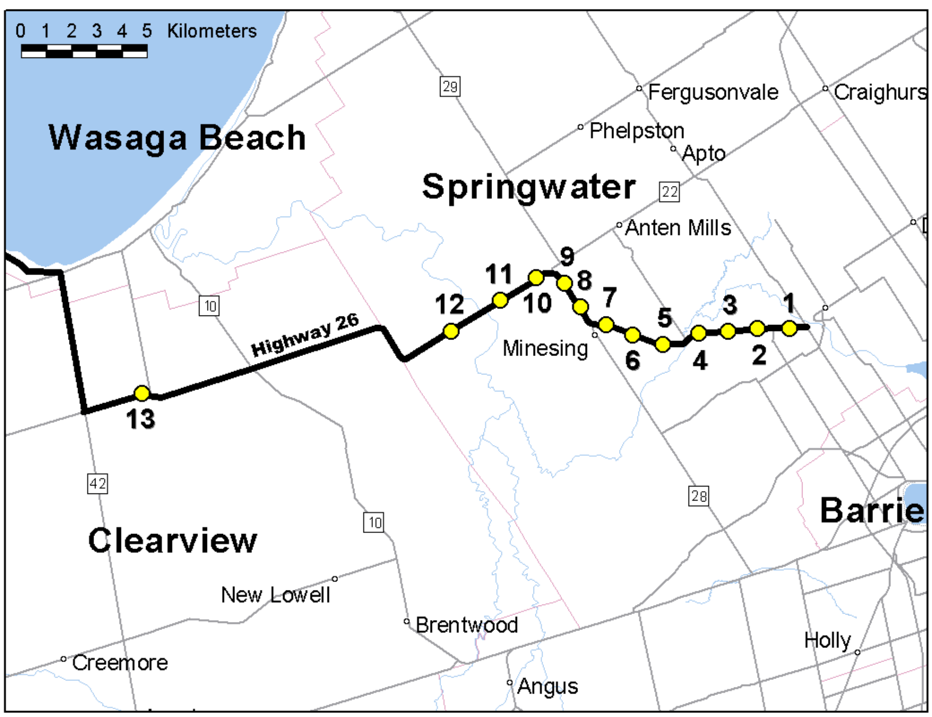


Figure 2: Surveillance camera sites on Highway 26, Barrie, 1995-96 to 1998-99

Table 1: 1998-99 Test Sites, Highway 26

Test Area	Site #	Distance from Simcoe County Bldg entrance (0.4 km from Hwy 26/27) (km)	Description
A	0	0	County Building lane
	1	0.65	at WB “bump” sign across from Wolfenden residence #1243
	--	.68	railroad crossing
	--	1.3	paint lines from Site 2 1997-98
	2	1.35	camera site
	3	2.4	same as 1997-98
B	--	2.75	Vespra Concession 7 crossing
	4	3.5	level, open site, 100 m east of curve sign
	--	4.3	Golf Course Road
	--	4.45	bridge
	--	5.1	Meyer Side Road
	5	5.2	at EB Meyer Side Road sign
	6	6.5	same as site 4 from 1997-98
C	7	8.15	same as site 5 from 1997-98
	--		Simcoe Rd 28, Minesing
	8	9.25	camera site south of Marl Creek
	--	9.65	Marl Creek bridge
	9	10.35	camera site north of Marl Creek
	--		Horseshoe Valley Road
D	10	12.1	camera site, Vespra Concession 11, same as 1997-98
	11	13.1	camera site east of Vespra Concession 12
	--		new Nottawasaga R. bridge
	12	14.85	camera site at Vespra Concession 13
	--	15.4	Flos Road 23, end of test area
E	13	30	Stayner east town limit, analogue recording camera site

Table 2: Test Sites 1997-98 – WB sign locations:

number WB side	location (distance from county bld, and description)	number EB side
1	near intersection Hwy 26/27	"end"
2	railroad crossing	1
3	1.9 km	2
4	2.7 km east side of Concession 7 crossing	3
5	east side of Golf Course Road	4
6	5.8 km (top of hill)	5
7	6.8 km	6
8	8.75	7
9	south end of Marl Creek Bridge	8
10	11.3 km; west of Horseshoe Valley Road intersection	9
11	12.65 km	10
12	14 km; west end of Nottawasaga Bridge	11
"end"	Flos Road 23	12

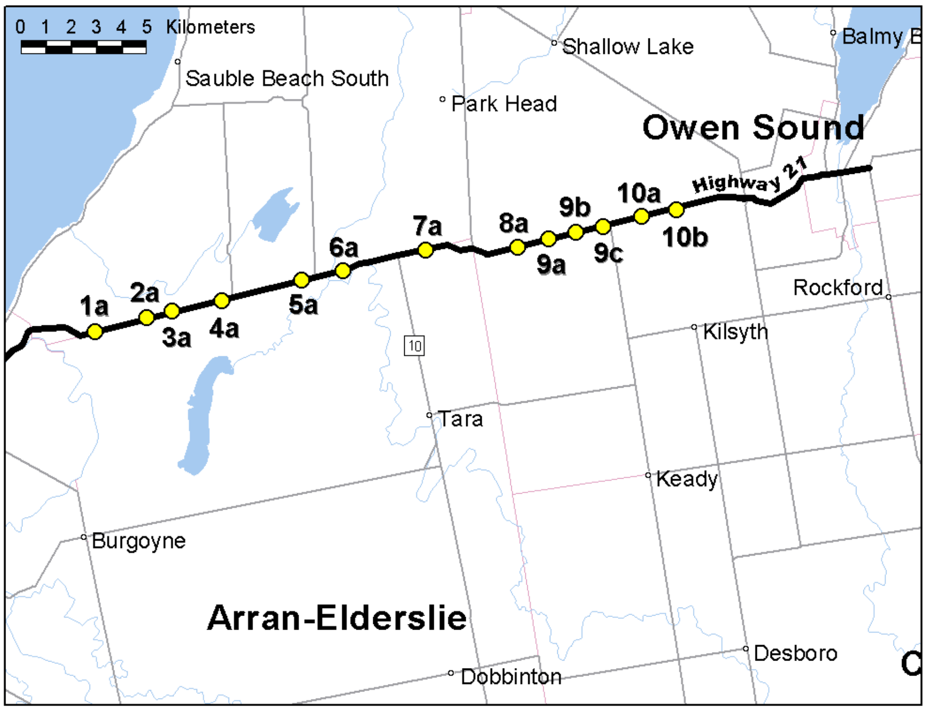


Figure 3: Test Sections and Surveillance Camera Sites on Highway 21, Owen Sound, 1999-2000 and 2000-2001

APPENDIX B. Sample Test Protocol

MAINTENANCE 2001 TEST PROTOCOLS WINTER 2000-01

DRY MATERIAL APPLICATION RATES FOR PRE-WETTED SALT:

PRECIPITATION	SURFACE TEMPERATURE (^oC)		
	0 to -5	**-5 to -10**	**-10 TO -18**
frost	50	70	70
light snow	70	100	130
heavy snow	130	130	170
freezing rain	130	170	170

Application rates in kg/2-lane km.

Application Notes:

Liquids used in each test section are as follows:
Port Elgin-Southampton: dry salt, not monitored
Sections 1-3, Craig St to patrol yard, 6.0 km: **Magic-0** (brown liquid)
Sections 4-6, patrol yard to Tara road, 7.7 km: NaCl (**salt brine**)
Sections 7-8, Tara road to Derby Conc. II, 6.3 km: $MgCl_2$ (**magnesium chloride**)
Sections 9-10, Conc. II-Springmount, 8.4 km: $CaCl_2$ (**calcium chloride**)
4-lane section of Hwy 21: dry salt, not monitored

The test plan shows material applications in every section but if no salt is needed in some sections then they should be passed over with no application. If a liquid chemical is not available or pre-wetting is not working, use dry salt at 130-170 kg in that section(s).
Surface temperature can be obtained from ARWIS at any time or from Infra-red Thermometer *if* the road is bare or wet but not snow covered.
Normally use slow spin setting (#1) on all spreaders in the test sections. If different settings are used then both spreaders should use the same setting and spread pattern. Record what settings are used.
Monitoring will be primarily with remote video cameras in the west end (Sections 1-6) and with the van in the east end (Sections 7-10) when only 1 monitor is on duty.

Liquid Anti-icing and Sand-Salt Mix Tests

Weather Conditions:
A: ground frost warm temperature

- Surface temperature is >-6 and <0, and lower than dew point temperature, no snow
A and B objective to compare brine with pre-wet salt

B: light snowfall warm temperature

-Surface temperature >-6 and <0, light snowfall (less than amount needed to plough)

C: overnight icing due to traffic packing light snowfall and cold temperatures

-Night or early morning, surface temperature <-10, light snowfall
C objective is to compare sweetened mix with pre-wetting under night-time conditions where salt is not very effective and ice could form from light snow, and too cold for liquid application

A and B require the brine truck, plus 2 pre-wetting spreaders
C requires 3 spreaders; sand in 1,2,3, pre-wet Magic in 4-6, pre-wet magnesium and calcium in 5-10

Follow variable rate table for dry material application rates and use pre-wetting rates as shown.

Liquid application:

Section	**Weather Conditions**	
	A or B	**C**
Port Elgin-Southam'n	NaCl, 15% pre-wet	30/70 mix, 570 kg/2-lane km
1	Magic-0, 5% pre-wet	30/70 salt/sand mix 570 kg/2-lane km
2,3	Magic-, 15% pre-wet	-same as #1
4,5	NaCl, 15% pre-wet	NaCl, 15% pre-wet
6	NaCl brine 100 litres/1-lane km	NaCl, 5% pre-wet
7	$MgCl_2$, 15% pre-wet	$MgCl_2$, 5% pre-wet
8	$MgCl_2$, 5% pre-wet	$MgCl_2$, 15% pre-wet
9	$CaCl_2$, 5% pre-wet	$CaCl_2$, 15% pre-wet
10	$CaCl_2$, 15% pre-wet	$CaCl_2$, 5% pre-wet
4-lane	$CaCl_2$, 5% pre-wet	$CaCl_2$, 5% pre-wet

NOTE: pre-wetting rates +/-2% depending on calibration.

Variable Rate Tests and Comparison of Pre-wetting Chemicals

Weather Condition: any conditions where salt would normally be used except frost, which is covered in the Liquid Anti-icing tests
Use variable rates table for dry salt application rates

Section	5% pre-wet	15% pre-wet
Port Elgin-Southampton	Dry Salt, 130-170	Dry salt, 130-170
1,2,3	Magic-0 pre-wet	Magic-0 pre-wet
4,5,6	NaCl pre-wet	NaCl pre-wet
7,8	$MgCl_2$ pre-wet	$MgCl_2$ pre-wet
9,10	$CaCl_2$ pre-wet	$CaCl_2$ pre-wet
4-lane	dry salt, 130-170	dry salt, 130-170

NOTE: pre-wetting rates +/-2% depending on calibration

Winter Sand Effectiveness and Retention

Weather Conditions:

A. packed snow due to snowfall and cold temperatures
-compare coarse, fine and standard gradations using dry sand

B. packed snow due to snowfall and cold temperatures
-compare dry sand vs pre-wet sand

C. packed snow due to heavy drifting or heavy snowfall
- compare 5%, 30/70 mix, and pre-wet sand

D. overnight sanding due to cold temperatures and light snowfall
- compare 5%, 30/70 mix, and pre-wet sand

E. packed snow due to snowfall and cold temperatures (same as A and B);
-compare application rates using standard, dry sand

A requires 3 spreaders, 1 for standard, 1 for coarse, 1 for fine sand
B requires 2 spreaders, 1 for dry and pre-wet Magic and NaCl, 1 for dry and pre-wet CaCl
C and D require 2 spreaders; 1 for standard, 1 for mix, 1 for standard with pre-wetting MgCl and CaCl
E requires 1 spreader

Section	A. 570 kg, different sands, dry	B. 570 kg, dry vs pre-wet sand	C. and D. 570 kg, pre-wet rates, 30/70	E. standard sand, test different rates
Port Elgin-Southampton	standard sand	dry standard sand	dry standard sand	
1	coarse sand	dry standard sand	dry standard sand	270 kg/2-lane km
2,3	same as 1	pre-wet Magic-0 5%	30/70 mix, dry	370
4,5,6	fine sand	pre-wet NaCl 5%	30/70 mix, dry	470
7,8	standard sand	dry standard sand	standard pre-wet $MgCl_2$, 5%	570
9,10	same as 7,8	pre-wet $CaCl_2$ 5%	standard pre-wet $CaCl_2$ 5%	670
4-lane	standard sand	dry standard sand	dry standard sand	570

30/70 = 30% salt 70% sand

APPENDIX C. DART Database Variable Definitions

Event: Consecutive ID number

Date: Date of test

Material: description of material applied

Material Code:

0 salt/sand mix 1 sand 2 brine 3 dry salt 4 pre-wet with NaCl	5 pre-wet with Magic 6 pre-wet with MgCl 7 pre-wet with CaCl 8 dry NAAC	9 dry NAAC 10 dry NAAC 11 dry NAAC 12 pre-wet sand or mix

Site: experimental monitoring site along test route

Rate (kg/2-lane km): dry material application rate (does not include liquid)

Initial Snow Cover (%): Percentage (0 to 100) of roadway covered with snow at start of test, estimated from video images.

Initial Snow Cover (fraction): Same as above, expressed as a decimal (0 to 1)

Air Temp (^{o}C): Air temperature measured by RWIS sensor or by infra-red thermometer on spreader or monitoring vehicle (+/- 1^{o}C).

Air Temp Time: Time at which air temperature was measured

Surface Temp (^{o}C): Surface temperature measured by RWIS sensor or by infrared thermometer on spreader or monitoring vehicle (+/- 1^{o}C)

Precip @ Application: Precipitation during test event, recorded by RWIS. (0 indicates no precipitation, 1 indicates precipitation)

Precip Sensor Time: Time from RWIS sensor

Snowfall: snowfall rate during test, interpreted from video

0: no snow
1: light snow
2: moderate snow
3: heavy snow

DaySnow: daily snowfall amount (mm) recorded at nearest Environment Canada weather station

Time Applied: Time at which sand or salt were spread at the test site, used as initial time for test event and for estimating melting rate or success rate of application.

Prior 4hrs, 6hrs, 12hrs: Dry salt equivalent of freeze-point suppressants (not including winter sand) applied to the test site in the previous 4, 6 and 12 hours period. 4, 6 and 12 hour amounts are cumulative, so 6 hours includes material in previous 4 hours and 12 hours includes material in previous 4 and 6 hours.

Pre-wet Material:

0: none (dry rock salt)
1: brine (sodium chloride)
2: Magic ($MgCl_2$ + agricultural byproducts)
3: NAAC (sodium acetate)
4: $CaCl_2$ (calcium chloride)
5: $MgCl_2$ (magnesium chloride)

NaCl Pre-wet Rate (%): % by mass of liquid added to dry salt
NOTE: NaCl pre-wet rate of 100L indicates direct liquid application of 100 l per lane km with no rock salt.

Other Pre-wet Rate (%): % by mass of liquid added to dry salt for liquids other than NaCl brine.

Time of analysed frame: Time annotation on video frame used to document initial snow cover condition

Initial Cover (m): Snow cover on pavement at start of test, in m of pavement width (max per lane is 3.65m) NOTE: some cases use 1 lane and some cases use 2 lanes; analysis should use % snow cover rather than width of snow cover

Trend (over 2, 1, or ½ hours): code that describes trend of snow cover over time period *X* hours from time of material application

0: Snow cover remained consistent
1: Snow cover decreased and later increased
2: Snow cover increased and later decreased
3: Snow cover increased consistently
4: Snow cover decreased consistently

Effect (over 2, 1, or ½ hours): Code that describes overall change in snow cover over from the time of application until the end of *X* hours.

0: Snow cover remained the same or increased
1: Snow cover decreased

MR (m/hr): Melting Rate: rate of reduction in snow covered area of pavement, beginning at time of material application and ending when snow cover is reduced to 25% of pavement width, expressed in metres/hour.

(Initial width-final width)/(final time/initial time)

Air Temp Trend: code describing the trend in air temperature in the 2 hours following material application.

- -1: Air temperature decreased
- 0: Air temperature remained the same
- 1: Air temperature increased

Hours from noon: (time of application-noon)

Hours/abs value from noon: Absolute value in hours, of:
(noon)-(time of material application)

"999", "na", or "NO DATA" indicates no information available for that cell.

END

Event	Date	Material	Material Code	Site	Rate kg/2lnkm (X6)	Initial Snow Cover % (X1)	Initial cover fraction	Air Temp (X2)	Air Temp Time	Surface Temp (X3)	Precip @ Application (X4)	Precip Sensor Time	Snowfall	DaySnow	Time Applied	Prior 4 hrs	Prior 6hrs	Prior 12hrs	Prewet Matereial	NaCl Prewet % Rate	Other Prewet % Rate	DLA	Time of analyzed frame	Initial Cover (m)	Trend, 2 hr	Effect, 2 hr	Trend, 1 hr	Effect, 1 hr	Trend, .5 hr	Effect, .5 hr	MR m/hr	Air Temp trend	hours from noon (hr)	abs value from noon
718	17-Feb-97	prewet salt	4	2	100	100	1	1	22:56:04	0	na	na	1	.	22:50	100	0	0	1	6	0	0	na	3.65	0a	1	0a	1	na	na	1.73	1	-1	1
573	22-Dec-97	dry salt	3	1	130	5	0.05	-2	20:20:31	-3	na	na	1	31	20:20	0	0	0	0	0	0	0	na	0.18	3	0	2	0	3	0	0.00	0	8.25	8.25
575	22-Dec-97	dry salt	3	2	130	0	0	-2	20:21:52	-3	na	na	1	31	20:21	0	0	0	0	0	0	0	na	0.00	3	0	3	0	3	0	0.00	0	8.25	8.25
577	22-Dec-97	dry salt	3	3	130	0	0	-2	20:23:51	-3	na	na	1	31	20:23	0	0	0	0	0	0	0	na	0.00	3	0	2	0	3	0	0.00	0	8.5	8.5
579	22-Dec-97	dry salt	3	4	130	0	0	-2	20:30:37	-3	na	na	1	31	20:30	0	0	0	0	0	0	0	na	0.00	3	0	3	0	3	0	0.00	0	8.5	8.5
581	22-Dec-97	dry salt	3	5	130	0	0	-2	20:32:20	-3	na	na	1	31	20:32	0	0	0	0	0	0	0	na	0.00	3	0	3	0	3	0	0.00	0	8.5	8.5
583	22-Dec-97	dry salt	3	6	130	0	0	-2	20:33:53	-3	na	na	1	31	20:33	0	0	0	0	0	0	0	na	0.00	2	0	3	0	3	0	0.00	0	8.5	8.5
585	22-Dec-97	dry salt	3	7	130	0	0	-2	20:34:46	-3	na	na	1	31	20:34	0	0	0	0	0	0	0	na	0.00	3	0	3	0	3	0	0.00	0	8.5	8.5
587	22-Dec-97	dry salt	3	8	130	0	0	-2	20:36:14	-3	na	na	1	31	20:36	0	0	0	0	0	0	0	na	0.00	3	0	3	0	3	0	0.00	0	8.5	8.5
589	22-Dec-97	dry salt	3	9	130	0	0	-2	20:39:01	-3	na	na	1	31	20:39	0	0	0	0	0	0	0	na	0.00	3	0	3	0	3	0	0.00	0	8.75	8.75
590	22-Dec-97	dry salt	3	10	130	0	0	-2	20:40:16	-3	na	na	1	31	20:40	0	0	0	0	0	0	0	na	0.00	3	0	3	0	3	0	0.00	0	8.75	8.75
591	22-Dec-97	dry salt	3	11	130	0	0	-2	20:43:23	-3	na	na	1	31	20:43	0	0	0	0	0	0	0	na	0.00	3	0	3	0	3	0	0.00	0	8.75	8.75
576	22-Dec-97	dry salt	3	3	130	80	0.8	-2	0:09:22	-3	na	na	2	31	23:55	0	0	0	0	0	0	0	na	2.92	3	0	na	na	na	na	0.00	0	-11.75	11.75
578	22-Dec-97	dry salt	3	4	130	95	0.95	-2	0:13:30	-3	na	na	2	31	23:55	0	0	0	0	0	0	0	na	3.47	0	0	na	na	na	na	0.00	0	-11.75	11.75
580	22-Dec-97	dry salt	3	5	130	100	1	-2	0:14:29	-3	na	na	2	31	23:55	0	0	0	0	0	0	0	na	3.65	0a	1	na	na	na	na	0.00	0	-11.75	11.75
582	22-Dec-97	dry salt	3	6	130	80	0.8	-2	0:15:22	-3	na	na	2	31	23:55	0	0	0	0	0	0	0	na	2.92	0	0	na	na	na	na	0.00	0	-11.75	11.75
584	22-Dec-97	dry salt	3	7	130	80	0.8	-2	0:16:06	-3	na	na	2	31	23:55	0	0	0	0	0	0	0	na	2.92	0a	1	na	na	na	na	0.00	0	-11.75	11.75
586	22-Dec-97	dry salt	3	8	130	80	0.8	-2	0:17:12	-3	na	na	2	31	23:55	0	0	0	0	0	0	0	na	2.92	0a	1	na	na	na	na	0.00	0	-11.75	11.75
588	22-Dec-97	dry salt	3	9	130	90	0.9	-2	0:19:06	-3	na	na	2	31	23:55	0	0	0	0	0	0	0	na	3.29	0a	1	na	na	na	na	0.00	0	-11.75	11.75
592	30-Dec-97	dry salt	3	2	130	5	0.05	-2	13:56:04	-2	na	na	1	26	13:56	0	0	0	0	0	0	0	na	0.18	na	na	na	na	0	0	0.00	0	2	2
593	30-Dec-97	dry salt	3	3	130	0	0	-2	13:56:54	-2	na	na	1	26	13:56	0	0	0	0	0	0	0	na	0.00	na	na	na	na	0	0	0.00	0	2	2
594	30-Dec-97	dry salt	3	4	130	45	0.45	-2	14:00:07	-2	na	na	1	26	14:00	0	0	0	0	0	0	0	na	1.64	na	na	na	na	3	0	0.00	0	2	2
595	30-Dec-97	dry salt	3	5	130	100	1	-2	14:00:58	-2	na	na	1	26	14:00	0	0	0	0	0	0	0	na	3.65	na	na	na	na	0	0	0.00	0	2	2
596	30-Dec-97	dry salt	3	6	130	0	0	-2	14:01:53	-2	na	na	1	26	14:01	0	0	0	0	0	0	0	na	0.00	na	na	0	0	0	0	0.00	0	2	2
597	30-Dec-97	dry salt	3	7	130	0	0	-2	14:02:22	-2	na	na	1	26	14:02	0	0	0	0	0	0	0	na	0.00	na	na	3	0	3	0	0.00	0	2	2
598	30-Dec-97	dry salt	3	8	130	0	0	-2	14:03:06	-2	na	na	1	26	14:03	0	0	0	0	0	0	0	na	0.00	na	na	3	0	3	0	0.00	0	2	2
599	30-Dec-97	dry salt	3	9	130	80	0.8	-2	14:04:47	-2	na	na	1	26	14:04	0	0	0	0	0	0	0	na	2.92	na	na	0a	1	0	0	0.00	0	2	2
600	30-Dec-97	prewet salt	4	10	130	85	0.85	-2	14:05:30	-2	na	na	1	26	14:05	0	0	0	1	6	0	0	na	3.10	na	na	1	1	0a	1	0.00	0	2	2
601	30-Dec-97	dry salt	3	11	130	70	0.7	-2	14:07:14	-2	na	na	1	26	14:07	0	0	0	0	0	0	0	na	2.56	na	na	1	0	0a	1	4.69	0	2	2
602	8-Jan-98	dry salt	3	1	150	0	0	na	16:08:46	na	na	na	0	6	16:00	0	0	150	0	0	0	0	na	0.00	0	0	0	0	0	0	0.00	na	4.25	4.25
603	8-Jan-98	dry salt	3	2	100	0	0	na	16:09:28	na	na	na	0	6	16:00	0	0	150	0	0	0	0	na	0.00	0	0	0	0	0	0	0.00	na	4.25	4.25
604	8-Jan-98	dry salt	3	3	50	0	0	na	16:10:22	na	na	na	0	6	16:00	0	0	50	0	0	0	0	na	0.00	0	0	0	0	0	0	0.00	na	4.25	4.25
605	8-Jan-98	dry salt	3	4	100	0	0	na	16:13:36	na	na	na	0	6	16:00	0	0	70	0	0	0	0	na	0.00	1	0	3	0	na	na	0.00	na	4.25	4.25
606	8-Jan-98	dry salt	3	5	100	0	0	na	16:14:29	na	na	na	0	6	16:00	0	0	100	0	0	0	0	na	0.00	3	0	3	0	na	na	0.00	na	4.25	4.25
607	8-Jan-98	dry salt	3	6	100	0	0	na	16:15:20	na	na	na	0	6	16:00	0	0	100	0	0	0	0	na	0.00	2	0	3	0	na	na	0.00	na	4.25	4.25
608	8-Jan-98	dry salt	3	7	100	0	0	na	16:15:48	na	na	na	0	6	16:00	0	0	100	0	0	0	0	na	0.00	2	0	3	0	na	na	0.00	na	4.25	4.25
609	8-Jan-98	dry salt	3	8	100	0	0	na	16:16:32	na	na	na	0	6	16:00	0	0	100	0	0	0	0	na	0.00	2	0	3	0	na	na	0.00	na	4.25	4.25
610	8-Jan-98	dry salt	3	9	130	0	0	na	16:18:07	na	na	na	0	6	16:00	0	0	130	0	0	0	0	na	0.00	2	0	3	0	na	na	0.00	na	4.25	4.25
611	8-Jan-98	dry salt	3	10	150	15	0.15	na	16:18:51	na	na	na	0	6	16:00	0	0	150	0	0	0	0	na	0.55	0a	1	0a	1	na	na	0.00	na	4.25	4.25
612	8-Jan-98	dry salt	3	11	150	0	0	na	16:20:26	na	na	na	0	6	16:00	0	0	150	0	0	0	0	na	0.00	2	0	0	0	na	na	0.00	na	4.25	4.25
613	14-Jan-98	dry salt	3	1	570	100	1	-12	5:29:48	-11	na	na	1	35	5:29	0	0	0	0	0	0	0	na	3.65	na	na	0a	1	na	na	0.00	1	-6.5	6.5
615	14-Jan-98	dry salt	3	2	570	100	1	-12	5:31:07	-11	na	na	1	35	5:29	0	0	0	0	0	0	0	na	3.65	na	na	0	0	na	na	0.00	1	-6.5	6.5
617	14-Jan-98	dry salt	3	3	570	100	1	-12	5:32:30	-11	na	na	1	35	5:29	0	0	0	0	0	0	0	na	3.65	na	na	0a	1	na	na	0.00	1	-6.5	6.5
619	14-Jan-98	dry salt	3	4	570	100	1	-12	5:37:30	-11	na	na	1	35	5:29	0	0	0	0	0	0	0	na	3.65	na	na	0a	1	na	na	0.00	1	-6.5	6.5
621	14-Jan-98	dry salt	3	5	570	100	1	-12	5:38:30	-11	na	na	1	35	5:29	0	0	0	0	0	0	0	na	3.65	na	na	0a	1	na	na	0.00	1	-6.25	6.25
623	14-Jan-98	dry salt	3	6	570	100	1	-12	5:40:00	-11	na	na	1	35	5:29	0	0	0	0	0	0	0	na	3.65	na	na	0a	1	na	na	0.00	1	-6.25	6.25
625	14-Jan-98	dry salt	3	7	570	100	1	-12	5:40:30	-11	na	na	1	35	5:29	0	0	0	0	0	0	0	na	3.65	na	na	0a	1	na	na	0.00	1	-6.25	6.25
626	14-Jan-98	dry salt	3	8	570	100	1	-12	5:41:45	-11	na	na	1	35	5:29	0	0	0	0	0	0	0	na	3.65	na	na	0a	1	na	na	0.00	1	-6.25	6.25
628	14-Jan-98	dry salt	3	9	570	100	1	-12	5:43:43	-11	na	na	1	35	5:29	0	0	0	0	0	0	0	na	3.65	na	na	0a	1	na	na	0.00	1	-6.25	6.25
630	14-Jan-98	dry salt	3	10	570	100	1	-12	5:45:00	-11	na	na	1	35	5:29	0	0	0	0	0	0	0	na	3.65	na	na	0a	1	na	na	0.00	1	-6.25	6.25
632	14-Jan-98	dry salt	3	11	570	100	1	-12	5:46:27	-11	na	na	1	35	5:29	0	0	0	0	0	0	0	na	3.65	na	na	0a	1	na	na	0.00	1	-6.25	6.25
614	14-Jan-98	dry salt	3	1	100	50	0.5	-11	20:52:04	-9	na	na	1	32	20:50	0	0	100	0	0	0	0	na	1.83	2	0	2	0	3	0	0.00	0	9	9
616	14-Jan-98	dry salt	3	2	100	20	0.2	-11	20:52:52	-9	na	na	1	32	20:50	0	0	100	0	0	0	0	na	0.73	2	0	2	0	3	0	0.00	0	9	9
618	14-Jan-98	dry salt	3	3	70	20	0.2	-11	20:53:54	-9	na	na	1	32	20:50	0	0	100	0	0	0	0	na	0.73	2	0	3	0	3	0	0.00	0	9	9
620	14-Jan-98	dry salt	3	4	130	70	0.7	-11	20:57:25	-9	na	na	1	32	20:50	0	0	100	0	0	0	0	na	2.56	3	0	3	0	3	0	0.00	0	9	9
622	14-Jan-98	dry salt	3	5	130	90	0.9	-11	20:58:24	-9	na	na	1	32	20:50	0	0	100	0	0	0	0	na	3.29	0a	1	0a	1	0a	1	0.00	0	9	9
624	14-Jan-98	dry salt	3	6	130	50	0.5	-11	20:59:18	-9	na	na	1	32	20:50	0	0	50	0	0	0	0	na	1.83	2	0	2	0	3	0	0.00	0	9	9
627	14-Jan-98	dry salt	3	8	100	70	0.7	-11	21:00:25	-9	na	na	1	32	20:50	0	0	50	0	0	0	0	na	2.56	2	1	3	0	3	0	0.00	0	9	9
629	14-Jan-98	dry salt	3	9	100	60	0.6	-11	21:02:10	-9	na	na	1	32	20:50	0	0	50	0	0	0	0	na	2.19	3	0	3	0	3	0	0.00	0	9	9
631	14-Jan-98	dry salt	3	10	130	60	0.6	-11	21:03:00	-9	na	na	1	32	20:50	0	0	50	0	0	0	0	na	2.19	2	0	2	0	3	0	0.00	0	9	9
633	14-Jan-98	dry salt	3	11	150	100	1	-11	21:04:45	-9	na	na	1	32	20:50	0	0	50	0	0	0	0	na	3.65	0a	1	1	1	0a	1	0.00	0	9	9
634	15-Jan-98	dry salt	3	1	100	100	1	-12	6:16:11	-12	na	na	3	32	6:00	0	0	100	0	0	0	0	na	3.65	na	na	0	0	na	na	0.00	0	-5.75	5.75
635	15-Jan-98	dry salt	3	2	100	100	1	-12	6:16:57	-12	na	na	3	32	6:00	0	0	100	0	0	0	0	na	3.65	na	na	0	0	na	na	0.00	0	-5.75	5.75
636	15-Jan-98	dry salt	3	3	70	100	1	-12	6:18:00	-12	na	na	3	32	6:00	0	0	70	0	0	0	0	na	3.65	na	na	0a	1	na	na	0.00	0	-5.75	5.75
637	15-Jan-98	dry salt	3	4	130	100	1	-12	6:21:50	-12	na	na	3	32	6:00	0	0	130	0	0	0	0	na	3.65	na	na	0	0	na	na	0.00	0	-5.75	5.75
638	15-Jan-98	dry salt	3	5	130	100	1	-12	6:22:33	-12	na	na	3	32	6:00	0	0	130	0	0	0	0	na	3.65	na	na	0	0	na	na	0.00	0	-5.75	5.75
639	15-Jan-98	dry salt	3	6	130	100	1	-12	6:23:35	-12	na	na	3	32	6:00	0	0	130	0	0	0	0	na	3.65	na	na	0a	1	na	na	0.00	0	-5.5	5.5
640	15-Jan-98	dry salt	3	7	100	100	1	-12	6:24:10	-12	na	na	3	32	6:00	0	0	100	0	0	0	0	na	3.65	na	na	0a	1	na	na	0.00	0	-5.5	5.5
641	15-Jan-98	dry salt	3	8	100	75	0.75	-12	6:24:53	-12	na	na	3	32	6:00	0	0	100	0	0	0	0	na	2.74	na	na	3	0	na	na	0.00	0	-5.5	5.5
642	15-Jan-98	dry salt	3	9	100	100	1	-12	6:26:38	-12	na	na	3	32	6:00	0	0	100	0	0	0	0	na	3.65	na	na	0a	1	na	na	0.00	0	-5.5	5.5
643	15-Jan-98	dry salt	3	10	130	100	1	-12	6:27:20	-12	na	na	3	32	6:00	0	0	130	0	0	0	0	na	3.65	na	na	0a	1	na	na	0.00	0	-5.5	5.5
644	15-Jan-98	dry salt	3	11	150	100	1	-12	6:29:02	-12	na	na	3	32	6:00	0	0	150	0	0	0	0	na	3.65	na	na	0a	1	na	na	0.00	0	-5.5	5.5
645	23-Jan-98	dry salt	3	1	130	80	0.8	-8	8:02:22	-8	na	na	3	47	8:00	0	0	0	0	0	0	0	na	2.92	na	na	3	0	na	na	0.00	1	-4	4
647	23-Jan-98	dry salt	3	2	130	80	0.8	-8	8:04:31	-8	na	na	3	47	8:00	0	0	0	0	0	0	0	na	2.92	na	na	3	0	na	na	0.00	1	-4	4
649	23-Jan-98	dry salt	3	3	130	70	0.7	-8	8:06:01	-8	na	na	3	47	8:00	0	0	0	0	0	0	0	na	2.56	na	na	3	0	na	na	0.00	1	-4	4
651	23-Jan-98	dry salt	3	4	130	70	0.7	-8	8:11:02	-8	na	na	3	47	8:00	0	0	0	0	0	0	0	na	2.56	na	na	3	0	na	na	0.00	1	-3.75	3.75
653	23-Jan-98	dry salt	3	5	130	70	0.7	-8	8:12:20	-8	na	na	3	47	8:00	0	0	0	0	0	0	0	na	2.56	na	na	3	0	na	na	0.00	1	-3.75	3.75
655	23-Jan-98	dry salt	3	6	130	80	0.8	-8	8:13:29	-8	na	na	3	47	8:00	0	0	0	0	0	0	0	na	2.92	na	na	3	0	na	na	0.00	1	-3.75	3.75
657	23-Jan-98	dry salt	3	7	130	60	0.6	-8	8:14:07	-8	na	na	3	47	8:00	0	0	0	0	0	0	0	na	2.19	na	na	3	0	na	na	0.00	1	-3.75	3.75
659	23-Jan-98	dry salt	3	8	130	60	0.6	-8	8:15:11	-8	na	na	3	47	8:00	0	0	0	0	0	0	0	na	2.19	na	na	3	0	na	na	0.00	1	-3.75	3.75
661	23-Jan-98	dry salt	3	9	130	70	0.7	-8	8:17:23	-8	na	na	3	47	8:00	0	0	0	0	0	0	0	na	2.56	na	na	3	0	na	na	0.00	1	-3.75	3.75
663	23-Jan-98	dry salt	3	10	130	60	0.6	-8	8:18:21	-8	na	na	3	47	8:00	0	0	0	0	0	0	0	na	2.19	na	na	3	0	na	na	0.00	1	-3.75	3.75

APPENDIX D. DART Database

Event	Date	Material	Material Code	Site	Rate kg/2lnkm (X6)	Initial Snow Cover % (X1)	Initial cover fraction	Air Temp (X2)	Air Temp Time	Surface Temp (X3)	Precip @ Application (X4)	Precip Sensor Time	Snowfall	DaySnow	Time Applied	Prior 4 hrs	Prior 6hrs	Prior 12hrs	Prewet Matereial	NaCl Prewet % Rate	Other Prewet % Rate	DLA	Time of analyzed frame	Initial Cover (m)	Trend, 2 hr	Effect, 2 hr	Trend, 1 hr	Effect, 1 hr	Trend, .5 hr	Effect, .5 hr	MR m/hr	Air Temp trend	hours from noon (hr)	abs value from noon
665	23-Jan-98	dry salt	3	11	130	70	0.7	-8	8:20:15	-8	na	na	3	47	8:00	0	0	0	0	0	0	0	na	2.56	na	na	3	0	na	na	0.00	1	-3.75	3.75
646	23-Jan-98	dry salt	3	1	130	90	0.9	-4	10:27:38	-3	na	na	3	47	10:00	0	0	0	0	0	0	0	na	3.29	0a	1	0	0	na	na	0.00	1	-1.5	1.5
648	23-Jan-98	dry salt	3	2	130	100	1	-4	10:28:37	-3	na	na	3	47	10:00	0	0	0	0	0	0	0	na	3.65	na	na	0	0	na	na	0.00	1	-1.5	1.5
650	23-Jan-98	dry salt	3	3	130	100	1	-4	10:29:45	-3	na	na	3	47	10:00	0	0	0	0	0	0	0	na	3.65	0a	1	0	0	na	na	0.00	1	-1.5	1.5
652	23-Jan-98	dry salt	3	4	130	100	1	-4	10:33:17	-3	na	na	3	47	10:00	0	0	0	0	0	0	0	na	3.65	0a	1	0	0	na	na	0.00	1	-1.5	1.5
654	23-Jan-98	dry salt	3	5	130	100	1	-4	10:34:25	-3	na	na	3	47	10:00	0	0	0	0	0	0	0	na	3.65	0a	1	0a	1	na	na	1.08	1	-1.5	1.5
658	23-Jan-98	dry salt	3	7	130	80	0.8	-4	10:36:10	-3	na	na	3	47	10:00	0	0	0	0	0	0	0	na	2.92	2	1	3	0	na	na	0.00	1	-1.5	1.5
660	23-Jan-98	dry salt	3	8	130	100	1	-4	10:37:15	-3	na	na	3	47	10:00	0	0	0	0	0	0	0	na	3.65	0a	1	0	0	na	na	1.21	1	-1.5	1.5
662	23-Jan-98	dry salt	3	9	130	100	1	-4	10:39:55	-3	na	na	3	47	10:00	0	0	0	0	0	0	0	na	3.65	0a	1	0a	1	na	na	0.00	1	-1.25	1.25
664	23-Jan-98	dry salt	3	10	130	100	1	-4	10:40:35	-3	na	na	3	47	10:00	0	0	0	0	0	0	0	na	3.65	0a	1	0a	1	na	na	0.00	1	-1.25	1.25
666	23-Jan-98	dry salt	3	11	130	100	1	-4	10:42:30	-3	na	na	3	47	10:00	0	0	0	0	0	0	0	na	3.65	0a	1	0a	1	na	na	0.00	1	-1.25	1.25
656	23-Jan-98	sand	1	6	350	0	0	-2	13:56:24	-4	na	na	3	47	13:50	0	130	0	0	0	0	0	na	0.00	3	0	na	na	na	na	0.00	1	2	2
667	29-Jan-98	brine	2	1	70lsb	80	0.8	1	11:38:34	-1	na	na	2	98	11:36	0	0	0	0	0	0	0	na	2.92	1	0	1	0	0a	1	0.00	-1	-0.25	0.25
670	29-Jan-98	brine	2	2	104lsb	90	0.9	1	11:39:14	-1	na	na	2	98	11:36	0	0	0	0	0	0	0	na	3.29	1	0	1	0	0a	1	0.00	-1	-0.25	0.25
673	29-Jan-98	brine	2	3	158lsb	60	0.6	1	11:40:23	-1	na	na	2	98	11:36	0	0	0	0	0	0	0	na	2.19	3	0	1	0	0a	1	0.00	-1	-0.25	0.25
676	29-Jan-98	brine	2	4	70lsb	40	0.4	1	11:43:41	-1	na	na	2	98	11:36	0	0	0	0	0	0	0	na	1.46	2	0	1	0	0a	1	0.00	-1	-0.25	0.25
679	29-Jan-98	brine	2	5	10pws	30	0.3	1	11:44:40	-1	na	na	2	98	11:36	0	0	0	0	0	0	0	na	1.10	2	0	1	0	0a	1	0.00	-1	-0.25	0.25
682	29-Jan-98	brine	2	6	30pws	20	0.2	1	11:45:34	-1	na	na	2	98	11:36	0	0	0	0	0	0	0	na	0.73	2	0	1	0	0a	1	0.00	-1	-0.25	0.25
685	29-Jan-98	brine	2	7	30ds	20	0.2	1	11:45:52	-1	na	na	2	98	11:36	0	0	0	0	0	0	0	na	0.73	2	0	1	0	0a	1	0.00	-1	-0.25	0.25
688	29-Jan-98	brine	2	8	30ds	30	0.3	1	11:48:48	-1	na	na	2	98	11:36	0	0	0	0	0	0	0	na	1.10	2	0	1	0	0a	1	0.00	-1	-0.25	0.25
691	29-Jan-98	brine	2	9	30pw	30	0.3	1	11:48:21	-1	na	na	2	98	11:36	0	0	0	0	0	0	0	na	1.10	2	0	1	0	0a	1	0.00	-1	-0.25	0.25
694	29-Jan-98	brine	2	10	50pw	40	0.4	1	11:49:02	-1	na	na	2	98	11:36	0	0	0	0	0	0	0	na	1.46	2	0	1	0	0a	1	0.00	-1	-0.25	0.25
697	29-Jan-98	brine	2	11	70pw	50	0.5	1	11:50:44	-1	na	na	2	98	11:36	0	0	0	0	0	0	0	na	1.83	2	1	1	0	0a	1	2.28	-1	-0.25	0.25
668	29-Jan-98	dry salt	3	1	100	30	0.3	1	17:43:55	-3	na	na	3	98	17:40	0	0	0	0	0	0	0	na	1.10	na	na	3	0	na	na	0.00	0	5.75	5.75
671	29-Jan-98	dry salt	3	2	100	30	0.3	1	17:47:48	-3	na	na	3	98	17:40	0	0	0	0	0	0	0	na	1.10	na	na	3	0	na	na	0.00	0	5.75	5.75
674	29-Jan-98	dry salt	3	3	100	20	0.2	1	17:50:00	-3	na	na	3	98	17:40	0	0	0	0	0	0	0	na	0.73	na	na	3	0	na	na	0.00	0	5.75	5.75
677	29-Jan-98	dry salt	3	4	100	40	0.4	1	17:56:58	-3	na	na	3	98	17:40	0	0	0	0	0	0	0	na	1.46	na	na	3	0	na	na	0.00	0	6	6
680	29-Jan-98	dry salt	3	5	100	40	0.4	1	17:58:55	-3	na	na	3	98	17:40	0	0	0	0	0	0	0	na	1.46	na	na	3	0	na	na	0.00	0	6	6
683	29-Jan-98	dry salt	3	6	100	60	0.6	1	18:00:45	-3	na	na	3	98	17:40	0	0	0	0	0	0	0	na	2.19	na	na	3	0	na	na	0.00	0	6	6
686	29-Jan-98	dry salt	3	7	100	50	0.5	1	18:01:35	-3	na	na	3	98	17:40	0	0	0	0	0	0	0	na	1.83	na	na	3	0	na	na	0.00	0	6	6
689	29-Jan-98	dry salt	3	8	100	50	0.5	1	18:03:15	-3	na	na	3	98	17:40	0	0	0	0	0	0	0	na	1.83	na	na	3	0	na	na	0.00	0	6	6
692	29-Jan-98	dry salt	3	9	100	80	0.8	1	18:08:16	-3	na	na	3	98	17:40	0	0	0	0	0	0	0	na	2.92	na	na	0a	1	na	na	0.00	0	6.25	6.25
695	29-Jan-98	dry salt	3	10	100	80	0.8	1	18:09:50	-3	na	na	3	98	17:40	0	0	0	0	0	0	0	na	2.92	na	na	0a	1	na	na	0.00	0	6.25	6.25
698	29-Jan-98	dry salt	3	11	100	80	0.8	1	18:12:45	-3	na	na	3	98	17:40	0	0	0	0	0	0	0	na	2.92	na	na	3	0	na	na	0.00	0	6.25	6.25
669	29-Jan-98	dry salt	3	1	70	40	0.4	1	19:47:32	-3	na	na	3	98	19:10	70	0	0	0	0	0	0	na	1.46	na	na	0a	1	na	na	0.00	0	7.75	7.75
672	29-Jan-98	dry salt	3	2	70	30	0.3	1	19:48:26	-3	na	na	3	98	19:10	100	0	0	0	0	0	0	na	1.10	na	na	0a	1	na	na	0.00	0	7.75	7.75
675	29-Jan-98	dry salt	3	3	70	20	0.2	1	19:49:29	-3	na	na	3	98	19:10	130	0	0	0	0	0	0	na	0.73	na	na	0a	1	na	na	0.00	0	7.75	7.75
678	29-Jan-98	dry salt	3	4		10	0.1	1	19:53:06	-3	na	na	3	98	19:10	150	0	0	0	0	0	0	na	0.37	na	na	0a	1	na	na	0.00	0	8	8
681	29-Jan-98	dry salt	3	5	70	20	0.2	1	19:54:01	-3	na	na	3	98	19:10	150	0	0	0	0	0	0	na	0.73	na	na	0	0	na	na	0.00	0	8	8
684	29-Jan-98	dry salt	3	6	70	10	0.1	1	19:54:59	-3	na	na	3	98	19:10	100	0	0	0	0	0	0	na	0.37	na	na	0	0	na	na	0.00	0	8	8
687	29-Jan-98	dry salt	3	7	70	20	0.2	1	19:55:25	-3	na	na	3	98	19:10	100	0	0	0	0	0	0	na	0.73	na	na	0a	1	na	na	0.00	0	8	8
690	29-Jan-98	dry salt	3	8	70	10	0.1	1	19:57:12	-3	na	na	3	98	19:10	70	0	0	0	0	0	0	na	0.37	na	na	3	0	na	na	0.00	0	8	8
693	29-Jan-98	dry salt	3	9	70	30	0.3	1	19:57:56	-3	na	na	3	98	19:10	70	0	0	0	0	0	0	na	1.10	na	na	0a	1	na	na	0.00	0	8	8
696	29-Jan-98	dry salt	3	10	70	20	0.2	1	19:58:42	-3	na	na	3	98	19:10	130	0	0	0	0	0	0	na	0.73	na	na	0a	1	na	na	0.00	0	8	8
699	29-Jan-98	dry salt	3	11	70	40	0.4	1	20:01:00	-3	na	na	3	98	19:10	100	0	0	0	0	0	0	na	1.46	na	na	0a	1	na	na	1.15	0	8	8
700	12-Feb-98	dry salt	3	9	130	30	0.3	0	16:52:35	-2	na	na	1	1	16:45	0	0	0	0	0	0	0	na	1.10	na	na	0a	1	0a	1	0.00	0	5	5
702	12-Feb-98	dry salt	3	10	130	30	0.3	0	16:53:20	-2	na	na	1	1	16:45	0	0	0	0	0	0	0	na	1.10	na	na	0	0	0	0	0.00	0	5	5
704	12-Feb-98	dry salt	3	11	130	30	0.3	0	17:00:53	-2	na	na	1	1	16:45	0	0	0	0	0	0	0	na	1.10	na	na	0a	1	0	0	0.00	0	5	5
701	12-Feb-98	dry salt	3	9	130	15	0.15	0	18:49:00	-2	na	na	1	1	18:06	0	0	0	0	0	0	0	na	0.55	na	na	3	0	3	0	0.00	0	6.75	6.75
703	12-Feb-98	dry salt	3	10	130	10	0.1	0	18:50:11	-2	na	na	1	1	18:06	0	0	0	0	0	0	0	na	0.37	na	na	3	0	3	0	0.00	0	6.75	6.75
705	12-Feb-98	dry salt	3	11	130	35	0.35	0	18:51:50	-2	na	na	1	1	18:06	0	0	0	0	0	0	0	na	1.28	na	na	2	0	0a	1	0.00	0	6.75	6.75
706	17-Feb-98	prewet salt	4	1	150	85	0.85	1	19:44:40	0	na	na	3	38	19:30	0	0	0	1	6	0	0	na	3.10	na	na	3	0	na	na	0.00	0	7.75	7.75
707	17-Feb-98	prewet salt	4	2	100	85	0.85	1	19:45:39	0	na	na	3	38	19:30	0	0	0	1	6	0	0	na	3.10	na	na	0	0	na	na	0.00	0	7.75	7.75
708	17-Feb-98	prewet salt	4	3	50	85	0.85	1	19:46:38	0	na	na	3	38	19:30	0	0	0	1	6	0	0	na	3.10	na	na	3	0	na	na	0.00	0	7.75	7.75
709	17-Feb-98	prewet salt	4	4	100	85	0.85	1	19:51:00	0	na	na	3	38	19:30	0	0	0	1	6	0	0	na	3.10	na	na	3	0	na	na	0.00	0	7.75	7.75
710	17-Feb-98	prewet salt	4	5	100	85	0.85	1	19:52:56	0	na	na	3	38	19:30	0	0	0	1	6	0	0	na	3.10	na	na	0	0	na	na	0.00	0	7.75	7.75
711	17-Feb-98	dry salt	3	6	100	75	0.75	1	19:53:48	0	na	na	3	38	19:30	0	0	0	0	0	0	0	na	2.74	na	na	3	0	na	na	0.00	0	8	8
712	17-Feb-98	dry salt	3	7	100	100	1	1	19:54:37	0	na	na	3	38	19:30	0	0	0	0	0	0	0	na	3.65	na	na	0a	1	na	na	0.00	0	8	8
713	17-Feb-98	prewet salt	4	9	130	20	0.2	1	19:56:54	0	na	na	3	38	19:30	0	0	0	1	6	0	0	na	0.73	na	na	3	0	na	na	0.00	0	8	8
714	17-Feb-98	prewet salt	4	10	150	85	0.85	1	19:57:48	0	na	na	3	38	19:30	0	0	0	1	6	0	0	na	3.10	na	na	3	0	na	na	0.00	0	8	8
715	17-Feb-98	prewet salt	4	11	150	70	0.7	1	19:59:45	0	na	na	3	38	19:30	0	0	0	1	6	0	0	na	2.56	na	na	3	0	na	na	0.00	0	8	8
716	17-Feb-98	prewet salt	4	1	150	100	1	1	22:55:01	0	na	na	1	.	22:50	150	0	0	1	6	0	0	na	3.65	0a	1	0a	1	na	na	1.72	1	-1	1
720	17-Feb-98	prewet salt	4	3	150	100	1	1	22:57:52	0	na	na	1	.	22:50	50	0	0	1	6	0	0	na	3.65	0a	1	0a	1	na	na	1.63	1	-1	1
722	17-Feb-98	prewet salt	4	4	100	85	0.85	1	23:02:23	0	na	na	1	.	22:50	100	0	0	1	6	0	0	na	3.10	0a	1	0a	1	na	na	1.41	1	-1	1
723	17-Feb-98	prewet salt	4	5	100	80	0.8	1	23:04:35	0	na	na	1	.	22:50	100	0	0	1	6	0	0	na	2.92	0a	1	0a	1	na	na	1.27	1	-1	1
724	17-Feb-98	dry salt	3	6	100	100	1	1	23:08:24	0	na	na	1	.	22:50	100	0	0	0	0	0	0	na	3.65	0a	1	0a	1	na	na	1.81	1	-0.75	0.75
725	17-Feb-98	dry salt	3	7	100	100	1	1	23:08:24	0	na	na	1	.	22:50	100	0	0	0	0	0	0	na	3.65	0a	1	0a	1	na	na	1.81	1	-0.75	0.75
726	17-Feb-98	prewet salt	4	8	100	70	0.7	1	23:15:03	0	na	na	1	.	22:50	100	0	0	1	6	0	0	na	2.56	0a	1	0a	1	na	na	1.79	1	-0.75	0.75
727	17-Feb-98	prewet salt	4	9	130	55	0.55	1	23:17:06	0	na	na	1	.	22:50	130	0	0	1	6	0	0	na	2.01	0a	1	0	0	na	na	0.74	1	-0.75	0.75
728	17-Feb-98	prewet salt	4	10	150	80	0.8	1	23:18:06	0	na	na	1	.	22:50	150	0	0	1	6	0	0	na	2.92	0a	1	0a	1	na	na	1.35	1	-0.75	0.75
729	17-Feb-98	prewet salt	4	11	150	40	0.4	1	23:20:55	0	na	na	1	.	22:50	150	0	0	1	6	0	0	na	1.46	0a	1	0a	1	na	na	0.61	1	-0.75	0.75
717	18-Feb-98	dry salt	3	1	130	30	0.3	2	6:05:52	0	na	na	1	38	5:30	200	150	150	0	0	0	0	na	1.10	na	na	na	na	0a	1	0.00	0	-6	6
719	18-Feb-98	dry salt	3	2	130	40	0.4	2	6:04:55	0	na	na	1	38	5:30	200	100	100	0	0	0	0	na	1.46	na	na	na	na	0a	1	1.78	0	-6	6
721	18-Feb-98	dry salt	3	3	130	40	0.4	2	6:03:55	0	na	na	1	38	5:30	200	150	50	0	0	0	0	na	1.46	na	na	na	na	0a	1	1.73	0	-6	6
1	9-Dec-98	Pre-Wet Salt	4	9	100	0.0%	0.00	5.82	19:11:46	0	0	19:11:46	no vid	0	19:11:01	0	0	0	1	6	0	0	19:13:01	0.00	0	0	0	0	0	0	0.00	-1	7.25	7.25
2	10-Dec-98	dry salt	3	8	50	0.0%	0.00	-1.39	1:12:16	0	0	1:12:16	no vid	0	1:12:08	0	100	100	0	0	0	0	1:13:01	0.00	0	0	0	0	0	0	0.00	1	-10.75	10.75
3	10-Dec-98	dry salt	3	9	50	0.0%	0.00	-0.98	1:13:57	0	0	1:13:57	no vid	0	1:13:36	0	100	100	0	0	0	0	1:18:01	0.00	0	0	0	0	0	0	0.00	-1	-10.75	10.75
6	10-Dec-98	dry salt	3	11	50	3.3%	0.03	-1.23	1:17:19	0	0	1:17:19	no vid	0	1:17:16	0	100	100	0	0	0	0	1:18:01	0.24	0	0	0	0	0	0	0.10	-1	-10.75	10.75
4	10-Dec-98	dry salt	3	8	100	0.0%	0.00	-1.82	2:57:00	0	0	2:57:00	no vid	0	2:57:08	50	50	150	0	0	0	0	2:58:01	0.00	0	0	0	0	0	0	0.00	-1	-9	9
5	10-Dec-98	dry salt	3	9	100	0.0%	0.00	-2.25	2:57:50	0	0	2:57:50	no vid	0	2:58:36	50	50	150	0	0	0	0	3:03:01	0.00	0	0	0	0	0	0	0.00	-1	-9	9
7	10-Dec-98	dry salt	3	11	100	3.3%	0.03	-2.01	3:02:04	0	0	3:02:04	no vid	0	3:02:16	50	50	150	0	0	0	0	3:03:01	0.24	0	0	0	0	0	0	0.24	1	-9	9
17	11-Dec-98	dry salt	3	1	100	100.0%	1.00	1.90	5:15:19	1	1	5:15:19	no vid	40	5:15:41	0	0	0	0	0	0	0	5:25:41	7.30	3	0	3	0	3	0	0.00	-1	-6.75	6.75

APPENDIX D. DART Database

Event	Date	Material	Material Code	Site	Rate kg/2lnkm (X6)	Initial Snow Cover % (X1)	Initial cover fraction	Air Temp (X2)	Air Temp Time	Surface Temp (X3)	Precip @ Application (X4)	Precip Sensor Time	Snowfall	DaySnow	Time Applied	Prior 4 hrs	Prior 6hrs	Prior 12hrs	Prewet Matereial	NaCl Prewet % Rate	Other Prewet % Rate	DLA	Time of analyzed frame	Initial Cover (m)	Trend, 2 hr	Effect, 2 hr	Trend, 1 hr	Effect, 1 hr	Trend, .5 hr	Effect, .5 hr	MR m/hr	Air Temp trend	hours from noon (hr)	abs value from noon
18	11-Dec-98	dry salt	3	2	100	100.0%	1.00	0.33	5:16:06	1	0	5:16:06	no vid	40	5:16:28	0	0	0	0	0	0	0	5:26:26	7.30	3	0	3	0	3	0	0.00	1	-6.75	6.75
19	11-Dec-98	dry salt	3	3	100	100.0%	1.00	2.05	5:17:48	1	1	5:17:48	no vid	40	5:17:39	0	0	0	0	0	0	0	5:27:25	7.30	0	0	0	0	0	0	0.00	-1	-6.75	6.75
20	11-Dec-98	dry salt	3	4	100	100.0%	1.00	1.85	5:18:38	1	1	5:18:38	no vid	40	5:18:04	0	0	0	0	0	0	0	5:35:38	7.30	3	0	3	0	3	0	0.00	-1	-6.75	6.75
16	11-Dec-98	dry salt	3	5	100	93.0%	0.93	1.95	5:20:18	1	1	5:20:18	no vid	40	5:20:45	0	0	0	0	0	0	0	5:35:18	6.79	3	0	2	1	3	0	0.00	-1	-6.75	6.75
21	11-Dec-98	dry salt	3	6	100	100.0%	1.00	1.00	5:22:08	1	0	5:22:08	no vid	40	5:22:13	0	0	0	0	0	0	0	5:35:31	7.30	3	0	3	0	2	0	0.00	-1	-6.5	6.5
15	11-Dec-98	dry salt	3	8	100	86.9%	0.87	1.17	5:25:16	1	1	5:25:16	2	40	5:25:16	0	0	0	0	0	0	0	5:30:00	6.35	1	1	1	1	0	1	7.43	-1	-6.5	6.5
13	11-Dec-98	dry salt	3	11	100	7.8%	0.08	1.49	5:31:05	1	1	5:31:05	1	40	5:31:35	0	0	0	0	0	0	0	5:35:04	0.57	0	0	0	1	0	1	0.17	-1	-6.5	6.5
14	11-Dec-98	dry salt	3	8	130	68.9%	0.69	1.20	6:29:19	1	1	6:29:19	3	40	6:30:16	100	100	100	0	0	0	0	6:35:00	5.03	0	0	0	1	1	1	6.47	-1	-5.5	5.5
12	11-Dec-98	dry salt	3	11	130	5.3%	0.05	1.40	6:36:49	1	1	6:36:49	3	40	6:36:35	100	100	100	0	0	0	0	6:40:04	0.39	0	0	0	1	0	1	0.69	-1	-5.5	5.5
10	11-Dec-98	dry salt	3	8	130	3.3%	0.03	0.13	7:30:24	1	1	7:30:24	no vid	40	7:30:16	230	230	230	0	0	0	0	7:35:00	0.24	0	0	0	0	0	0	0.00	-1	-4.5	4.5
8	11-Dec-98	dry salt	3	11	130	0.0%	0.00	0.24	7:35:29	1	1	7:35:29	no vid	40	7:36:35	230	230	230	0	0	0	0	7:40:04	0.00	0	0	0	0	0	0	0.00	-1	-4.5	4.5
11	11-Dec-98	dry salt	3	8	130	3.3%	0.03	-0.69	8:30:21	1	1	8:30:57	no vid	40	8:30:16	360	360	360	0	0	0	0	8:35:00	0.24	1	1	0	1	0	1	0.27	-1	-3.5	3.5
9	11-Dec-98	dry salt	3	11	130	0.0%	0.00	-0.56	8:36:01	1	1	8:36:01	no vid	40	8:36:35	360	360	360	0	0	0	0	8:40:04	0.00	0	0	0	0	0	0	0.00	-1	-3.5	3.5
23	16-Dec-98	Brine	2	8	75	0.0%	0.00	1.87	21:21:39	1	1	21:21:39	no vid	20	21:22:48	0	0	0	0	0	0	0	21:26:22	0.00	0	0	0	0	0	0	0.00	-1	9.5	9.5
31	16-Dec-98	Brine	2	9	100	5.0%	0.05	1.89	21:24:49	1	1	21:24:49	no vid	20	21:23:45	0	0	0	0	0	0	0	21:26:24	0.37	0	0	0	0	0	0	0.00	-1	9.5	9.5
22	16-Dec-98	Brine	2	10	100	0.0%	0.00	1.89	21:24:49	1	1	21:24:49	no vid	20	21:25:15	0	0	0	0	0	0	0	21:26:15	0.00	0	0	0	0	0	0	0.00	-1	9.5	9.5
24	16-Dec-98	Brine	2	11	100	0.0%	0.00	-0.23	21:26:12	1	0	21:27:36	no vid	20	21:26:06	0	0	0	0	0	0	0	21:29:48	0.00	0	0	3	0	0	0	0.00	0	9.5	9.5
26	16-Dec-98	dry salt	3	8	100	0.0%	0.00	1.83	23:17:09	1	1	23:17:09	no vid	20	23:17:08	41.1	41.1	41.1	0	0	0	0	23:21:22	0.00	0	0	0	0	0	0	0.00	-1	11.25	11:25
32	16-Dec-98	dry salt	3	9	100	5.0%	0.05	1.83	23:17:09	1	1	23:17:09	no vid	20	23:18:36	54.7	54.7	54.7	0	0	0	0	23:21:24	0.37	0	0	0	0	0	0	0.00	-1	11.25	11.25
25	16-Dec-98	dry salt	3	10	100	0.0%	0.00	0.41	23:20:53	1	1	23:20:53	no vid	20	23:20:56	54.7	54.7	54.7	0	0	0	0	23:21:15	0.00	0	0	0	0	0	0	0.00	1	11:25	11:25
27	16-Dec-98	dry salt	3	11	100	0.0%	0.00	0.23	23:23:59	1	1	23:23:59	no vid	20	23:22:16	54.7	54.7	54.7	0	0	0	0	23:24:48	0.00	0	0	0	0	0	0	0.00	1	11.5	11.5
29	16-Dec-98	dry salt	3	8	100	0.0%	0.00	1.72	23:41:45	1	1	23:41:45	no vid	20	23:42:08	141.1	141.1	141.1	0	0	0	0	23:46:22	0.00	3	0	2	0	3	0	-0.30	-1	11.75	11.75
33	16-Dec-98	dry salt	3	9	100	5.0%	0.05	0.14	23:43:51	1	1	23:43:51	no vid	20	23:43:36	154.7	154.7	154.7	0	0	0	0	23:46:24	0.37	0	0	0	1	0	0	-0.19	-1	11.75	11.75
28	16-Dec-98	dry salt	3	10	100	0.0%	0.00	1.33	23:45:55	1	0	23:45:55	no vid	20	23:45:56	154.7	154.7	154.7	0	0	0	0	23:46:15	0.00	3	0	3	0	0	0	-0.09	-1	11.75	11.75
30	16-Dec-98	dry salt	3	11	100	0.0%	0.00	1.50	23:47:16	1	1	23:47:16	no vid	20	23:47:16	154.7	154.7	154.7	0	0	0	0	23:49:48	0.00	3	0	3	0	3	0	-0.80	-1	11.75	11.75
36	18-Dec-98	Pre-Wet Salt	4	1	50	0.0%	0.00	-1.24	20:30:11	n/a	0	20:30:12	0	0	20:30:48	0	0	100	1	6	0	0	20:25:03	0.00	0	0	0	0	0	0	0.00	-1	8.5	8.5
35	18-Dec-98	Pre-Wet Salt	4	2	50	0.0%	0.00	-3.57	20:31:01	n/a	0	20:31:01	0	0	20:31:44	0	0	100	1	6	0	0	20:25:02	0.00	0	0	0	0	0	0	0.00	-1	8.5	8.5
34	18-Dec-98	Pre-Wet Salt	4	3	50	0.0%	0.00	-0.64	20:33:34	n/a	1	20:33:34	0	0	20:33:08	0	0	100	1	6	0	0	20:24:58	0.00	0	0	0	0	0	0	0.00	-1	8.5	8.5
44	18-Dec-98	Pre-Wet Salt	4	4	50	12.5%	0.13	-0.23	20:34:19	n/a	0	20:34:20	1	0	20:34:36	0	0	100	1	6	0	0	20:42:29	0.91	0	0	0	1	0	1	0.91	-1	8.5	8.5
38	18-Dec-98	Pre-Wet Salt	4	5	100	0.0%	0.00	-3.87	20:36:49	n/a	0	20:36:00	1	0	20:36:48	0	0	100	1	6	0	0	20:33:45	0.00	0a	1	0	0	0	0	0.00	-1	8.5	8.5
37	18-Dec-98	Pre-Wet Salt	4	6	100	0.0%	0.00	-4.01	20:37:54	n/a	0	20:37:54	1	0	20:38:32	0	0	100	1	6	0	0	20:33:42	0.00	0	0	0	0	0	0	0.00	1	8.5	8.5
43	18-Dec-98	Pre-Wet Salt	4	9	130	11.0%	0.11	-0.50	20:43:31	n/a	1	20:43:31	1	0	20:43:36	0	0	100	1	6	0	0	20:44:36	0.80	2	0	0	1	0	1	-0.08	-1	8.75	8.75
39	18-Dec-98	Pre-Wet Salt	4	10	130	1.4%	0.01	-0.23	20:44:19	n/a	0	20:46:02	1	0	20:45:56	0	0	100	1	6	0	0	20:45:00	0.10	2	0	2	1	3	0	-0.05	-1	8.75	8.75
42	18-Dec-98	Pre-Wet Salt	4	11	130	10.0%	0.10	-4.05	20:47:56	n/a	0	20:47:56	1	0	20:47:16	0	0	100	1	6	0	0	20:50:40	0.73	2	1	2	1	2	0	0.32	1	8.75	8.75
45	18-Dec-98	dry salt	3	9	70	13.3%	0.13	-4.64	22:58:46	n/a	1	22:58:46	no vid	0	22:58:36	130	130	130	0	0	0	0	22:59:36	0.97	0a	1	0	1	0	1	0.98	1	11	11
40	18-Dec-98	dry salt	3	10	70	3.1%	0.03	-4.85	22:59:36	n/a	0	23:01:50	no vid	0	23:00:56	130	130	130	0	0	0	0	23:05:00	0.22	0a	1	0	0	0	0	0.04	1	11	11
41	18-Dec-98	dry salt	3	11	70	5.0%	0.05	-4.43	23:02:05	n/a	1	23:02:05	no vid	0	23:02:16	130	130	130	0	0	0	0	23:05:40	0.37	0a	1	0	1	0	0	0.12	1	11	11
47	22-Dec-98	dry salt	3	8	130	64.2%	0.64	-0.81	4:53:24	2	1	4:53:24	no vid	97	4:53:24	0	0	0	0	0	0	0	4:55:00	4.68	1	0	1	0	0	1	0.73	-1	-7	7
53	22-Dec-98	Sand Mix	0	8	130	92.2%	0.92	-3.51		2	1	8:27:08	no vid	97	8:27:34	130	130	0	0	0	0	0	8:30:00	6.73	2	0	0	1	0	0	1.00	-1	-3.5	3.5
48	22-Dec-98	Sand Mix	0	8	570	68.3%	0.68	-4.90		2	1	10:12:08	no vid	27	10:12:51	238	238	0	0	0	0	0	10:15:00	4.99	1	0	2	0	3	1	-0.96	-1	-1.75	1.75
54	22-Dec-98	dry salt	3	1	100	100.0%	1.00	-11.96	19:30:03	2	1	19:30:03	no vid	27	19:30:48	0	0	307.5	0	0	0	0	19:55:02	7.30	1	1	1	0	0	1	1.82	1	7.5	7.5
55	22-Dec-98	dry salt	3	2	100	100.0%	1.00	-9.21	19:31:35	2	1	19:31:01	no vid	27	19:31:44	0	0	307.5	0	0	0	0	19:56:02	7.30	1	1	1	0	0	1	0.12	-1	7.5	7.5
50	22-Dec-98	dry salt	3	1	130	83.0%	0.83	-9.22	19:33:30	2	1	19:33:30	no vid	27	19:33:08	0	0	307.5	0	0	0	0	19:57:29	6.06	0a	1	0	1	0	1	0.67	-1	7.5	7.5
49	22-Dec-98	dry salt	3	4	130	78.0%	0.78	-9.21	19:34:18	2	1	19:34:18	no vid	27	19:34:36	0	0	307.5	0	0	0	0	20:06:03	5.69	0a	1	0	1	0	1	0.74	-1	7.5	7.5
51	22-Dec-98	dry salt	3	5	170	83.5%	0.84	-12.33	19:36:09	2	1	19:36:09	no vid	27	19:36:48	0	0	307.5	0	0	0	0	20:06:06	6.10	1	1	1	1	0	1	0.08	-1	7.5	7.5
52	22-Dec-98	dry salt	3	6	170	89.0%	0.89	-9.62	19:38:29	2	1	19:38:29	no vid	27	19:38:32	0	0	307.5	0	0	0	0	20:05:46	6.50	0a	1	1	1	0	1	0.71	-1	7.5	7.5
46	22-Dec-98	dry salt	3	8	130	56.9%	0.57	-10.23	19:42:43	2	1	19:42:43	no vid	27	19:42:08	0	0	307.5	0	0	0	0	19:45:00	4.15	2	0	1	0	1	0	0.02	-1	7.25	7.75
63	23-Dec-98	dry salt	3	8	170	39.4%	0.39	-11.11	5:42:40	2	0	5:42:40	no vid	0	5:42:08	0	0	0	0	0	0	0	5:45:01	2.88	1	0	0	1	1	0	0.04	1	-6.25	6.25
67	23-Dec-98	dry salt	3	9	170	81.7%	0.82	-14.27	5:43:09	2	0	5:43:09	no vid	0	5:43:36	0	0	0	0	0	0	0	5:45:00	5.96	0a	1	0	1	0	1	0.74	1	-6.25	6.25
58	23-Dec-98	dry salt	3	10	170	21.4%	0.21	-11.15	5:46:00	2	0	5:46:00	no vid	0	5:45:56	0	0	0	0	0	0	0	5:45:01	1.56	3	0	3	0	3	0	-0.07	-1	-6.25	6.25
66	23-Dec-98	dry salt	3	11	170	56.7%	0.57	-11.53	5:46:49	2	0	5:46:49	no vid	0	5:47:16	0	0	0	0	0	0	0	5:50:00	4.14	0	0	0	0	0	0	0.14	-1	-6.25	6.25
61	23-Dec-98	dry salt	3	8	130	37.2%	0.37	-12.14	10:12:42	2	1	10:12:42	no vid	0	10:12:08	0	170	170	0	0	0	0	10:15:01	2.72	2	1	2	1	2	1	0.50	1	-1.75	1.75
64	23-Dec-98	dry salt	3	9	130	42.8%	0.43	-12.14	10:12:42	2	1	10:12:42	no vid	0	10:13:36	0	170	170	0	0	0	0	10:15:00	3.12	0	0	0	1	0	0	0.14	-1	-1.75	1.75
59	23-Dec-98	dry salt	3	10	130	25.8%	0.26	-12.26	10:15:10	2	1	10:15:10	no vid	0	10:15:56	0	170	170	0	0	0	0	10:15:01	1.89	0a	1	0	1	0	1	0.43	1	-1.75	1.75
65	23-Dec-98	dry salt	3	11	130	49.4%	0.49	-15.49	10:17:04	2	0	10:17:04	no vid	0	10:17:16	0	170	170	0	0	0	0	10:20:00	3.61	0a	1	0	1	0	1	0.69	1	-1.75	1.75
57	23-Dec-98	dry salt	3	8	150	13.3%	0.13	-13.00	13:42:43	2	1	13:42:43	no vid	0	13:42:08	130	130	300	0	0	0	0	13:45:01	0.97	0a	1	0	1	0	1	0.16	1	1.75	1.75
62	23-Dec-98	dry salt	3	9	150	38.1%	0.38	-12.65	13:43:04	2	1	13:43:04	no vid	0	13:43:36	130	130	300	0	0	0	0	13:45:00	2.78	0a	1	0	1	0	1	0.23	1	1.75	1.75
56	23-Dec-98	dry salt	3	10	150	7.2%	0.07	-12.82	13:44:23	2	1	13:44:23	no vid	0	13:45:56	130	130	300	0	0	0	0	13:45:01	0.53	2	0	3	0	3	0	0.14	1	1.75	1.75
60	23-Dec-98	dry salt	3	11	150	27.8%	0.28	-12.19	13:47:36	2	0	13:47:36	no vid	0	13:47:16	130	130	300	0	0	0	0	13:50:00	2.03	0a	1	0	1	0	1	0.25	1	1.75	1.75
69	24-Dec-98	dry salt	3	8	100	8.3%	0.08	-9.06	6:02:08	-8	0	6:02:08	no vid	0	6:02:08	0	0	0	0	0	0	0	6:06:37	0.61	0	0	0	0	0	0	0.00	-1	-6	6
70	24-Dec-98	dry salt	3	9	100	26.9%	0.27	-10.94	6:03:56	-8	0	6:03:56	no vid	0	6:03:36	0	0	0	0	0	0	0	6:05:01	1.97	0a	1	0	0	0	0	0.12	1	-6	6
68	24-Dec-98	dry salt	3	10	100	0.0%	0.00	-9.11	6:04:21	-8	0	6:04:21	no vid	0	6:05:56	0	0	0	0	0	0	0	6:05:21	0.00	0	0	0	0	0	0	0.00	-1	-6	6
71	24-Dec-98	dry salt	3	11	100	35.0%	0.35	-10.12	6:07:20	-8	0	6:07:20	no vid	0	6:07:16	0	0	0	0	0	0	0	6:10:01	2.56	0a	1	0	0	0	0	0.08	1	-6	6
78	25-Dec-98	dry salt	3	8	130	5.0%	0.05	-8.58	6:21:56	n/a	0	6:21:56	no vid	0	6:22:08	171	171	171	0	0	0	0	6:25:00	0.37	0	0	0	0	0	0	0.02	-1	-5.5	5..5
83	25-Dec-98	dry salt	3	9	130	22.8%	0.23	-8.82	6:24:26	n/a	0	6:24:26	no vid	0	6:23:36	171	171	171	0	0	0	0	6:25:01	1.66	0a	1	0	0	0	0	0.07	-1	-5.5	5.5
72	25-Dec-98	dry salt	3	10	130	0.0%	0.00	-8.64	6:25:53	n/a	0	6:25:53	no vid	0	6:25:56	171	171	171	0	0	0	0	6:42:15	0.00	0	0	0	0	0	0	0.00	-1	-5.5	6.5
86	25-Dec-98	dry salt	3	11	130	27.8%	0.28	-9.88	6:27:53	n/a	0	6:27:53	no vid	0	6:27:16	171	171	171	0	0	0	0	6:30:01	2.03	0a	1	0	0	0	0	0.09	-1	-5.5	5.5
77	25-Dec-98	dry salt	3	8	210	3.3%	0.03	-8.02	11:22:45	n/a	0	11:22:45	no vid	0	11:22:08	0	130	301	0	0	0	0	11:25:00	0.24	0a	1	0	1	0	1	0.05	1	-0.5	0.5
81	25-Dec-98	dry salt	3	9	210	17.8%	0.18	-8.02	11:23:08	n/a	0	11:23:08	no vid	0	11:23:36	0	130	301	0	0	0	0	11:25:01	1.30	0a	1	0	1	0	1	0.53	-1	-0.5	0.5
73	25-Dec-98	dry salt	3	10	210	0.0%	0.00	-8.24	11:25:14	n/a	0	11:25:14	no vid	0	11:25:56	0	130	301	0	0	0	0	11:43:06	0.00	0	0	0	0	0	0	0.00	1	-0.75	0.75
85	25-Dec-98	dry salt	3	11	210	24.2%	0.24	-7.79	11:27:43	n/a	0	11:27:43	no vid	0	11:27:16	0	130	301	0	0	0	0	11:30:01	1.76	0a	1	0	1	0	0	0.66	1	-0.5	0.5
76	25-Dec-98	dry salt	3	8	150	2.2%	0.02	-7.46	13:02:51	n/a	0	13:02:51	no vid	0	13:02:08	210	210	511	0	0	0	0	13:05:00	0.16	0a	1	0	0	0	0	0.04	1	1	1
80	25-Dec-98	dry salt	3	9	150	9.1%	0.09	-8.52	13:03:03	n/a	0	13:03:03	no vid	0	13:03:36	210	210	511	0	0	0	0	13:05:01	0.66	0a	1	0	1	0	1	0.07	1	1	1
74	25-Dec-98	dry salt	3	10	150	0.0%	0.00	-7.35	13:05:07	n/a	0	13:05:07	no vid	0	13:05:56	210	210	511	0	0	0	0	13:32:30	0.00	0	0	0	0	0	0	-0.05	-1	1	1
82	25-Dec-98	dry salt	3	11	150	20.0%	0.20	-7.70	13:05:57	n/a	0	13:05:57	no vid	0	13:07:16	210	210	511	0	0	0	0	13:10:01	1.46	0a	1	0	0	0	0	0.11	1	1	1
79	25-Dec-98	Sand Mix	0	8	570	5.0%	0.05	-9.61		n/a	0	5:12:08	no vid	0	5:12:16	0	0	0	0	0	0	0	5:15:00	0.37	0	0	0	0	0	0	0.00	1	-6.75	6.75
84	25-Dec-98	Sand Mix	0	9	570	22.8%	0.23	-8.16		n/a	0	5:13:36	no vid	0	5:13:33	0	0	0	0	0	0	0	5:15:01	1.66	0	0	0	0	0	0	0.00	1	-6.75	6.75
75	25-Dec-98	Sand Mix	0	10	570	0.0%	0.00	-8.24		n/a	0	5:15:56	no vid	0	5:16:03	0	0	0	0	0	0	0	5:20:12	0.00	0	0	0	0	0	0	0.00	1	-6.75	6.75
87	25-Dec-98	Sand Mix	0	11	570	27.8%	0.28	-8.22		n/a	0	5:17:16	no vid	0	5:17:12	0	0	0	0	0	0	0	5:20:01	2.03	0	0	0	0	0	0	0.00	1	-6.75	6.75
91	26-Dec-98	dry salt	3	8	150	0.8%	0.01	-4.48	11:32:45	n/a	0	11:32:45	no vid	0	11:32:08	0	0	0	0	0	0	0	11:35:01	0.06	0a	1	0	1	0	1	0.11	1	-0.5	0.5
90	26-Dec-98	dry salt	3	9	150	0.7%	0.01	-4.48	11:32:45	n/a	0	11:32:45	no vid	0	11:33:36	0	0	0	0	0	0	0	11:35:01	0.05	3	0	0	0	0	0	-0.70	1	-0.5	0.5
98	26-Dec-98	dry salt	3	11	150	25.8%	0.26	-4.50	11:37:09	n/a	0	11:37:09	no vid	0	11:37:16	0	0	0	0	0	0	0	11:40:01	1.89	0a	1	2	1	2	1	0.63	1	-0.5	0.5

Event	Date	Material	Material Code	Site	Rate kg/2lnkm (X6)	Initial Snow Cover % (X1)	Initial cover fraction	Air Temp (X2)	Air Temp Time	Surface Temp (X3)	Precip @ Application (X4)	Precip Sensor Time	Snowfall	DaySnow	Time Applied	Prior 4 hrs	Prior 6hrs	Prior 12hrs	Prewet Matereial	NaCl Prewet % Rate	Other Prewet % Rate	DLA	Time of analyzed frame	Initial Cover (m)	Trend, 2 hr	Effect, 2 hr	Trend, 1 hr	Effect, 1 hr	Trend, .5 hr	Effect, .5 hr	MR m/hr	Air Temp trend	hours from noon (hr)	abs value from noon
88	26-Dec-98	dry salt	3	8	150	0.0%	0.00	-3.55	13:10:09	n/a	0	13:10:09	no vid	0	13:12:08	150	150	150	0	0	0	0	13:15:01	0.00	0	0	0	0	0	0	0.00	1	1.25	1.25
95	26-Dec-98	dry salt	3	9	150	16.7%	0.17	-3.54	13:15:43	n/a	0	13:15:43	no vid	0	13:13:36	150	150	150	0	0	0	0	13:15:01	1.22	1	1	0	1	0	1	1.78	1	1.25	1.25
94	26-Dec-98	dry salt	3	11	150	11.4%	0.11	-4.01	13:17:07	n/a	0	13:17:07	no vid	0	13:17:16	150	150	150	0	0	0	0	13:20:01	0.83	0a	1	0	1	0	1	0.57	1	1.25	1.25
89	26-Dec-98	dry salt	3	8	130	0.0%	0.00	-2.91	14:42:45	n/a	0	14:42:45	no vid	0	14:42:08	300	300	300	0	0	0	0	14:45:01	0.00	2	0	2	0	3	0	-0.19	1	2.75	2.75
92	26-Dec-98	dry salt	3	9	130	0.8%	0.01	-2.91	14:44:55	n/a	0	14:44:55	no vid	0	14:43:36	300	300	300	0	0	0	0	14:45:01	0.06	2	0	2	0	3	0	-2.11	1	2.75	2.75
93	26-Dec-98	dry salt	3	11	130	2.2%	0.02	-3.24	14:47:35	n/a	0	14:47:35	no vid	0	14:47:16	300	300	300	0	0	0	0	14:50:01	0.16	2	0	2	0	3	0	-1.14	1	2.75	2.75
101	26-Dec-98	dry salt	3	9	130	58.6%	0.59	-1.05	16:43:33	n/a	0	16:43:33	no vid	0	16:43:36	280	430	430	0	0	0	0	16:45:01	4.28	0a	1	0	1	0	1	0.64	-1	4.75	4.75
100	26-Dec-98	dry salt	3	11	130	33.3%	0.33	-2.12	16:47:12	n/a	1	16:47:12	no vid	0	16:47:16	280	430	430	0	0	0	0	16:50:01	2.43	2	1	2	0	2	1	0.29	1	4.75	4.75
96	26-Dec-98	dry salt	3	8	130	16.7%	0.17	-3.40	20:57:50	n/a	1	20:57:50	no vid	0	20:57:08	0	130	560	0	0	0	0	21:00:01	1.22	0a	1	0	1	0	1	1.28	-1	9	9
99	26-Dec-98	dry salt	3	9	130	25.8%	0.26	-3.08	20:58:40	n/a	1	20:58:40	no vid	0	20:58:36	0	130	560	0	0	0	0	21:00:01	1.89	0a	1	0	1	0	1	0.24	-1	9	9
97	26-Dec-98	dry salt	3	11	130	18.3%	0.18	-3.03	21:02:00	n/a	1	21:02:00	no vid	0	21:02:16	0	130	560	0	0	0	0	21:05:01	1.34	0a	1	0	1	0	1	0.20	-1	9	9
102	27-Dec-98	Sand Mix	0	8	570	0.0%	0.00	-0.42			1	14:42:08	no vid	0	14:42:43	0	0	0	0	0	0	0	14:45:01	0.00	0	0	0	0	0	0	0.00	-1	2.75	2.75
103	27-Dec-98	Sand Mix	0	9	570	0.0%	0.00	-5.41			1	14:43:36	no vid	0	14:43:33	0	0	0	0	0	0	0	14:45:01	0.00	0	0	0	0	0	0	0.00	1	2.75	2.75
104	27-Dec-98	Sand Mix	0	11	570	0.0%	0.00	-5.25			1	14:47:16	no vid	0	14:48:32	0	0	0	0	0	0	0	14:50:01	0.00	0	0	0	0	0	0	0.00	1	2.75	2.75
105	29-Dec-98	dry salt	3	8	130	0.0%	0.00	-1.11	12:08:29	-7	0	12:08:29	no vid	12	12:08:24	0	0	0	0	0	0	0	12:10:01	0.00	0	0	0	0	0	0	0.00	1	0	0
106	29-Dec-98	dry salt	3	9	130	0.0%	0.00	-1.05	12:09:05	-7	0	12:09:05	no vid	12	12:09:25	0	0	0	0	0	0	0	12:10:01	0.00	2	0	2	0	3	0	-0.06	1	0	0
107	29-Dec-98	dry salt	3	11	130	0.0%	0.00	-1.09	12:11:48	-7	0	12:11:48	no vid	12	12:11:57	0	0	0	0	0	0	0	12:15:01	0.00	0	0	0	0	0	0	0.00	1	0.25	0.25
117	29-Dec-98	dry salt	3	1	50	100.0%	1.00	1.88	19:08:23	-7	1	19:08:23	2	12	19:10:48	0	0	130	0	0	0	0	19:25:19	7.30	0	0	0	0	0	0	0.00	-1	7.25	7.25
118	29-Dec-98	dry salt	3	2	50	100.0%	1.00	1.54	19:13:58	-7	1	19:13:58	2	12	19:11:44	0	0	130	0	0	0	0	19:26:24	7.30	1	0	0	0	0	0	0.00	-1	7.25	7.25
119	29-Dec-98	dry salt	3	3	50	100.0%	1.00	1.54	19:13:58	-7	1	19:13:58	2	12	19:13:08	0	0	130	0	0	0	0	19:27:40	7.30	1	0	0	0	0	0	0.12	1	7.25	7.25
113	29-Dec-98	dry salt	3	4	50	90.0%	0.90	1.40	19:14:36	-7	1	19:14:36	2	12	19:14:36	0	0	130	0	0	0	0	19:35:34	6.57	1	0	0	1	0	1	0.00	1	7.25	7.25
120	29-Dec-98	dry salt	3	5	70	100.0%	1.00	2.23	19:17:13	-7	1	19:17:13	no vid	12	19:16:48	0	0	130	0	0	0	0	19:35:30	7.30	0	0	0	0	0	0	0.00	-1	7.25	7.25
115	29-Dec-98	dry salt	3	6	70	94.0%	0.94	1.87	19:17:31	-7	1	19:17:31	no vid	12	19:18:32	0	0	130	0	0	0	0	19:35:31	6.86	3	0	3	0	3	0	-0.24	-1	7.25	7.25
109	29-Dec-98	dry salt	3	8	70	25.6%	0.26	1.65	19:24:07	-7	1	19:24:07	2	12	19:22:08	0	0	130	0	0	0	0	19:25:01	1.87	2	0	3	0	3	0	-0.65	-1	7.5	7.5
108	29-Dec-98	dry salt	3	9	100	16.6%	0.17	1.45	19:24:32	-7	1	19:24:32	1	12	19:23:36	0	0	130	0	0	0	0	19:25:01	1.21	3	0	2	0	2	0	-1.65	-1	7.5	7.5
110	29-Dec-98	dry salt	3	11	100	33.9%	0.34	2.23	19:27:09	-7	1	19:27:09	1	12	19:27:16	0	0	130	0	0	0	0	19:30:01	2.47	0a	1	0	1	0	0	0.47	-1	7.5	7.5
121	29-Dec-98	dry salt	3	1	150	100.0%	1.00	1.87	21:02:39	-7	1	20:57:34	1	12	21:00:48	50	50	180	0	0	0	0	21:00:48	7.30	1	0	1	0	0	1	0.13	-1	9	9
122	29-Dec-98	dry salt	3	2	150	100.0%	1.00	1.87	21:02:39	-7	1	21:02:39	1	12	21:01:44	50	50	180	0	0	0	0	21:01:48	7.30	1	0	1	0	0	1	0.43	-1	9	9
116	29-Dec-98	dry salt	3	3	150	97.0%	0.97	1.32	21:03:06	-7	1	21:03:06	2	12	21:03:08	50	50	180	0	0	0	0	21:11:22	7.08	1	0	1	1	0	1	0.40	-1	9	9
114	29-Dec-98	dry salt	3	4	150	90.0%	0.90	1.32	21:03:06	-7	1	21:03:06	2	12	21:04:36	50	50	180	0	0	0	0	21:11:20	6.57	1	0	0	1	0	1	0.99	-1	9	9
123	29-Dec-98	dry salt	3	5	70	100.0%	1.00	1.54	21:06:29	-7	1	21:06:29	3	12	21:06:48	70	70	200	0	0	0	0	21:11:22	7.30	1	0	1	1	0	1	0.33	-1	9	9
124	29-Dec-98	dry salt	3	6	70	100.0%	1.00	1.61	21:06:43	-7	1	21:06:43	2	12	21:08:32	70	70	200	0	0	0	0	21:11:23	7.30	0	0	0	0	0	0	0.00	-1	9	9
111	29-Dec-98	dry salt	3	8	70	41.9%	0.42	1.91	21:12:44	-7	1	21:12:44	2	12	21:12:08	70	70	200	0	0	0	0	21:15:01	3.06	3	0	2	1	2	0	-0.19	-1	9.25	9.25
112	29-Dec-98	dry salt	3	9	70	58.1%	0.58	1.09	21:13:02	-7	1	21:13:02	2	12	21:13:36	100	100	230	0	0	0	0	21:15:01	4.24	0	0	1	1	0	1	0.39	-1	9.25	9.25
131	30-Dec-98	dry salt	3	8	130	21.9%	0.22	-13.62	10:18:05	n/a	0	10:18:05	no vid	37	10:18:24	171	342	513	0	0	0	0	10:20:01	1.60	0a	1	0	1	0	1	0.79	-1	-1.75	1.75
133	30-Dec-98	dry salt	3	9	130	22.5%	0.23	-20.11	10:18:31	n/a	1	10:18:31	no vid	37	10:19:25	171	342	370.5	0	0	0	0	10:20:01	1.64	1	1	0	1	0	1	1.31	-1	1.75	1.75
125	30-Dec-98	dry salt	3	10	130	1.7%	0.02	-20.36	10:21:07	n/a	1	10:21:07	no vid	37	10:21:02	171	342	370.5	0	0	0	0	10:20:01	0.12	2	1	0	0	0	0	0.04	-1	-1.5	1.5
127	30-Dec-98	dry salt	3	11	130	5.6%	0.06	-20.55	10:21:57	n/a	1	10:21:57	no vid	37	10:21:57	171	342	370.5	0	0	0	0	10:25:01	0.41	0	0	0	0	0	0	0.00	-1	-1.5	1.5
137	30-Dec-98	Sand Mix	0	8	570	50.7%	0.51	-15.00			1	5:27:08	no vid	12	5:27:13	0	98.5	0	0	0	0	0	5:30:01	3.70	0a	1	0	1	0	0	0.45	-1	-6.5	6.5
139	30-Dec-98	Sand Mix	0	9	570	55.3%	0.55	-15.12			1	5:28:36	no vid	12	5:28:32	0	198.5	0	0	0	0	0	5:30:01	4.04	0a	1	0	1	0	1	0.36	-1	-6.5	6.5
129	30-Dec-98	Sand Mix	0	10	570	11.4%	0.11	-15.30			1	5:30:56	no vid	12	5:30:12	0	128.5	0	0	0	0	0	5:30:01	0.83	0	0	0	0	0	0	0.07	1	-6.5	6.5
132	30-Dec-98	Sand Mix	0	11	570	22.2%	0.22	-15.18			1	5:32:16	no vid	12	5:33:32	0	28.5	0	0	0	0	0	5:35:01	1.62	0a	1	0	0	0	0	0.34	-1	-6.5	6.5
134	30-Dec-98	Sand mix	0	8	570	34.2%	0.34	-18.73			1	9:12:08	no vid	37	9:11:49	171	269.5	0	0	0	0	0	9:15:01	2.49	0a	1	0	1	0	1	0.81	-1	-2.75	2.75
135	30-Dec-98	Sand Mix	0	9	570	36.9%	0.37	-19.07			1	9:13:36	no vid	37	9:14:18	171	269.5	0	0	0	0	0	9:15:01	2.70	0a	1	0	1	0	1	0.96	-1	-2.75	2.75
126	30-Dec-98	Sand Mix	0	10	570	3.9%	0.04	-14.11			0	9:15:56	no vid	37	9:15:30	171	198.5	0	0	0	0	0	9:15:01	0.28	0a	1	0	1	0	1	0.60	-1	-2.75	2.75
128	30-Dec-98	Sand Mix	0	11	570	6.4%	0.06	-18.76			1	9:17:16	no vid	37	9:16:47	171	198.5	0	0	0	0	0	9:20:01	0.47	0	0	0	0	0	0	0.06	-1	-2.75	2.75
138	30-Dec-98	Sand Mix	0	8	570	54.2%	0.54	-13.91			0	14:12:08	no vid	37	14:12:08	301	472	0	0	0	0	0	14:15:01	3.95	1	1	1	1	1	1	0.20	-1	2.25	2.25
140	30-Dec-98	Sand Mix	0	9	570	70.0%	0.70	-22.09			1	14:13:36	no vid	37	14:13:33	301	472	0	0	0	0	0	14:15:01	5.11	1	0	1	0	0	1	2.61	1	2.25	2.25
130	30-Dec-98	Sand Mix	0	10	570	18.1%	0.18	-13.60			0	14:15:56	no vid	37	14:15:01	301	472	0	0	0	0	0	14:15:01	1.32	1	0	1	0	1	0	-0.10	-1	2.25	2.25
136	30-Dec-98	Sand Mix	0	11	570	41.1%	0.41	-21.22			1	14:17:16	no vid	37	14:17:42	301	472	0	0	0	0	0	14:20:01	3.00	1	0	0	1	0	1	0.86	1	2.25	2.25
147	31-Dec-98	dry salt	3	8	130	80.0%	0.80	-10.29	8:23:04	n/a	1	8:23:04	no vid	37	8:23:24	199.5	199.5	228	0	0	0	0	8:25:01	5.84	1	1	2	0	2	0	0.05	-1	-3.5	3.5
148	31-Dec-98	dry salt	3	10	130	84.2%	0.84	-17.69	8:28:01	n/a	1	8:28:01	no vid	37	8:26:02	198.5	198.5	227	0	0	0	0	8:25:01	6.14	na	na	na	na	na	na	-0.15	1	-3.5	3.5
144	31-Dec-98	dry salt	3	8	210	35.0%	0.35	-17.36	12:38:33	n/a	1	12:38:33	no vid	24	12:38:24	0	301	329.5	0	0	0	0	12:40:01	2.56	0a	1	0	1	0	1	0.72	1	0.5	0.5
146	31-Dec-98	dry salt	3	10	210	63.6%	0.64	-17.47	12:41:03	n/a	1	12:41:03	no vid	24	12:41:02	0	301	472	0	0	0	0	12:40:01	4.64	na	na	na	na	na	na	2.76	1	0.75	0.75
145	31-Dec-98	dry salt	3	8	130	40.3%	0.40	-15.86	14:38:42	n/a	1	14:38:42	no vid	24	14:38:24	210	210	539.5	0	0	0	0	14:40:01	2.94	2	1	2	1	3	0	0.50	1	2.5	2.5
141	31-Dec-98	dry salt	3	10	130	2.2%	0.02	-16.26	14:43:50	n/a	1	14:43:50	no vid	24	14:41:02	210	210	539.5	0	0	0	0	14:40:01	0.16	na	na	na	na	na	na	-0.02	1	2.75	275
143	31-Dec-98	dry salt	3	8	130	33.1%	0.33	-12.61	15:41:24	n/a	1	15:41:24	no vid	24	15:42:08	340	340	669.5	0	0	0	0	15:45:01	2.41	1	0	1	0	0	1	1.22	1	3.75	3.75
142	31-Dec-98	dry salt	3	10	130	2.5%	0.03	-13.35	15:45:07	n/a	1	15:45:07	no vid	24	15:45:56	340	340	669.5	0	0	0	0	15:45:01	0.18	na	na	na	na	na	na	-0.20	1	3.75	3.75
149	31-Dec-98	Sand Mix	0	8	570	90.0%	0.90	-17.98			1	6:42:08	no vid	37	6:42:38	28.5	85.5	0	0	0	0	0	6:45:01	6.57	0a	1	0	1	0	1	0.43	1	-5.25	5.25
150	31-Dec-98	Sand Mix	0	10	570	100.0%	1.00	-17.65			1	6:45:56	no vid	37	6:45:57	28.5	57	0	0	0	0	0	6:45:01	7.30	na	na	na	na	na	na	1.08	1	-5.25	5.25
170	1-Jan-99	Sand Mix	0	8	570	100.0%	1.00	-9.39		-9.97	1	5:12:08	no vid	24	5:12:38	0	28.5	0	0	0	0	0	5:15:01	7.30	1	1	1	1	1	1	0.32	-1	-6.75	6.75
171	1-Jan-99	Sand Mix	0	9	570	100.0%	1.00	-9.39		-9.97	1	5:13:36	no vid	24	5:13:36	0	28.5	0	0	0	0	0	5:15:01	7.30	0a	1	0	1	0	1	0.91	-1	-6.75	6.75
172	1-Jan-99	Sand Mix	0	10	570	100.0%	1.00	-10.89		-9.32	1	5:15:56	no vid	24	5:16:50	0	28.5	0	0	0	0	0	5:15:01	7.30	0a	1	1	1	0	1	0.99	-1	-6.75	6.75
173	1-Jan-99	Sand Mix	0	11	570	100.0%	1.00	-8.75		-8.77	1	5:17:16	no vid	24	5:17:49	0	28.5	0	0	0	0	0	5:20:01	7.30	0a	1	0	0	0	0	0.12	-1	-6.75	6.75
168	1-Jan-99	Sand Mix	0	8	570	95.6%	0.96	-9.23		-8.68	1	6:12:08	no vid	24	6:12:36	171	171	0	0	0	0	0	6:15:01	6.98	1	0	1	0	1	0	0.01	-1	-5.75	5.75
162	1-Jan-99	Sand Mix	0	9	570	87.5%	0.88	-9.42		-10.35	1	6:13:36	no vid	24	6:13:26	171	171	0	0	0	0	0	6:15:01	6.39	3	0	0	0	0	0	0.10	-1	-5.75	5.75
161	1-Jan-99	Sand Mix	0	10	570	86.4%	0.86	-9.97		-10.29	1	6:15:56	no vid	24	6:15:56	171	171	0	0	0	0	0	6:15:01	6.31	3	0	3	0	3	0	-0.14	-1	-5.75	5.75
169	1-Jan-99	Sand Mix	0	11	570	98.3%	0.98	-9.46		-9.09	1	6:17:16	no vid	24	6:17:10	171	171	0	0	0	0	0	6:20:01	7.18	1	0	1	0	0	1	-0.03	-1	-5.75	5.75
166	1-Jan-99	Sand Mix	0	8	570	95.0%	0.95	-11.45		-11.21	1	10:02:08	no vid	56	10:02:09	342	342	0	0	0	0	0	10:05:01	6.94	0a	1	0	1	0	1	0.17	-1	-2	2
160	1-Jan-99	Sand Mix	0	9	570	82.2%	0.82	-15.39		-11.04	1	10:03:36	no vid	56	10:03:30	342	342	0	0	0	0	0	10:05:01	6.00	0a	1	0	1	0	1	0.30	-1	-2	2
165	1-Jan-99	Sand Mix	0	10	570	93.9%	0.94	-15.46		-10.62	1	10:05:56	no vid	56	10:05:10	342	342	0	0	0	0	0	10:05:01	6.85	0a	1	0	0	0	0	0.28	-1	-2	2
174	1-Jan-99	Sand Mix	0	11	570	100.0%	1.00	-16.13		-13.3	1	10:07:16	no vid	56	10:06:49	342	342	0	0	0	0	0	10:10:01	7.30	0a	1	0	1	0	0	0.31	-1	-2	2
164	1-Jan-99	Sand Mix	0	8	570	92.2%	0.92	-11.32		-9.43	1	11:12:08	no vid	56	11:12:08 AM	513	513	0	0	0	0	0	11:15:01	6.73	1	1	0	1	0	0	0.54	-1	-0.75	0.75
163	1-Jan-99	Sand Mix	0	10	570	89.4%	0.89	-16.02		-10.09	1	11:15:56	no vid	56	11:15:09	513	513	0	0	0	0	0	11:15:01	6.53	2	1	2	1	3	0	1.83	1	-0.75	0.75
167	1-Jan-99	Sand Mix	0	11	570	95.0%	0.95	-16.16		-11.69	1	11:17:16	no vid	56	11:15:59	513	513	0	0	0	0	0	11:20:01	6.94	0a	1	0	0	0	0	1.12	-1	-0.75	0.75
159	1-Jan-99	dry salt	3	8	170	81.7%	0.82	-20.20	12:37:33	-14.19	1	12:37:33	no vid	56	12:37:08	342	342	684	0	0	0	0	12:40:01	5.96	0a	1	0	1	0	1	0.99	1	0.5	0.5
156	1-Jan-99	dry salt	3	9	170	65.6%	0.66	-20.20	12:37:33	-14.19	1	12:37:33	no vid	56	12:38:36	342	342	684	0	0	0	0	12:40:01	4.79	0a	1	0	1	0	0	0.59	-1	0.75	0.75
155	1-Jan-99	dry salt	3	10	170	53.9%	0.54	-13.39	12:40:30	-11.15	1	12:40:30	no vid	56	12:40:56	342	342	684	0	0	0	0	12:40:01	3.93	2	1	2	1	3	0	0.47	-1	0.75	0.75
157	1-Jan-99	dry salt	3	11	170	73.3%	0.73	-20.12	12:42:36	-10.99	1	12:42:36	no vid	56	12:42:16	342	342	684	0	0	0	0	12:45:01	5.35	0a	1	0	1	0	1	0.77	-1	0.75	0.75
158	1-Jan-99	Sand Mix	0	9	570	77.5%	0.78	-16.40		-9.52	1	11:13:36	no vid	56	11:13:41	513	513	0	0	0	0	0	11:15:01	5.66	0a	1	0	1	0	0	0.62	-1	-0.75	0.75
151	1-Jan-99	Sand Mix	0	8	570	22.8%	0.23	-15.61		-7.24	0	16:57:08	no vid	56	16:58:00	341	854	0	0	0	0	0	17:00:01	1.66	3	0	3	0	3	0	-3.18	1	5	5
153	1-Jan-99	Sand Mix	0	9	570	30.6%	0.31	-21.58		-16.28	1	16:58:36	no vid	56	16:58:30	341	854	0	0	0	0	0	17:00:01	2.23	3	0	3	0	3	0	-5.57	1	5	5

APPENDIX D. DART Database

Event	Date	Material	Material Code	Site	Rate kg/2lnkm (X6)	Initial Snow Cover % (X1)	Initial cover fraction	Air Temp (X2)	Air Temp Time	Surface Temp (X3)	Precip @ Application (X4)	Precip Sensor Time	Snowfall	DaySnow	Time Applied	Prior 4 hrs	Prior 6hrs	Prior 12hrs	Prewet Matereial	NaCl Prewet % Rate	Other Prewet % Rate	DLA	Time of analyzed frame	Initial Cover (m)	Trend, 2 hr	Effect, 2 hr	Trend, 1 hr	Effect, 1 hr	Trend, .5 hr	Effect, .5 hr	MR m/hr	Air Temp trend	hours from noon (hr)	abs value from noon
152	1-Jan-99	Sand mix	0	10	570	25.8%	0.26	-22.38		-12.33	1	17:00:56	no vid	56	16:59:46	341	854	0	0	0	0	0	17:00:01	1.89	3	0	1	0	0	1	-3.42	1	5	5
154	1-Jan-99	Sand Mix	0	11	570	47.2%	0.47	-21.52		-12.33	1	17:02:16	no vid	56	17:02:00	341	854	0	0	0	0	0	17:05:01	3.45	3	0	3	0	2	0	-10.99	1	5	5
190	2-Jan-99	Sand Mix	0	8	570	98.9%	0.99	-18.46		-14.01	1	6:42:08	no vid	56	6:42:20	0	0	0	0	0	0	0	6:45:01	7.22	0a	1	0	1	0	0	1.19	-1	-5.25	5.25
187	2-Jan-99	Sand Mix	0	9	570	82.2%	0.82	-23.06		-13.46	1	6:43:36	no vid	56	6:42:57	0	0	0	0	0	0	0	6:45:01	6.00	0a	1	0	0	0	0	0.26	-1	-5.25	5.25
182	2-Jan-99	Sand Mix	0	10	570	66.9%	0.67	-23.06		-15.27	1	6:45:56	no vid	56	6:42:57	0	0	0	0	0	0	0	6:45:01	4.89	3	0	3	0	3	0	-0.13	-1	-5.25	5.25
188	2-Jan-99	Sand Mix	0	11	570	87.2%	0.87	-18.78		-15.01	0	6:47:16	no vid	56	6:49:13	0	0	0	0	0	0	0	6:50:01	6.37	1	0	0	0	0	0	-0.05	-1	-5.25	5.25
184	2-Jan-99	Sand Mix	0	8	570	73.1%	0.73	-18.32		-14.18	0	8:17:08	no vid	56	8:17:55	171	171	0	0	0	0	0	8:20:01	5.33	1	1	0	1	0	0	0.21	1	-3.75	3.75
186	2-Jan-99	Sand Mix	0	9	570	76.7%	0.77	-26.32		-17.06	1	8:18:36	no vid	56	8:18:54	171	171	0	0	0	0	0	8:20:01	5.60	0a	1	0	1	0	1	0.37	1	-3.75	3.75
183	2-Jan-99	Sand Mix	0	10	570	69.7%	0.70	-16.93		-13.38	0	8:20:56	no vid	56	8:20:32	171	171	0	0	0	0	0	8:20:01	5.09	2	1	2	1	3	0	0.79	1	-3.75	3.75
189	2-Jan-99	Sand Mix	0	11	570	88.3%	0.88	-26.63		-16.32	1	8:22:16	no vid	56	8:22:44	171	171	0	0	0	0	0	8:25:01	6.45	0a	1	0	1	0	0	0.40	1	-3.5	3.5
181	2-Jan-99	dry salt	3	8	260	65.6%	0.66	-26.14	10:57:21	-16.09	1	10:57:21	no vid	172	10:57:08	171	342	342	0	0	0	0	11:00:01	4.79	0a	1	0	1	0	0	0.74	1	-1	1
180	2-Jan-99	dry salt	3	9	260	63.3%	0.63	-26.73	10:58:06	-17.1	1	10:58:06	no vid	172	10:58:36	171	342	342	0	0	0	0	11:00:01	4.62	0a	1	0	1	0	1	0.73	1	-1	1
178	2-Jan-99	dry salt	3	10	260	40.8%	0.41	-26.25	11:01:46	-15.73	1	11:01:46	no vid	172	11:00:56	171	342	342	0	0	0	0	11:00:01	2.98	0a	1	0	1	0	1	0.34	1	-1	1
185	2-Jan-99	dry salt	3	11	260	73.9%	0.74	-26.82	11:02:37	-19	1	11:02:37	no vid	172	11:02:16	171	342	342	0	0	0	0	11:05:01	5.39	1	1	1	0	0	0	0.40	1	-1	1
176	2-Jan-99	Sand Mix	0	8	570	15.0%	0.15	-19.66		-12.34	1	15:57:08	no vid	172	15:57:54	260	602	0	0	0	0	0	16:00:01	1.10	2	0	0	0	0	0	-0.10	-1	4	4
175	2-Jan-99	Sand Mix	0	9	570	13.6%	0.14	-20.02		-14.79	1	15:58:36	no vid	172	15:59:34	260	431	0	0	0	0	0	16:00:01	0.99	1	0	0	1	0	1	0.96	1	4	4
177	2-Jan-99	Sand Mix	0	10	570	17.5%	0.18	-19.38		-13.01	1	16:00:56	no vid	172	16:01:16	260	602	0	0	0	0	0	16:00:01	1.28	0a	1	0	1	0	0	0.05	1	4	4
179	2-Jan-99	Sand Mix	0	11	570	46.7%	0.47	-20.69		-13.29	1	16:02:16	no vid	172	16:02:09	260	602	0	0	0	0	0	16:05:01	3.41	0a	1	0	1	0	1	0.67	1	4	4
194	4-Jan-99	Sand Mix	0	8	570	24.6%	0.25	-8.88		-7.78	1	1:27:08	no vid	13	1:27:39	0	0	0	0	0	0	0	1:30:01	1.79	0	0	3	0	0	0	0.07	-1	-10.5	10.5
191	4-Jan-99	Sand Mix	0	9	570	21.9%	0.22	-8.99		-9.5	1	1:28:36	no vid	13	1:28:29	0	0	0	0	0	0	0	1:30:01	1.60	0	0	0	0	0	0	0.00	-1	-10.5	10.5
196	4-Jan-99	Sand Mix	0	10	570	31.3%	0.31	-8.61		-8.41	1	1:30:56	no vid	13	1:30:30	0	0	0	0	0	0	0	1:30:01	2.28	2	1	3	0	3	0	0.11	-1	-10.5	10.5
197	4-Jan-99	Sand Mix	0	11	570	39.1%	0.39	-9.02		-8.84	1	1:34:36	no vid	13	1:35:08	0	0	0	0	0	0	0	1:35:01	2.86	0	0	0	0	0	0	0.00	-1	-10.5	10.5
193	4-Jan-99	Sand Mix	0	8	570	22.9%	0.23	-8.92		-7.97	1	3:12:08	no vid	13	3:11:50	171	171	0	0	0	0	0	3:15:01	1.67	0	0	0	0	0	0	0.01	-1	-8.75	8.75
192	4-Jan-99	Sand Mix	0	9	570	21.9%	0.22	-9.02		-10.29	1	3:13:36	no vid	13	3:11:50	171	171	0	0	0	0	0	3:15:01	1.60	0	0	0	0	0	0	0.01	-1	-8.75	8.75
195	4-Jan-99	Sand Mix	0	10	570	28.5%	0.29	-9.02		-10.29	1	3:15:56	no vid	13	3:15:59	171	171	0	0	0	0	0	3:15:01	2.08	0a	1	0	0	0	0	0.07	-1	-8.75	8.75
198	4-Jan-99	Sand Mix	0	11	570	39.1%	0.39	-9.36		-9.66	1	3:19:36	no vid	13	3:19:46	171	171	0	0	0	0	0	3:20:01	2.86	0	0	0	0	0	0	0.01	-1	-8.75	8.75
200	4-Jan-99	Sand Mix	0	8	570	100.0%	1.00	-10.51		-10.37	1	23:12:08	no vid	21	23:12:44	28.5	85.5	0	0	0	0	0	23:15:01	7.30	0	0	0	0	0	0	0.03	-1	11.25	11.25
201	4-Jan-99	Sand Mix	0	9	570	100.0%	1.00	-10.54		-8.17	1	23:13:36	no vid	21	23:13:34	28.5	85.5	0	0	0	0	0	23:15:01	7.30	0	0	0	0	0	0	0.00	-1	11.25	11.25
199	4-Jan-99	Sand Mix	0	10	570	99.2%	0.99	-12.34		-9.89	1	23:15:56	no vid	21	23:15:43	28.5	85.5	0	0	0	0	0	23:15:01	7.24	0	0	0	0	0	0	0.00	1	11.25	11.25
202	4-Jan-99	Sand Mix	0	11	570	100.0%	1.00	-9.68		-8.27	1	23:19:36	no vid	21	23:19:23	28.5	85.5	0	0	0	0	0	23:20:01	7.30	0	0	3	0	3	0	0.03	-1	11.25	11.25
211	5-Jan-99	dry salt	3	8	130	87.2%	0.87	-12.07	5:59:35	-9.01	1	5:59:35	no vid	21	5:58:24	0	0	199.5	0	0	0	0	6:00:01	6.37	0a	1	0	0	0	0	0.71	-1	-6	6
212	5-Jan-99	dry salt	3	9	130	95.0%	0.95	-11.91	6:00:25	-9.01	1	5:59:35	no vid	21	5:59:25	0	0	199.5	0	0	0	0	6:00:01	6.94	0a	1	0	1	0	0	0.63	-1	-6	6
213	5-Jan-99	dry salt	3	10	130	96.7%	0.97	-15.29	6:01:34	-13.48	1	6:01:34	no vid	21	6:01:02	0	0	198.5	0	0	0	0	6:00:01	7.06	0a	1	1	1	0	1	0.84	1	-6	6
214	5-Jan-99	dry salt	3	11	130	100.0%	1.00	-15.08	6:01:39	-12.44	1	6:01:39	no vid	21	6:01:57	0	0	0	0	0	0	0	6:05:01	7.30	0a	1	0	0	0	0	0.46	1	-6	6
207	5-Jan-99	dry salt	3	8	130	51.7%	0.52	-15.71	9:38:56	-14.53	1	9:38:56	no vid	8	9:38:24	130	130	158.5	0	0	0	0	9:40:01	3.77	1	1	0	1	0	0	0.49	1	-2.5	2.5
209	5-Jan-99	dry salt	3	9	130	63.3%	0.63	-15.44	9:39:00	-13.28	0	9:39:00	no vid	8	9:39:25	130	130	301	0	0	0	0	9:40:01	4.62	0a	1	0	1	0	1	1.29	-1	-2.25	2.25
208	5-Jan-99	dry salt	3	10	130	54.7%	0.55	-15.43	9:41:43	-12.42	1	9:41:43	no vid	8	9:41:02	130	130	301	0	0	0	0	9:40:01	3.99	1	1	0	1	0	1	1.74	-1	-2.25	2.25
210	5-Jan-99	dry salt	3	11	130	76.7%	0.77	-15.32	9:42:08	-13.27	1	9:42:08	no vid	8	9:41:57	130	130	130	0	0	0	0	9:45:01	5.60	0a	1	0	1	0	1	1.42	-1	-2.25	2.25
206	5-Jan-99	dry salt	3	8	130	30.0%	0.30	-11.57	12:52:05	-12.42	1	12:52:05	no vid	8	12:53:24	130	130	260	0	0	0	0	12:55:01	2.19	2	1	2	1	3	0	0.23	1	1	1
205	5-Jan-99	dry salt	3	9	130	13.3%	0.13	-11.78	12:54:34	-12.4	1	12:54:34	no vid	8	12:54:25	130	130	260	0	0	0	0	12:55:01	0.97	0a	1	0	1	0	1	4.56	1	1	1
203	5-Jan-99	dry salt	3	10	130	5.0%	0.05	-18.62	12:56:29	-14.49	1	12:56:29	no vid	8	12:56:02	130	130	260	0	0	0	0	12:55:01	0.37	2	1	0	0	0	0	-0.01	1	1	1
204	5-Jan-99	dry salt	3	11	130	13.3%	0.13	-17.86	12:57:13	-14.8	1	12:57:13	no vid	8	12:56:57	130	130	431	0	0	0	0	13:00:01	0.97	0a	1	0	1	0	1	1.12	1	1	1
217	6-Jan-99	dry salt	3	8	130	30.0%	0.30	-5.74	17:57:05	-3.08	1	17:57:05	no vid	115	17:57:08	28.5	28.5	28.5	0	0	0	0	18:00:01	2.19	0a	1	0	0	0	0	0.03	-1	6	6
216	6-Jan-99	dry salt	3	9	130	29.2%	0.29	-5.88	17:57:53	-1.92	1	17:57:53	no vid	115	17:58:36	171	171	171	0	0	0	0	18:00:01	2.13	2	1	3	0	0	0	0.12	-1	6	6
215	6-Jan-99	dry salt	3	11	130	19.4%	0.19	-5.02	18:02:03	-4.48	1	18:02:03	no vid	115	18:02:16	28.5	28.5	28.5	0	0	0	0	18:05:01	1.42	0a	1	0	1	0	1	-0.26	-1	6	6
218	6-Jan-99	Sand Mix	0	8	570	66.1%	0.66	-5.48		-5.58	1	22:42:08	no vid	115	22:41:22	158.5	187	0	0	0	0	0	22:45:01	4.83	3	0	2	0	3	0	-1.77	-1	10.75	10.75
219	6-Jan-99	Sand Mix	0	9	570	81.7%	0.82	-5.52		-4.34	1	22:43:36	no vid	115	22:43:01	158.5	187	0	0	0	0	0	22:45:01	5.96	2	0	3	0	0	0	-1.88	-1	10.75	10.75
220	6-Jan-99	Sand Mix	0	11	570	100.0%	1.00	-5.50		-6.18	1	22:47:16	no vid	115	22:47:11	158.5	187	0	0	0	0	0	22:50:01	7.30	1	0	1	0	0	1	0.00	-1	10.75	10.75
226	8-Jan-99	dry salt	3	9	130	25.0%	0.25	-17.83	9:42:56	-14.17	0	9:42:56		43	9:43:36	0	0	0	0	0	0	0	9:45:01	1.83	0a	1	0	1	0	1	0.76	1	-2.25	2.25
223	8-Jan-99	dry salt	3	10	130	12.8%	0.13	-17.96	9:45:25	-15.31	0	9:45:25		43	9:45:56	0	0	0	0	0	0	0	9:45:01	0.93	0a	1	0	1	0	1	0.23	1	-2.25	2.25
227	8-Jan-99	dry salt	3	11	130	32.5%	0.33	-18.73	9:50:25	-15.31	0	9:45:25		43	9:47:16	0	0	0	0	0	0	0	9:50:01	2.37	0a	1	0	1	0	0	0.63	1	-2.25	2.25
230	8-Jan-99	dry salt	3	1	130	100.0%	1.00	-7.62	19:09:27	-3.44	0	19:09:27	1	43	19:10:48	0	0	130	0	0	0	0	18:54:28	7.30	0a	1	0	1	0	0	1.01	-1	7.25	7.25
232	8-Jan-99	dry salt	3	2	130	100.0%	1.00	-7.84	19:11:07	-4.81	0	19:11:07	1	43	19:11:44	0	0	130	0	0	0	0	18:54:28	7.30	0a	1	0	1	0	0	0.98	-1	7.25	7.25
231	8-Jan-99	dry salt	3	3	130	100.0%	1.00	-7.43	19:13:36	-3.83	0	19:13:36	1	43	19:13:08	0	0	130	0	0	0	0	18:54:28	7.30	0a	1	0	1	0	0	0.65	-1	7.25	7.25
233	8-Jan-99	dry salt	3	4	130	100.0%	1.00	-8.55	19:14:38	-6.55	1	19:14:38	1	43	19:14:36	0	0	130	0	0	0	0	18:54:30	7.30	0a	1	0	1	0	0	0.91	1	7.25	7.25
234	8-Jan-99	dry salt	3	5	130	100.0%	1.00	-7.44	19:15:14	-3.63	0	19:15:14	no vid	43	19:16:48	0	0	130	0	0	0	0	18:54:36	7.30	0a	1	0	1	0	0	0.75	-1	7.25	7.25
235	8-Jan-99	dry salt	3	6	130	100.0%	1.00	-8.11	19:19:25	-5.5	0	19:19:25	no vid	43	19:18:32	0	0	130	0	0	0	0	18:54:44	7.30	0a	1	0	1	0	0	0.72	-1	7.25	7.25
225	8-Jan-99	dry salt	3	9	130	23.3%	0.23	-8.70	19:23:52	-4.96	1	19:23:52	no vid	43	19:23:36	0	0	130	0	0	0	0	19:25:01	1.70	2	0	3	0	3	0	-0.41	1	7.5	7.5
221	8-Jan-99	dry salt	3	10	130	8.9%	0.09	-7.75	19:25:18	-3.63	0	19:25:18	no vid	43	19:25:56	0	0	130	0	0	0	0	19:25:01	0.65	2	0	2	1	1	0	-0.08	-1	7.5	7.5
224	8-Jan-99	dry salt	3	11	130	18.3%	0.18	-7.43	19:27:55	-3.13	0	19:27:55	1	43	19:27:16	0	0	130	0	0	0	0	19:30:01	1.34	1	0	0	1	0	0	0.56	-1	7.5	7.5
229	8-Jan-99	dry salt	3	9	170	39.2%	0.39	-7.90	22:13:43	-6.84	0	22:13:43	no vid	43	22:13:36	130	130	130	0	0	0	0	22:15:01	2.86	0a	1	0	1	0	0	0.34	-1	10.25	10.25
222	8-Jan-99	dry salt	3	10	170	11.9%	0.12	-8.05	22:17:01	-6.84	0	22:13:43	no vid	43	22:15:56	130	130	130	0	0	0	0	22:20:01	0.87	2	0	3	0	3	0	-0.13	-1	10.25	10.25
228	8-Jan-99	dry salt	3	11	130	35.0%	0.35	-8.20	22:18:41	-7.14	0	22:17:01	no vid	43	22:17:16	130	130	130	0	0	0	0	22:20:01	2.56	1	1	1	0	1	0	0.44	-1	10.25	10.25
244	9-Jan-99	dry salt	3	8	130	49.4%	0.49	-8.52	0:41:44	-8.49	1	0:41:44	0	43	0:42:08	210	340	340	0	0	0	0	0:45:01	3.61	0a	1	0	1	0	1	0.88	-1	-11.25	11.25
246	9-Jan-99	dry salt	3	9	130	55.6%	0.56	-8.65	0:43:33	-7.74	1	0:43:33	0	43	0:43:36	170	300	300	0	0	0	0	0:45:01	4.06	1	1	0	1	2	1	0.76	-1	-11.25	11.25
248	9-Jan-99	dry salt	3	11	210	58.9%	0.59	-8.73	0:47:42	-7.88	1	0:47:42	1	43	0:47:16	130	260	260	0	0	0	0	0:50:01	4.30	1	1	0	1	2	0	1.27	1	-11.25	11.25
249	9-Jan-99	dry salt	3	1	130	67%	0.67	-8.69	7:45:41	-7.54	1	7:45:19	no vid	43	7:45:48	0	0	300	0	0	0	0	8:16:52	4.91	0a	1	0	1	0	1	0.87	1	-4.25	4.25
251	9-Jan-99	dry salt	3	2	130	71%	0.71	-8.93	7:46:14	-7.62	1	7:46:14	no vid	43	7:46:44	0	0	300	0	0	0	0	8:16:37	5.19	0a	1	0	1	0	1	0.90	1	-4.25	4.25
250	9-Jan-99	dry salt	3	3	130	69%	0.69	-9.03	7:48:38	-7.17	1	7:48:38	no vid	43	7:48:08	0	0	280	0	0	0	0	8:16:35	5.05	0A	1	0	1	0	1	0.88	1	-4.25	4.25
258	9-Jan-99	dry salt	3	8	130	96.7%	0.97	-8.79	7:57:45	-7.89	1	7:57:45	no vid	43	7:57:08	0	0	340	0	0	0	0	8:00:01	7.06	0a	1	0	1	0	1	1.83	-1	-4	4
247	9-Jan-99	dry salt	3	9	130	56.1%	0.56	-9.00	7:59:25	-6.64	1	7:59:25	no vid	43	7:58:36	0	0	300	0	0	0	0	8:00:01	4.10	0a	1	0	1	0	1	1.08	-1	-4	4
240	9-Jan-99	dry salt	3	10	130	40.0%	0.40	-9.10	8:01:54	-6.87	1	8:01:54	no vid	43	8:00:56	0	0	300	0	0	0	0	7:59:37	2.92	1	1	0	1	0	1	1.48	1	-4	4
241	9-Jan-99	dry salt	3	11	130	41.7%	0.42	-9.29	8:02:44	-8.11	1	8:02:44	no vid	43	8:02:16	0	0	340	0	0	0	0	8:05:01	3.04	2	0	2	1	3	0	1.29	1	-4	4
236	9-Jan-99	Sand Mix	0	1	570	3%	0.03	-7.02		-3.01	1	16:30:48	no vid	53	16:30:22	0	130	0	0	0	0	0	13:07:25	0.24	3	0	3	0	3	0	-1.01	1	4.5	4.5
237	9-Jan-99	Sand Mix	0	2	570	5%	0.05	-7.17		-2.09	1	16:31:44	no vid	53	16:31:57	0	130	0	0	0	0	0	13:07:26	0.37	3	0	3	0	3	0	-0.79	-1	4.5	4.5
238	9-Jan-99	Sand Mix	0	3	570	5%	0.05	-7.16		-3.7	1	16:33:08	no vid	53	16:34:43	0	130	0	0	0	0	0	13:07:28	0.37	3	0	3	0	3	0	-0.79	1	4.5	4.5
243	9-Jan-99	Sand Mix	0	8	570	48.3%	0.48	-6.53		-2.77	1	16:42:08	no vid	53	16:42:11	0	130	0	0	0	0	0	16:45:01	3.53	0a	1	0	1	0	1	0.88	-1	4.75	4.75
245	9-Jan-99	Sand Mix	0	9	570	51.1%	0.51	-6.18		-1.87	1	16:43:36	no vid	53	16:43:01	0	130	0	0	0	0	0	16:45:01	3.73	0a	1	0	1	0	1	0.43	-1	4.75	4.75
239	9-Jan-99	Sand Mix	0	10	570	33.9%	0.34	-6.29		-1.31	1	16:45:56	no vid	53	16:46:20	0	130	0	0	0	0	0	16:49:37	2.47	0a	1	0	1	0	1	0.33	-1	4.75	4.75
242	9-Jan-99	Sand Mix	0	11	570	42.2%	0.42	-6.31		-2.63	1	16:47:16	no vid	53	16:47:09	0	130	0	0	0	0	0	16:50:01	3.08	0a	1	0	1	0	0	0.62	-1	4.75	4.75
256	9-Jan-99	Sand Mix	0	1	570	93%	0.93	-7.46		-10.37	0	23:00:48	no vid	53	23:01:45	0	171	0	0	0	0	0	23:23:45	6.81	3	0	3	0	3	0	0.00	-1	11	11
252	9-Jan-99	Sand Mix	0	2	570	75%	0.75	-7.46		-10.37	0	23:01:44	no vid	53	23:01:45	0	171	0	0	0	0	0	23:23:43	5.48	3	0	3	0	3	0	0.00	-1	11	11

APPENDIX D. DART Database

Event	Date	Material	Material Code	Site	Rate kg/2lnkm (X6)	Initial Snow Cover % (X1)	Initial cover fraction	Air Temp (X2)	Air Temp Time	Surface Temp (X3)	Precip @ Application (X4)	Precip Sensor Time	Snowfall	DaySnow	Time Applied	Prior 4 hrs	Prior 6hrs	Prior 12hrs	Prewet Matereial	NaCl Prewet % Rate	Other Prewet % Rate	DLA	Time of analyzed frame	Initial Cover (m)	Trend, 2 hr	Effect, 2 hr	Trend, 1 hr	Effect, 1 hr	Trend, .5 hr	Effect, .5 hr	MR m/hr	Air Temp trend	hours from noon (hr)	abs value from noon
253	9-Jan-99	Sand Mix	0	3	570	75%	0.75	-7.56		-7.88	0	23:03:08	no vid	53	23:03:34	0	171	0	0	0	0	0	23:23:43	5.48	3	0	3	0	3	0	0.00	-1	11	11
254	9-Jan-99	Sand Mix	0	8	570	76.1%	0.76	-7.83		-7.33	1	23:12:08	no vid	53	23:11:54	0	171	0	0	0	0	0	23:15:01	5.56	0a	1	2	1	3	0	1.07	-1	11.25	11.25
259	9-Jan-99	Sand Mix	0	9	570	100.0%	1.00	-8.17		-8.49	1	23:13:36	1	53	23:14:23	0	171	0	0	0	0	0	23:15:01	7.30	0a	1	0	1	0	1	0.57	-1	11.25	11.25
255	9-Jan-99	Sand Mix	0	10	570	88.6%	0.89	-8.17		-7.1	1	23:15:56	1	53	23:15:13	0	171	0	0	0	0	0	23:19:37	6.47	0a	1	0	1	0	0	0.98	-1	11.25	11.25
257	9-Jan-99	Sand Mix	0	11	570	95.0%	0.95	-8.54		-8.13	1	23:17:16	1	53	23:17:43	0	171	0	0	0	0	0	23:20:01	6.94	0a	1	0	1	0	1	0.63	-1	11.25	11.25
271	10-Jan-99	dry salt	3	1	100	62.5%	0.63	-17.46	8:10:58	-12.7	1	8:10:30	0	53	8:10:48	0	0	171	0	0	0	0	8:02:48	4.56	0a	1	0	1	0	1	1.23	-1	-3.75	3.75
272	10-Jan-99	dry salt	3	2	100	62.5%	0.63	-17.47	8:11:35	-12.61	1	8:11:35	0	53	8:11:44	0	0	171	0	0	0	0	8:02:48	4.56	2	1	2	1	3	0	0.89	-1	-3.75	3.75
268	10-Jan-99	dry salt	3	3	100	50.0%	0.50	-17.56	8:14:21	-11.68	1	8:14:21	0	53	8:13:08	0	0	171	0	0	0	0	8:02:49	3.65	0a	1	0	1	0	1	0.55	1	-3.75	3.75
274	10-Jan-99	dry salt	3	4	100	70.0%	0.70	-17.56	8:14:21	-11.68	1	8:14:21	0	53	8:14:36	0	0	171	0	0	0	0	8:02:49	5.11	1	1	0	1	0	1	1.37	1	-3.75	3.75
266	10-Jan-99	dry salt	3	5	130	40.0%	0.40	-17.16	8:16:03	-11.54	1	8:16:03	0	53	8:16:48	0	0	171	0	0	0	0	8:02:46	2.92	0a	1	0	1	0	1	0.82	-1	-3.75	3.75
273	10-Jan-99	dry salt	3	6	130	70.0%	0.70	-15.94	8:19:41	-13.93	1	8:19:41	0	53	8:18:32	0	0	171	0	0	0	0	8:02:44	5.11	0a	1	0	1	0	1	1.30	-1	-3.75	3.75
269	10-Jan-99	dry salt	3	9	150	54.7%	0.55	-17.78	8:21:46	-12.53	1	8:21:46	0	53	8:23:36	0	0	171	0	0	0	0	8:25:01	3.99	0a	1	0	1	0	1	0.77	1	-3.5	3.5
270	10-Jan-99	dry salt	3	10	150	61.7%	0.62	-17.26	8:25:25	-10.47	1	8:25:25	0	53	8:25:56	0	0	171	0	0	0	0	8:29:37	4.50	0a	1	0	1	0	1	3.10	-1	-3.5	3.5
267	10-Jan-99	dry salt	3	11	150	48.3%	0.48	-17.79	8:27:06	-13.95	1	8:27:06	0	53	8:27:16	0	0	171	0	0	0	0	8:30:01	3.53	0a	1	0	1	0	1	0.85	-1	-3.5	3.5
261	10-Jan-99	dry salt	3	1	100	17.5%	0.18	-17.72	10:50:41	-16.15	0	10:50:16	no vid	57	10:50:48	100	100	271	0	0	0	0	11:20:46	1.28	0a	1	0	1	0	1	0.41	-1	-1.25	1.25
264	10-Jan-99	dry salt	3	2	100	30.0%	0.30	-18.48	10:51:58	-14.32	0	10:51:08	no vid	57	10:51:44	100	100	271	0	0	0	0	11:20:47	2.19	0a	1	0	1	0	1	0.28	-1	-1.25	1.25
265	10-Jan-99	dry salt	3	3	100	30.0%	0.30	-18.13	10:52:49	-14.66	0	10:52:49	no vid	57	10:53:08	100	100	271	0	0	0	0	11:20:50	2.19	0a	1	0	1	0	1	0.14	1	-1	1
262	10-Jan-99	dry salt	3	4	100	20.0%	0.20	-18.13	10:52:49	-14.66	0	10:52:49	no vid	57	10:54:36	100	100	271	0	0	0	0	11:20:49	1.46	0a	1	0	1	0	1	0.58	-1	-1	1
260	10-Jan-99	dry salt	3	5	130	10.0%	0.10	-16.70	10:58:07	-14.45	1	10:58:07	no vid	57	10:56:48	0	130	301	0	0	0	0	11:20:52	0.73	0a	1	0	1	0	1	0.30	-1	-1	1
263	10-Jan-99	dry salt	3	6	130	22.5%	0.23	-17.04	10:58:21	-14.45	1	10:58:21	no vid	57	10:58:32	130	130	301	0	0	0	0	11:20:50	1.64	0a	1	0	1	0	1	0.46	-1	-1	1
282	11-Jan-99	dry salt	3	1	100	95.0%	0.95	-14.48	9:44:30	-9.4	1	9:44:30	0	72	9:45:33	0	28.5	28.5	0	0	0	0	9:56:20	6.94	0a	1	0	1	0	1	0.32	-1	-2.25	2.25
280	11-Jan-99	dry salt	3	2	100	87.5%	0.88	-14.69	9:48:38	-10.19	1	9:48:38	0	72	9:46:12	0	28.5	28.5	0	0	0	0	9:56:25	6.39	2	1	2	1	3	0	0.09	-1	-2.25	2.25
283	11-Jan-99	dry salt	3	3	100	95.0%	0.95	-14.69	9:48:38	-10.19	1	9:48:38	0	72	9:47:10	0	28.5	28.5	0	0	0	0	9:56:33	6.94	0a	1	0	1	0	1	0.09	-1	-2.25	2.25
285	11-Jan-99	dry salt	3	4	100	97.5%	0.98	-14.69	9:48:38	-10.19	1	9:48:38	0	72	9:48:11	0	28.5	28.5	0	0	0	0	9:56:37	7.12	0a	1	0	0	0	0	0.19	-1	-2.25	2.25
284	11-Jan-99	dry salt	3	5	170	95.0%	0.95	-14.96	9:49:28	-8.9	1	9:49:28	0	72	9:49:42	0	28.5	28.5	0	0	0	0	9:56:39	6.94	0a	1	0	0	0	0	0.19	-1	-2.25	2.25
286	11-Jan-99	dry salt	3	6	170	100.0%	1.00	-14.84	9:51:08	-10.26	1	9:51:08	0	72	9:50:54	0	28.5	28.5	0	0	0	0	9:56:41	7.30	0a	1	0	0	0	0	0.42	-1	-2.25	2.25
281	11-Jan-99	dry salt	3	9	130	93.3%	0.93	-15.21	9:54:27	-10.32	1	9:54:27	0	72	9:54:25	0	28.5	28.5	0	0	0	0	9:55:01	6.81	0a	1	0	0	0	0	0.59	-1	-2	2
277	11-Jan-99	dry salt	3	10	130	56.9%	0.57	-15.29	9:56:56	-9.24	1	9:56:56	0	72	9:56:02	0	28.5	28.5	0	0	0	0	9:54:37	4.16	2	0	2	0	3	0	0.52	-1	-2	2
279	11-Jan-99	dry salt	3	11	130	85.6%	0.86	-15.29	9:56:56	-9.24	1	9:56:56	0	72	9:56:57	0	28.5	28.5	0	0	0	0	10:00:01	6.25	0	0	0	0	0	0	0.18	-1	-2	2
276	11-Jan-99	dry salt	3	9	130	56.7%	0.57	-20.13	14:24:38	-15.16	1	14:24:38	0	72	14:24:25	28.5	158.5	187	0	0	0	0	14:25:01	4.14	1	1	0	1	0	1	0.66	1	2.5	2.5
275	11-Jan-99	dry salt	3	10	130	25.0%	0.25	-19.95	14:26:19	-15.35	1	14:26:19	0	72	14:26:02	28.5	158.5	187	0	0	0	0	14:29:37	1.83	1	1	0	1	0	1	0.52	1	2.5	2.5
278	11-Jan-99	dry salt	3	11	130	74.7%	0.75	-19.95	14:26:19	-15.35	1	14:27:09	0	72	14:26:57	28.5	158.5	187	0	0	0	0	14:30:01	5.45	0a	1	0	1	0	1	0.43	1	2.5	2.5
295	13-Jan-99	dry salt	3	1	130	80.0%	0.80	-13.51	7:11:59	-8.47	1	7:11:59	no vid	73	7:10:48	0	0	28.5	0	0	0	0	7:53:56	5.84	0a	1	0	1	0	1	0.13	-1	-4.75	4.75
299	13-Jan-99	dry salt	3	2	130	92.5%	0.93	-13.51	7:11:59	-8.47	1	7:11:59	no vid	73	7:11:44	0	0	28.5	0	0	0	0	7:53:52	6.75	0a	1	0	1	0	1	0.25	-1	-4.75	4.75
296	13-Jan-99	dry salt	3	3	130	82.5%	0.83	-10.62	7:12:59	-8.09	1	7:12:59	no vid	73	7:13:08	0	0	28.5	0	0	0	0	7:53:53	6.02	0a	1	0	1	0	1	0.38	-1	-4.75	4.75
291	13-Jan-99	dry salt	3	4	130	62.5%	0.63	-13.63	7:14:05	-10.31	1	7:14:05	no vid	73	7:14:36	0	0	28.5	0	0	0	0	7:53:51	4.56	0a	1	0	1	0	1	0.51	-1	-4.75	4.75
300	13-Jan-99	dry salt	3	5	180	100.0%	1.00	-13.66	7:16:07	-9.59	1	7:16:07	no vid	73	7:16:48	0	0	28.5	0	0	0	0	7:53:50	7.30	0a	1	0	1	0	1	0.67	-1	-4.75	4.75
298	13-Jan-99	dry salt	3	6	180	92.5%	0.93	-13.41	7:16:57	-9.2	1	7:16:57	no vid	73	7:18:32	0	0	28.5	0	0	0	0	7:53:49	6.75	0a	1	0	1	0	0	0.29	-1	-4.75	4.75
297	13-Jan-99	dry salt	3	10	100	82.8%	0.83	-13.92	7:25:29	-9.39	1	7:25:29	no vid	73	7:25:56	0	0	28.5	0	0	0	0	7:22:45	6.04	0a	1	0	1	0	1	1.00	1	-4.5	4.5
292	13-Jan-99	Pre-Wet Salt 6%	4	1	130	72.5%	0.73	-17.46	11:30:23	-15.32	1	11:30:23	no vid	3	11:30:48	130	130	130	1	6	0	0	10:38:04	5.29	0a	1	0	1	0	1	0.98	-1	-0.5	0.5
294	13-Jan-99	Pre-Wet Salt	4	3	130	77.5%	0.78	-12.03	11:31:28	-12.35	1	11:31:04	no vid	3	11:31:44	0	130	130	1	6	0	0	10:38:05	5.66	0a	1	0	1	0	1	0.67	-1	-0.5	0.5
289	13-Jan-99	Pre-Wet Salt	4	3	130	60.0%	0.60	-17.39	11:33:42	-13.81	0	11:33:42	no vid	3	11:33:08	0	130	130	1	6	0	0	10:38:15	4.38	0	0	0	1	0	1	0.00	1	-0.5	0.5
288	13-Jan-99	Pre-Wet Salt	4	4	130	32.5%	0.33	-17.39	11:33:42	-13.81	0	11:33:42	no vid	3	11:34:36	0	130	130	1	6	0	0	10:38:16	2.37	0a	1	0	0	0	0	2.21	1	-0.5	0.5
290	13-Jan-99	Pre-Wet Salt	4	5	180	60.0%	0.60	-12.48	11:39:39	-9.58	1	11:39:39	no vid	3	11:36:48	0	180	180	1	6	0	0	10:38:20	4.38	0	0	0	1	0	1	0.00	1	-0.5	0.5
293	13-Jan-99	Pre-Wet Salt	4	6	180	75.0%	0.75	-12.48	11:39:39	-9.58	1	11:39:39	no vid	3	11:38:32	0	180	180	1	6	0	0	10:38:23	5.48	0a	1	0	1	0	1	1.27	1	-0.5	0.5
287	13-Jan-99	Pre-Wet Salt	4	10	100	23.6%	0.24	-18.03	11:45:20	-13.07	0	11:45:20	no vid	3	11:45:56	0	100	100	1	6	0	0	11:47:45	1.72	0a	1	0	1	0	1	0.29	1	-0.25	0.25
301	15-Jan-99	dry salt	3	10	170	45.8%	0.46	-15.08	11:01:01	-14.23	1	11:01:01	no vid	49	11:00:56	28.5	57	57	0	0	0	0	10:57:44	3.35	0a	1	0	1	0	1	0.85	1	-1	1
302	16-Jan-99	dry salt	3	10	130	5.6%	0.06	-18.83	6:00:30	-17.13	1	6:00:30	no vid	49	6:00:56	0	0	0	0	0	0	0	6:00:01	0.41	0a	1	0	0	0	0	0.06	1	-6	6
303	16-Jan-99	dry salt	3	11	130	6.7%	0.07	-18.82	6:02:02	-13.1	1	6:02:02	no vid	49	6:02:16	0	0	0	0	0	0	0	6:05:00	0.49	0a	1	0	0	0	0	0.05	1	-6	6
309	17-Jan-99	dry salt	3	10	130	6.1%	0.06	-0.49	3:20:58	-2.99	0	3:20:58	no vid	0	3:20:56	0	0	0	0	0	0	0	3:20:01	0.45	0a	1	0	0	0	0	0.03	-1	-8.75	8.75
304	17-Jan-99	dry salt	3	11	130	2.2%	0.02	2.23	3:22:49	-2.43	0	3:22:49	no vid	0	3:22:16	0	0	0	0	0	0	0	3:25:01	0.16	0	0	0	0	0	0	0.00	-1	-8.5	8.5
307	17-Jan-99	dry salt	3	10	130	5.6%	0.06	0.99	4:45:13	-2.4	0	4:45:13	no vid	0	4:45:56	130	130	130	0	0	0	0	4:45:01	0.41	0	0	0	0	0	0	0.00	-1	-7.25	7.25
305	17-Jan-99	dry salt	3	11	130	2.2%	0.02	-0.99	4:49:46	-3.57	0	4:49:46	no vid	0	4:47:16	130	130	130	0	0	0	0	4:50:01	0.16	0	0	0	0	0	0	0.00	1	-7.25	7.25
308	17-Jan-99	dry salt	3	10	130	5.6%	0.06	0.53	6:12:43	-2.77	99	6:15:45	no vid	0	6:15:56	260	260	260	0	0	0	0	6:15:01	0.41	0a	1	0	0	0	0	0.06	1	-5.75	5.75
306	17-Jan-99	dry salt	3	11	130	2.2%	0.02	0.49	6:18:32	-4.82	0	6:18:32	no vid	0	6:17:16	260	260	260	0	0	0	0	6:20:01	0.16	0a	1	0	0	0	0	0.10	-1	-5.75	5.75
310	18-Jan-99	dry salt	3	10	130	0.0%	0.00	2.27	20:15:07	2.28	1	20:15:07	no vid	1	20:15:56	0	0	0	0	0	0	0	20:15:01	0.00	0	0	0	0	0	0	0.00	-1	8.25	8.25
311	18-Jan-99	dry salt	3	11	130	0.0%	0.00	1.20	20:15:25	2.62	1	20:20:06	no vid	1	20:17:16	0	0	0	0	0	0	0	20:20:01	0.00	0	0	0	0	0	0	0.00	-1	8.25	8.25
312	19-Jan-99	dry salt	3	10	130	0.8%	0.01	1.12	4:45:35	0.03	1	4:45:35	no vid	1	4:45:56	0	0	130	0	0	0	0	4:45:01	0.06	0	0	0	0	0	0	0.00	-1	-7.25	7.25
313	19-Jan-99	dry salt	3	11	130	16.7%	0.17	0.87	4:47:14	-0.22	1	4:47:14	no vid	1	4:47:16	0	0	130	0	0	0	0	4:50:01	1.22	0a	1	0	1	0	1	0.85	-1	-7.25	7.25
314	22-Jan-99	dry salt	3	8	130	0.0%	0.00	-0.78	9:38:46	0.31	0	9:38:46	no vid	0	9:38:24	0	0	0	0	0	0	0	9:40:01	0.00	2	0	0	0	0	0	0.00	-1	-2.25	2.25
315	22-Jan-99	dry salt	3	10	130	0.0%	0.00	-0.92	9:41:16	-0.69	0	9:41:16	no vid	0	9:41:02	0	0	0	0	0	0	0	9:40:01	0.00	0	0	0	0	0	0	0.00	1	-2.25	2.25
346	27-Jan-99	Pre-Wet Salt	4	8	100	28.3%	0.28	-1.04	15:42:32	-0.98	1	15:42:32	no vid	20	15:42:08	0	0	0	1	6	0	0	15:45:01	2.07	1	1	1	1	1	0	1.53	1	3.75	3.75
347	27-Jan-99	Pre-Wet Salt	4	9	100	29.4%	0.29	-1.08	15:43:22	0.18	1	15:43:22	no vid	20	15:43:36	0	0	0	1	6	0	0	15:45:00	2.15	0a	1	0	1	0	1	1.22	1	3.75	3.75
339	27-Jan-99	Pre-Wet Salt	4	10	70	16.7%	0.17	-0.83	15:45:01	0.48	1	15:45:01	no vid	20	15:45:56	0	0	0	1	6	0	0	15:45:01	1.22	2	1	2	1	1	0	0.67	1	3.75	3.75
340	27-Jan-99	Pre-Wet Salt	4	11	70	16.7%	0.17	-1.18	15:47:31	0.3	1	15:47:31	no vid	20	15:47:16	0	0	0	1	6	0	0	15:50:00	1.22	2	1	2	1	3	0	0.14	1	3.75	3.75
350	27-Jan-99	Pre-Wet Salt 6%	4	1	150	35.0%	0.35	-0.71	16:30:01	1.4	1	16:30:54	no vid	20	16:30:48	150	150	150	1	6	0	0	16:18:39	2.56	0a	1	0	1	0	1	0.65	-1	4.5	4.5
351	27-Jan-99	Pre-Wet Salt	4	1	150	40.0%	0.40	-0.55	16:32:06	5.86	1	16:32:06	no vid	20	16:31:44	150	150	150	1	6	0	0	16:18:34	2.92	0a	1	0	1	0	1	0.65	-1	4.5	4.5
348	27-Jan-99	Pre-Wet Salt	4	3	150	32.5%	0.33	-0.73	16:33:21	2.63	1	16:33:21	no vid	20	16:33:08	150	150	150	1	6	0	0	16:18:35	2.37	0a	1	0	1	0	1	0.32	1	4.5	4.5
352	27-Jan-99	Pre-Wet Salt	4	4	130	52.5%	0.53	-0.55	16:35:26	1.68	1	16:35:26	no vid	20	16:34:36	130	130	130	1	6	0	0	16:18:29	3.83	0a	1	0	1	0	1	0.89	-1	4.5	4.5
343	27-Jan-99	Pre-Wet Salt	4	5	130	22.5%	0.23	-0.59	16:36:40	3.38	1	16:36:40	no vid	20	16:36:48	130	130	130	1	6	0	0	16:18:31	1.64	0a	1	0	1	0	1	0.16	-1	4.75	4.75
349	27-Jan-99	Pre-Wet Salt	4	6	130	32.5%	0.33	-0.59	16:38:20	3.07	1	16:38:20	no vid	20	16:38:32	130	130	130	1	6	0	0	16:18:38	2.37	0a	1	0	1	1	0	0.57	-1	4.5	4.5
330	27-Jan-99	Pre-Wet Salt	4	8	100	8.1%	0.08	-0.51	16:42:09	2.95	1	16:42:09	no vid	20	16:42:08	100	100	100	1	6	0	0	16:45:01	0.59	0a	1	0	1	0	0	0.10	-1	4.75	4.75
335	27-Jan-99	Pre-Wet Salt	4	9	100	12.8%	0.13	-0.47	16:43:20	2.17	1	16:43:20	no vid	20	16:43:36	100	100	100	1	6	0	0	16:45:00	0.93	0a	1	0	1	3	0	0.63	-1	4.75	4.75
333	27-Jan-99	Pre-Wet Salt	4	10	70	9.7%	0.10	-0.61	16:45:43	1.48	1	16:45:43	no vid	20	16:45:56	70	70	70	1	6	0	0	16:50:01	0.71	0a	1	1	0	1	0	0.12	1	4.75	4.75
336	27-Jan-99	Pre-Wet Salt	4	11	70	14.7%	0.15	-0.67	16:47:29	2.56	1	16:47:29	no vid	20	16:47:16	70	70	70	1	6	0	0	16:50:00	1.07	0a	1	0	1	0	1	0.85	-1	4.75	4.75
329	27-Jan-99	Pre-Wet Salt	4	12	70	7.8%	0.08	-1.03	16:50:48	1.26	1	16:50:48	no vid	20	16:49:36	70	70	70	1	6	0	0	16:50:01	0.57	0a	1	0	1	0	1	0.12	-1	4.75	4.75
338	27-Jan-99	dry salt	3	1	130	15.0%	0.15	-0.91	18:45:44	0.54	1	18:45:44	no vid	20	18:45:48	300	300	300	0	0	0	0	16:44:28	1.10	0a	1	0	1	0	1	0.23	-1	6.75	6.75
342	27-Jan-99	dry salt	3	2	130	20.0%	0.20	-0.46	18:46:24	0.15	1	18:46:24	no vid	20	18:46:44	300	300	300	0	0	0	0	16:44:28	1.46	0a	1	0	1	0	1	0.27	1	6.75	6.75
344	27-Jan-99	dry salt	3	3	130	22.5%	0.23	-0.81	18:48:13	0.4	1	18:48:33	no vid	20	18:48:08	300	300	300	0	0	0	0	16:44:28	1.64	0a	1	0	1	0	1	0.27	1	6.75	6.75
345	27-Jan-99	dry salt	3	4	130	25.0%	0.25	0.89	18:49:31	3.92	1	18:49:53	no vid	20	18:49:36	260	260	260	0	0	0	0	16:44:24	1.83	0a	1	0	1	0	1	0.23	-1	6.75	6.75
341	27-Jan-99	dry salt	3	5	130	17.5%	0.18	-1.29	18:51:33	2.07	1	18:51:33	no vid	20	18:51:48	260	260	260	0	0	0	0	16:44:25	1.28	0a	1	0	1	0	1	0.27	-1	6.75	6.75
322	27-Jan-99	dry salt	3	8	130	5.0%	0.05	-1.29	18:57:22	0.19	1	18:57:22	no vid	20	18:57:08	200	200	200	0	0	0	0	19:00:01	0.37	0a	1	0	1	0	0	0.03	-1	7	7

APPENDIX D. DART Database

Event	Date	Material	Material Code	Site	Rate kg/2lnkm (X6)	Initial Snow Cover % (X1)	Initial cover fraction	Air Temp (X2)	Air Temp Time	Surface Temp (X3)	Precip @ Application (X4)	Precip Sensor Time	Snowfall	DaySnow	Time Applied	Prior 4 hrs	Prior 6hrs	Prior 12hrs	Prewet Matereial	NaCl Prewet % Rate	Other Prewet % Rate	DLA	Time of analyzed frame	Initial Cover (m)	Trend, 2 hr	Effect, 2 hr	Trend, 1 hr	Effect, 1 hr	Trend, .5 hr	Effect, .5 hr	MR m/hr	Air Temp trend	hours from noon (hr)	abs value from noon
332	27-Jan-99	dry salt	3	9	130	9.4%	0.09	-1.09	18:58:11	0.36	1	18:58:11	no vid	20	18:58:36	200	200	200	0	0	0	0	19:00:00	0.69	0a	1	0	1	0	1	0.12	-1	7	7
331	27-Jan-99	dry salt	3	10	130	8.1%	0.08	-1.24	19:00:41	-0.5	1	19:00:41	no vid	20	19:00:56	140	140	140	0	0	0	0	19:00:01	0.59	0a	1	0	1	0	1	0.10	-1	7	7
328	27-Jan-99	dry salt	3	11	130	7.2%	0.07	-0.94	19:02:20	0.17	1	19:02:20	no vid	20	19:02:16	140	140	140	0	0	0	0	19:05:00	0.53	0a	1	0	1	0	1	0.25	-1	7	7
327	27-Jan-99	dry salt	3	12	130	6.4%	0.06	-1.03	19:04:50	-0.79	1	19:04:50	no vid	20	19:04:36	140	140	140	0	0	0	0	19:05:01	0.47	0a	1	0	1	0	1	0.12	-1	7	7
317	27-Jan-99	dry salt	3	1	150	0.0%	0.00	-1.76	23:31:17	-0.52	1	23:31:17	no vid	20	23:30:48	0	130	430	0	0	0	0	0:00:51	0.00	0	0	0	0	0	0	0.00	-1	11.5	11.5
320	27-Jan-99	dry salt	3	2	150	2.5%	0.03	-1.51	23:31:29	-1.41	1	23:31:29	no vid	20	23:31:44	0	130	430	0	0	0	0	0:00:47	0.18	0	0	0	0	0	0	0.00	-1	11.5	11.5
326	27-Jan-99	dry salt	3	3	150	5.0%	0.05	-1.74	23:33:08	-1.56	1	23:33:08	no vid	20	23:33:08	0	130	430	0	0	0	0	0:00:42	0.37	0a	1	0	1	0	0	0.00	-1	11.5	11.5
334	27-Jan-99	dry salt	3	4	150	10.0%	0.10	-1.51	23:34:48	-1.73	1	23:34:48	no vid	20	23:34:36	0	130	390	0	0	0	0	0:00:35	0.73	0a	1	0	1	0	1	0.47	-1	11.5	11.5
316	27-Jan-99	dry salt	3	5	130	0.0%	0.00	-0.34	23:36:04	1.16	1	23:36:27	no vid	20	23:36:48	0	130	390	0	0	0	0	0:00:29	0.00	0a	1	0	0	0	0	0.00	1	11.5	11.5
325	27-Jan-99	dry salt	3	6	130	5.0%	0.05	-0.46	23:38:01	0.71	1	23:38:01	no vid	20	23:38:32	0	130	390	0	0	0	0	0:00:31	0.37	0a	1	0	1	0	1	0.00	-1	11.75	11.75
337	27-Jan-99	dry salt	3	6	130	15.0%	0.15	-1.07	18:53:13	0.76	1	18:53:13	no vid	20	23:38:32	260	260	260	0	0	0	0	16:44:25	1.10	0a	1	0	1	0	1	0.15	1	11.75	11.75
321	27-Jan-99	dry salt	3	8	130	3.3%	0.03	-1.55	23:41:28	-2.32	1	23:41:28	no vid	20	23:42:08	0	130	330	0	0	0	0	23:45:01	0.24	0a	1	0	1	0	1	0.02	-1	11.75	11.75
319	27-Jan-99	dry salt	3	9	130	1.9%	0.02	-1.47	23:43:58	-0.13	1	23:43:58	no vid	20	23:43:36	0	130	330	0	0	0	0	23:45:00	0.14	0	0	0	0	0	0	0.00	1	11.75	11.75
323	27-Jan-99	dry salt	3	10	130	5.0%	0.05	-1.85	23:45:37	-2.35	1	23:45:37	no vid	20	23:45:56	0	130	270	0	0	0	0	23:45:01	0.37	0	0	0	0	0	0	0.00	1	11.75	11.75
318	27-Jan-99	dry salt	3	11	130	1.7%	0.02	-1.42	23:47:17	-1.48	1	23:47:17	no vid	20	23:47:16	0	130	270	0	0	0	0	23:50:00	0.12	0	0	0	0	0	0	0.00	1	11.75	11.75
324	27-Jan-99	dry salt	3	12	130	5.0%	0.05	-7.47	23:50:09	-6.15	1	23:49:28	no vid	20	23:49:36	0	130	270	0	0	0	0	23:50:01	0.37	0a	1	0	0	0	0	-0.53	1	11.75	11.75
365	28-Jan-99	dry salt	3	8	130	78.9%	0.79	-2.43	3:42:18	-3.8	1	3:42:18	no vid	20	3:42:08	130	130	460	0	0	0	0	3:45:01	5.76	0a	1	0	1	0	1	3.57	-1	-8.25	8.25
367	28-Jan-99	dry salt	3	10	130	98.6%	0.99	-0.59	3:45:27	-0.22	1	3:45:27	no vid	20	3:45:56	130	130	400	0	0	0	0	3:45:01	7.20	0	0	0	0	0	0	2.84	-1	-8.25	8.25
366	28-Jan-99	dry salt	3	11	130	96.7%	0.97	-1.97	3:47:17	-1.67	1	3:47:17	no vid	20	3:47:16	130	130	400	0	0	0	0	3:50:01	7.06	2	0	3	0	3	0	2.80	-1	-8.25	8.25
368	28-Jan-99	dry salt	3	12	130	100.0%	1.00	-2.06	3:48:07	-2.37	1	3:48:07	no vid	20	3:49:36	130	130	400	0	0	0	0	3:45:01	7.30	3	0	0	0	0	0	3.77	1	-8.25	8.25
360	28-Jan-99	dry salt	3	8	70	30.0%	0.30	0.11	4:43:03	1.6	0	4:43:03	no vid	20	4:42:08	130	260	490	0	0	0	0	4:45:01	2.19	1	1	0	1	0	1	0.60	-1	-7.25	7.25
364	28-Jan-99	dry salt	3	10	70	59.7%	0.60	-0.33	4:44:34	0.43	1	4:44:34	no vid	20	4:45:56	130	260	460	0	0	0	0	4:45:01	4.36	1	1	0	1	0	1	0.45	-1	-7.25	7.25
363	28-Jan-99	dry salt	3	11	70	58.3%	0.58	-2.35	4:47:09	-2.06	1	4:47:09	no vid	20	4:47:16	130	260	460	0	0	0	0	4:50:01	4.26	0a	1	0	1	0	1	0.57	-1	-7.25	7.25
362	28-Jan-99	dry salt	3	12	70	48.3%	0.48	-2.55	4:49:38	-3.23	1	4:49:38	no vid	20	4:49:36	130	260	460	0	0	0	0	4:55:01	3.53	0a	1	0	1	0	0	0.41	-1	-7.25	7.25
356	28-Jan-99	dry salt	3	8	130	1.7%	0.02	-6.66	17:38:27	-3.7	1	17:38:27	no vid	36	17:38:24	0	0	0	0	0	0	0	17:40:01	0.12	2	0	3	0	0	0	-0.22	-1	5.75	5.75
354	28-Jan-99	dry salt	3	10	130	0.8%	0.01	-7.08	17:41:48	-3.7	1	17:41:48	no vid	36	17:41:02	0	0	0	0	0	0	0	17:40:01	0.06	2	0	3	0	0	0	0.07	-1	5.75	5.75
355	28-Jan-99	dry salt	3	11	130	0.8%	0.01	-7.08	17:41:48	-3.7	1	17:41:48	no vid	36	17:41:57	0	0	0	0	0	0	0	17:45:01	0.06	2	0	0	0	0	0	-0.46	1	5.75	5.75
353	28-Jan-99	dry salt	3	12	130	0.0%	0.00	1.25	17:44:45	3.18	1	17:44:45	no vid	36	17:43:34	0	0	0	0	0	0	0	17:40:01	0.00	0	0	0	0	0	0	-0.42	-1	5.75	5.75
359	28-Jan-99	dry salt	3	8	70	27.2%	0.27	0.16	22:23:19	1.03	1	22:23:19	no vid	36	22:23:24	0	130	130	0	0	0	0	22:25:01	1.98	0a	1	1	1	0	1	0.33	-1	10.5	10.5
357	28-Jan-99	dry salt	3	10	70	10.6%	0.11	-6.88	22:25:56	-4.74	1	22:25:56	no vid	36	22:26:02	0	130	130	0	0	0	0	22:25:01	0.77	0a	1	0	1	0	1	0.31	1	10.5	10.5
361	28-Jan-99	dry salt	3	11	70	31.7%	0.32	-6.88	22:25:56	-4.74	1	22:25:56	no vid	36	22:26:57	0	130	0	0	0	0	0	22:30:01	2.31	0a	1	0	0	0	0	0.49	-1	10.5	10.5
358	28-Jan-99	dry salt	3	12	70	21.1%	0.21	-6.88	22:25:56	-4.74	1	22:25:56	no vid	36	22:28:34	0	130	130	0	0	0	0	22:25:01	1.54	0a	1	0	1	0	0	0.58	-1	10.5	10.5
375	29-Jan-99	dry salt	3	8	100	7.8%	0.08	-4.33	6:38:01	-2.9	1	6:38:44	no vid	36	6:38:24	0	0	70	0	0	0	0	6:40:01	0.57	0a	1	0	1	0	0	0.39	1	-5.25	5.25
373	29-Jan-99	dry salt	3	10	100	4.7%	0.05	-9.70	6:41:14	-6.5	1	6:41:14	no vid	36	6:41:02	0	0	70	0	0	0	0	6:40:01	0.34	0a	1	0	0	0	0	0.08	1	-5.25	5.25
376	29-Jan-99	dry salt	3	11	100	9.4%	0.09	-9.70	6:41:14	-6.5	1	6:41:14	no vid	36	6:41:57	0	0	70	0	0	0	0	6:45:01	0.69	0a	1	0	0	0	0	0.30	1	-5.25	5.25
374	29-Jan-99	dry salt	3	12	70	6.1%	0.06	-9.41	6:42:54	-5.78	0	6:42:54	no vid	36	6:43:34	0	0	70	0	0	0	0	6:40:01	0.45	0a	1	0	1	0	0	0.24	1	-5.25	5.25
372	29-Jan-99	dry salt	3	8	70	4.2%	0.04	-4.98	23:19:28	-2.18	1	23:19:28	no vid	2	23:18:24	0	0	0	0	0	0	0	23:20:01	0.30	2	1	0	1	0	0	0.31	1	11.25	11.25
370	29-Jan-99	dry salt	3	10	70	0.0%	0.00	-5.08	23:21:29	-3.82	1	23:21:29	no vid	2	23:21:02	0	0	0	0	0	0	0	23:20:01	0.00	0	0	0	0	0	0	0.00	1	11.25	11.25
371	29-Jan-99	dry salt	3	11	70	3.3%	0.03	-5.08	23:21:29	-3.82	1	23:21:29	no vid	2	23:21:57	0	0	0	0	0	0	0	23:25:01	0.24	0a	1	0	1	0	0	0.31	1	11.25	11.25
369	29-Jan-99	dry salt	3	12	70	0.0%	0.00	-4.52	23:24:50	-2.26	1	23:24:50	no vid	2	23:23:34	0	0	0	0	0	0	0	23:20:01	0.00	0	0	0	0	0	0	0.00	1	11.5	11.5
379	1-Feb-99	dry salt	3	11	130	3.3%	0.03	-1.58	20:41:59	1.56	1	20:41:39	no vid	13	20:41:57	0	0	0	0	0	0	0	20:45:01	0.24	0	0	0	0	0	0	-0.19	1	8.75	8.75
377	1-Feb-99	dry salt	3	12	130	0.0%	0.00	-1.89	20:43:28	4.25	0	20:43:28	no vid	13	20:43:34	0	0	0	0	0	0	0	20:45:00	0.00	0	0	0	0	0	0	-0.82	1	8.75	8.75
386	1-Feb-99	dry salt	3	1	170	40.0%	0.40	-1.05	22:00:24	0.72	0	22:00:24	no vid	13	22:00:33	130	130	130	0	0	0	0	22:34:55	2.92	0a	1	0	1	0	1	0.54	-1	10	10
384	1-Feb-99	dry salt	3	2	170	15.0%	0.15	-0.06	22:01:28	1.41	1	22:01:28	no vid	13	22:01:12	130	130	130	0	0	0	0	22:35:00	1.10	0	0	0	0	0	0	0.00	1	10	10
385	1-Feb-99	dry salt	3	3	130	25.0%	0.25	-1.04	22:01:35	2.68	0	22:01:35	no vid	13	22:02:10	130	130	130	0	0	0	0	22:35:00	1.83	0a	1	0	1	0	1	0.37	1	10	10
383	1-Feb-99	dry salt	3	4	130	12.5%	0.13	-0.79	22:03:01	0.73	0	22:03:01	no vid	13	22:03:11	130	130	130	0	0	0	0	22:35:00	0.91	0	0	0	0	0	0	0.00	1	10	10
380	1-Feb-99	dry salt	3	5	85	7.5%	0.08	-0.30	22:03:36	2.48	0	22:03:36	no vid	13	22:04:42	130	130	130	0	0	0	0	22:34:59	0.55	0a	1	0	1	0	1	0.38	-1	10	10
382	1-Feb-99	dry salt	3	6	85	10.0%	0.10	-0.83	22:07:52	1.95	0	22:07:52	no vid	13	22:05:54	130	130	130	0	0	0	0	22:34:59	0.73	0a	1	0	1	0	1	0.79	1	10	10
381	1-Feb-99	dry salt	3	11	170	8.9%	0.09	-0.06	22:11:24	1.16	1	22:11:24	no vid	13	22:11:57	130	130	130	0	0	0	0	22:15:01	0.65	0a	1	0	1	0	1	0.61	-1	10.25	10.25
378	1-Feb-99	dry salt	3	12	170	1.1%	0.01	-0.56	22:13:19	1.62	0	22:13:19	no vid	13	22:13:34	130	130	130	0	0	0	0	22:15:00	0.08	2	1	2	1	2	1	0.08	-1	10.25	10.25
387	2-Feb-99	Sand Mix	0	8	350	5.0%	0.05	-0.03		-1.02	1	1:42:08	no vid	13	1:42:10	215	215	0	0	0	0	0	1:45:01	0.37	0	0	0	0	0	0	0.03	1	-10.25	10.25
388	4-Feb-99	Sand Mix	0	8	350	0.0%	0.00	2.81		4.74	0	17:27:08	no vid	14	17:27:34	0	0	0	0	0	0	0	17:30:00	0.00	0	0	0	0	0	0	0.00	-1	5.5	5.5
389	4-Feb-99	Sand Mix	0	9	350	0.0%	0.00	2.96		5.61	0	17:28:36	no vid	14	17:28:21	0	0	0	0	0	0	0	17:30:00	0.00	0	0	0	0	0	0	0.00	-1	5.5	5.5
390	4-Feb-99	Sand Mix	0	11	350	0.0%	0.00	2.84		4.88	1	17:32:16	no vid	14	17:32:39	0	0	0	0	0	0	0	17:35:00	0.00	0	0	0	0	0	0	0.00	-1	5.5	5.5
391	4-Feb-99	Sand Mix	0	12	350	0.0%	0.00	2.53		3.72	1	17:34:36	no vid	14	17:34:00	0	0	0	0	0	0	0	17:30:01	0.00	0	0	0	0	0	0	0.00	-1	5.5	5.5
394	5-Feb-99	dry salt	3	9	130	2.3%	0.02	-7.51	8:14:00	-7.49	1	8:14:00	no vid	14	8:13:36	0	0	0	0	0	0	0	8:15:01	0.17	0a	1	0	1	0	0	0.11	1	-3.75	3.75
393	5-Feb-99	dry salt	3	10	130	0.6%	0.01	-5.56	8:15:55	-4.46	1	8:15:55	no vid	14	8:15:56	0	0	0	0	0	0	0	8:15:01	0.04	0a	1	0	0	0	0	0.02	1	-3.75	3.75
395	5-Feb-99	dry salt	3	11	130	2.5%	0.03	-5.67	8:18:24	-6.07	1	8:18:24	no vid	14	8:17:16	0	0	0	0	0	0	0	8:20:01	0.18	0a	1	0	1	0	0	0.17	1	-3.75	3.75
392	5-Feb-99	dry salt	3	12	130	0.0%	0.00	-7.15	8:19:35	-5.99	0	8:19:35	no vid	14	8:19:36	0	0	0	0	0	0	0	8:15:01	0.00	0	0	0	0	0	0	0.00	1	-3.75	3.75
400	6-Feb-99	dry salt	3	6	100	7.5%	0.08	-1.69	5:00:39	-1.25	0	5:00:39	no vid	10	5:00:48	0	0	0	0	0	0	0	5:49:42	0.55	0a	1	0	1	0	1	0.00	-1	-7	7
398	6-Feb-99	dry salt	3	2	100	5.0%	0.05	-3.16	5:01:05	-2.52	1	5:01:05	no vid	10	5:01:44	0	0	0	0	0	0	0	5:49:33	0.37	0a	1	0	1	0	1	0.21	-1	-7	7
399	6-Feb-99	dry salt	3	3	100	7.5%	0.08	-3.12	5:02:45	-2.35	1	5:02:45	no vid	10	5:03:08	0	0	0	0	0	0	0	5:49:36	0.55	0a	1	0	1	0	1	0.31	-1	-7	7
404	6-Feb-99	dry salt	3	4	100	30.0%	0.30	-3.11	5:04:11	-2.32	1	5:04:11	no vid	10	5:04:36	0	0	0	0	0	0	0	5:49:33	2.19	0a	1	0	1	0	1	0.95	-1	-7	7
403	6-Feb-99	Pre-Wet Salt	4	5	100	10.0%	0.10	-3.27	5:06:48	-1.68	0	5:06:48	no vid	10	5:06:48	0	0	0	1	6	0	0	5:49:31	0.73	0a	1	0	1	0	1	0.22	1	-7	7
397	6-Feb-99	Pre-Wet Salt	4	6	100	5.0%	0.05	-3.44	5:09:15	-1.32	0	5:09:15	no vid	10	5:08:32	0	0	0	1	6	0	0	5:49:29	0.37	0a	1	0	1	0	1	0.22	1	-7	7
402	6-Feb-99	prewet salt	5	1	100	8.6%	0.09	-3.17	5:15:30	-1.65	0	5:15:30	no vid	10	5:15:56	0	0	0	2	0	6	0	5:15:01	0.63	0	0	0	0	0	0	0.10	1	-6.75	6.75
401	6-Feb-99	prewet salt	5	11	100	8.1%	0.08	-3.27	5:16:32	-1.68	0	5:16:32	no vid	10	5:17:16	0	0	0	2	0	6	0	5:20:01	0.59	0a	1	0	0	0	0	0.22	1	-6.75	6.75
396	6-Feb-99	prewet salt	5	12	100	4.2%	0.04	-2.94	5:19:20	-2.07	1	5:19:20	no vid	10	5:19:36	0	0	0	2	0	6	0	5:15:01	0.30	0a	1	0	0	0	0	0.13	1	-6.75	6.75
411	13-Feb-99	prewet salt	5	8	130	61.9%	0.62	-6.65	10:46:58	-6.36	1	10:46:58	no vid	22	10:47:08	0	105	105	2	0	3	0	10:50:01	4.52	2	1	0	1	0	1	0.71	1	-1.25	1.25
409	13-Feb-99	prewet salt	5	10	130	18.9%	0.19	-3.85	10:50:02	-4.53	1	10:50:02	no vid	22	10:50:56	0	105	105	2	0	6	0	10:50:01	1.38	1	0	0	1	0	1	0.26	1	-1.25	1.25
412	13-Feb-99	prewet salt	5	11	130	70.6%	0.71	-8.82	10:52:41	-7.1	1	10:52:41	no vid	22	10:52:16	0	105	105	2	0	6	0	10:55:00	5.15	1	1	0	1	0	1	0.28	1	-1.25	1.25
410	13-Feb-99	prewet salt	5	12	130	35.3%	0.35	-9.22	10:54:42	-7.19	1	10:54:42	no vid	22	10:54:36	0	105	105	2	0	6	0	10:50:01	2.58	1	0	1	1	0	1	1.76	1	-1	1
405	13-Feb-99	Sand Mix	0	8	350	0.0%	0.00	-3.83		-2.94	1	6:02:08	no vid	1	6:02:00	0	0	0	0	0	0	0	6:05:01	0.00	1	0	0	0	0	0	0.00	1	-6	6
407	13-Feb-99	Sand Mix	0	10	350	2.2%	0.02	-4.05		-4.22	1	6:05:56	no vid	1	6:05:19	0	0	0	0	0	0	0	6:05:01	0.16	0	0	0	0	0	0	0.00	1	-6	6
408	13-Feb-99	Sand Mix	0	11	350	4.2%	0.04	-4.03		-5.52	0	6:07:16	no vid	1	6:07:05	0	0	0	0	0	0	0	6:10:00	0.30	0	0	0	0	0	0	0.00	-1	-6	6
406	13-Feb-99	Sand Mix	0	12	350	0.0%	0.00	-3.57		-3.44	1	6:09:36	no vid	1	6:08:38	0	0	0	0	0	0	0	6:05:01	0.00	0	0	0	0	0	0	0.00	1	-6	6
414	16-Feb-99	prewet salt	5	8	100	0.0%	0.00	-0.74	3:27:08	-0.53	0	3:27:08	no vid	0	3:27:08	0	0	0	2	0	3	0	3:30:01	0.00	0	0	0	0	0	0	0.00	1	-8.5	8.5
413	16-Feb-99	prewet salt	5	10	100	0.0%	0.00	-0.64	3:30:08	-0.66	0	3:30:08	no vid	0	3:30:56	0	0	0	2	0	3	0	3:30:01	0.00	0	0	0	0	0	0	0.00	1	-8.5	8.5
416	16-Feb-99	prewet salt	5	11	100	0.0%	0.00	-0.68	3:32:02	-0.82	0	3:32:02	no vid	0	3:32:16	0	0	0	2	0	3	0	3:35:01	0.00	0	0	0	0	0	0	0.00	1	-8.5	8.5
415	16-Feb-99	prewet salt	5	12	100	0.0%	0.00	-0.70	3:34:31	-1.61	0	3:34:31	no vid	0	3:34:36	0	0	0	2	0	3	0	3:30:01	0.00	0	0	0	0	0	0	0.00	1	-8.5	8.5
426	16-Feb-99	prewet salt	5	1	130	42.5%	0.43	7.58	20:15:28	12.16	0	20:15:58	no vid	1	20:15:48	0	0	0	2	0	3	0	21:27:13	3.10	3	0	3	0	3	0	-0.10	-1	8.25	8.25
425	16-Feb-99	prewet salt	5	2	130	25.0%	0.25	-0.45	20:16:00	1.76	0	20:16:00	no vid	1	20:16:44	0	0	0	2	0	3	0	21:27:09	1.83	0a	1	0	1	0	1	0.20	-1	8.25	8.25

APPENDIX D. DART Database

Event	Date	Material	Material Code	Site	Rate kg/2lnkm (X6)	Initial Snow Cover % (X1)	Initial cover fraction	Air Temp (X2)	Air Temp Time	Surface Temp (X3)	Precip @ Application (X4)	Precip Sensor Time	Snowfall	DaySnow	Time Applied	Prior 4 hrs	Prior 6hrs	Prior 12hrs	Prewet Matereial	NaCl Prewet % Rate	Other Prewet % Rate	DLA	Time of analyzed frame	Initial Cover (m)	Trend, 2 hr	Effect, 2 hr	Trend, 1 hr	Effect, 1 hr	Trend, .5 hr	Effect, .5 hr	MR m/hr	Air Temp trend	hours from noon (hr)	abs value from noon
421	16-Feb-99	prewet salt	5	3	130	0.0%	0.00	7.73	20:17:35	10.72	0	20:17:35	no vid	1	20:18:08	0	0	0	2	0	3	0	21:26:57	0.00	3	0	3	0	3	0	-0.61	-1	8.25	8.25
423	16-Feb-99	prewet salt	5	4	130	5.0%	0.05	8.07	20:19:44	12.29	0	20:19:44	no vid	1	20:19:36	0	0	0	2	0	3	0	21:26:47	0.37	0	0	0	0	0	0	0.00	-1	8.25	8.25
424	16-Feb-99	prewet salt	5	5	130	5.0%	0.05	-0.93	20:21:26	3.07	0	20:21:26	no vid	1	20:21:48	0	0	0	2	0	3	0	21:27:00	0.37	0a	1	0	1	0	1	0.20	-1	8.25	8.25
422	16-Feb-99	prewet salt	5	6	130	5.0%	0.05	-1.48	20:22:44	1.14	0	20:22:44	no vid	1	20:23:32	0	0	0	2	0	3	0	21:26:39	0.37	0a	1	0	1	0	1	0.20	1	8.25	8.25
418	16-Feb-99	prewet salt	5	8	100	0.0%	0.00	7.94	20:28:51	5.61	0	20:26:10	no vid	1	20:27:08	0	0	0	2	0	3	0	20:30:01	0.00	0	0	0	1	0	1	0.00	-1	8.5	8.5
417	16-Feb-99	prewet salt	5	10	100	0.0%	0.00	2.37	20:30:01	4.93	0	20:30:01	no vid	1	20:30:56	0	0	0	2	0	3	0	20:30:01	0.00	0	0	0	0	0	0	0.00	1	8.5	8.5
420	16-Feb-99	prewet salt	5	11	100	0.0%	0.00	6.99	20:32:03	11.58	0	20:32:03	no vid	1	20:32:16	0	0	0	2	0	3	0	20:35:01	0.00	0	0	0	0	0	0	0.00	-1	8.5	8.5
419	16-Feb-99	prewet salt	5	12	100	0.0%	0.00	-0.29	20:34:00	1.59	0	20:34:00	no vid	1	20:34:36	0	0	0	2	0	3	0	20:30:01	0.00	0	0	0	0	0	0	0.00	1	8.5	8.5
430	18-Feb-99	dry salt	3	8	130	27.5%	0.28	0.88	5:18:44	2.5	0	5:18:44	no vid	12	5:18:24	0	0	0	0	0	0	0	5:20:01	2.01	0a	1	0	1	0	0	2.58	-1	-6.75	6.75
428	18-Feb-99	dry salt	3	10	130	20.6%	0.21	1.27	5:21:10	-0.06	0	5:21:10	no vid	12	5:21:02	0	0	0	0	0	0	0	5:25:01	1.50	2	1	2	1	2	1	2.03	-1	-6.75	6.75
429	18-Feb-99	dry salt	3	11	130	23.6%	0.24	-2.09	5:21:50	-0.64	0	5:21:39	no vid	12	5:21:57	0	0	0	0	0	0	0	5:25:01	1.72	0a	1	0	1	0	1	1.12	-1	-6.75	6.75
427	18-Feb-99	dry salt	3	12	130	13.3%	0.13	-2.01	5:23:29	-1.73	0	5:23:29	no vid	12	5:23:34	0	0	0	0	0	0	0	5:20:01	0.97	0a	1	0	1	0	1	2.37	-1	-6.75	6.75
431	19-Feb-99	prewet salt	5	8	130	0.0%	0.00	-4.86	23:27:02	-2.51	0	23:27:02	no vid	1	23:27:08	0	0	0	2	0	3	0	23:30:01	0.00	0	0	0	0	0	0	0.00	1	11.5	11.5
433	19-Feb-99	prewet salt	5	10	130	0.0%	0.00	-7.52	23:30:11	-4.37	0	23:30:11	no vid	1	23:30:56	0	0	0	2	0	3	0	0:05:01	0.00	0	0	0	0	0	0	0.00	1	11.5	11.5
432	19-Feb-99	prewet salt	5	11	130	0.0%	0.00	-8.87	23:32:00	-4.79	0	23:32:00	no vid	1	23:32:16	0	0	0	2	0	3	0	23:35:01	0.00	0	0	0	0	0	0	0.00	1	11.5	11.5
440	1-Mar-99	Dry NAAC	10 dry	1	130	25%	0.25	-1.92	21:30:13	-0.99	0	21:29:33	no vid	5	21:30:48	0	0	0	0	0	0	0	22:55:26	1.83	1	0	1	0	0	1	-1.51	-1	9.5	9.5
439	1-Mar-99	Dry NAAC	9 dry	2	130	25%	0.25	-1.87	21:31:53	3.73	0	21:29:33	no vid	5	21:31:44	0	0	0	0	0	0	0	22:55:23	1.83	2	0	2	0	3	0	-0.47	-1	9.5	9.5
441	1-Mar-99	Dry NAAC	11 dry	3	130	28%	0.28	-1.78	21:33:32	-0.4	0	21:29:33	no vid	5	21:33:08	0	0	0	0	0	0	0	22:55:22	2.01	1	0	1	0	0	1	-1.23	1	9.5	9.5
438	1-Mar-99	Dry NAAC	8 dry	4	100	13%	0.13	-1.59	21:34:21	-0.56	0	21:29:33	no vid	5	21:34:36	0	0	0	0	0	0	0	22:55:22	0.91	3	0	3	0	3	0	-1.23	-1	9.5	9.5
434	1-Mar-99	Dry NAAC	8 dry	5	100	0%	0.00	-1.38	21:36:01	-0.29	0	21:29:33	no vid	5	21:36:48	0	0	0	0	0	0	0	22:55:23	0.00	3	0	3	0	0	0	-0.76	-1	9.5	9.5
436	1-Mar-99	Dry NAAC	8 dry	6	100	8%	0.08	-2.01	21:38:29	-0.67	0	21:29:33	no vid	5	21:38:32	0	0	0	0	0	0	0	22:55:27	0.55	3	0	3	0	3	0	-2.83	-1	9.75	9.75
437	1-Mar-99	3%NAAC	8	10	100	8.6%	0.09	-1.42	21:45:07	-0.49	0	21:29:33	no vid	5	21:45:56	0	0	0	3	0	0	0	21:45:01	0.63	3	0	3	0	0	0	-0.47	-1	9.75	9.75
435	1-Mar-99	3%NAAC	8	11	100	3.9%	0.04	-2.04	21:47:25	1.92	0	21:29:33	no vid	5	21:47:16	0	0	0	3	0	0	0	21:50:01	0.28	2	0	3	0	0	0	-0.30	1	9.75	9.75
443	2-Mar-99	dry salt	3	8	130	22.2%	0.22	-1.83	4:53:23	-0.47	99		no vid	5	4:53:24	0	0	130	0	0	0	0	4:55:01	1.62	0a	1	0	1	0	1	0.79	1	-7	7
444	2-Mar-99	dry salt	3	10	130	25.0%	0.25	-2.79	4:56:08	-2.06	99		no vid	5	4:56:02	0	0	100	0	0	0	0	4:55:01	1.83	0a	1	0	1	0	1	8.26	1	-7	7
442	2-Mar-99	dry salt	3	11	130	20.0%	0.20	-2.98	4:56:58	-8.59	99		no vid	5	4:56:57	0	0	100	0	0	0	0	5:00:01	1.46	0a	1	0	1	0	1	1.85	1	-7	7
457	3-Mar-99	dry salt	3	8	130	73.3%	0.73	-1.47	6:18:53	-1.55	0	6:18:01	no vid	9	6:18:24	0	0	0	0	0	0	0	6:20:01	5.35	2	1	3	0	3	0	2.65	-1	-5.75	5.75
450	3-Mar-99	dry salt	3	10	130	8.1%	0.08	-1.38	6:21:08	0.1	0	6:21:08	no vid	9	6:21:02	0	0	0	0	0	0	0	6:20:01	0.59	1	1	1	0	0	1	-0.86	1	-5.75	5.75
453	3-Mar-99	dry salt	3	11	130	35.0%	0.35	-1.38	6:21:08	-0.25	0	6:22:01	no vid	9	6:21:57	0	0	0	0	0	0	0	6:25:01	2.56	1	0	1	1	0	1	0.37	-1	-5.75	5.75
454	3-Mar-99	Pre-Wet Salt 6%	4	8	130	40.8%	0.41	-0.92	7:12:00	-0.93	0	7:12:26	no vid	9	7:12:08	130	130	130	1	6	0	0	7:15:01	2.98	1	1	3	0	2	0	0.85	1	-4.75	4.75
451	3-Mar-99	Pre-Wet Salt 6%	4	10	130	18.9%	0.19	-1.48	7:15:13	-1.38	0	7:15:13	no vid	9	7:15:56	130	130	130	1	6	0	0	7:15:01	1.38	1	1	1	1	0	1	5.36	1	-4.75	4.75
446	3-Mar-99	dry salt	3	10	130	1.7%	0.02	-1.87	11:21:16	-2.26	0	11:24:00	1	81	11:21:02	0	260	260	0	0	0	0	11:20:01	0.12	0	0	0	0	0	0	0.25	1	-0.75	0.75
449	3-Mar-99	dry salt	3	11	130	3.3%	0.03	-1.95	11:22:06	-1.02	0	11:24:00	1	81	11:21:57	0	130	260	0	0	0	0	11:25:01	0.24	0	0	0	0	0	0	0.04	1	-0.75	0.75
448	3-Mar-99	dry salt	3	8	100	2.5%	0.03	-1.71	14:08:34	-1.04	0	14:08:07	no vid	81	14:08:24	0	0	260	0	0	0	0	14:10:01	0.18	0	0	0	0	0	0	-0.07	1	2	2
445	3-Mar-99	dry salt	3	10	100	0.0%	0.00	-1.55	14:11:04	-2.06	0	14:08:07	no vid	81	14:11:02	130	130	390	0	0	0	0	14:10:01	0.00	0	0	0	0	0	0	-0.11	1	2.25	2.25
447	3-Mar-99	dry salt	3	11	100	1.7%	0.02	-1.62	14:11:44	1.96	0	14:08:07	no vid	81	14:11:57	130	130	390	0	0	0	0	14:15:01	0.12	3	0	3	0	0	0	-0.32	-1	2.25	2.25
456	3-Mar-99	Pre-Wet Salt 9%	4	8	130	46.7%	0.47	0.00	18:42:38	-2.1	0	18:45:30	no vid	81	18:42:08	100	100	230	1	9	0	0	18:45:01	3.41	0a	1	0	1	0	1	2.07	-1	6.75	6.75
452	3-Mar-99	Pre-Wet Salt12%	4	10	130	18.9%	0.19	-2.05	18:45:30	2.79	0	18:45:30	no vid	81	18:45:56	100	100	360	1	12	0	0	18:45:01	1.38	2	1	2	1	0	0	0.24	-1	6.75	6.75
455	3-Mar-99	Pre-Wet Salt12%	4	11	130	43.6%	0.44	-0.86	18:47:36	-3.96	0	18:45:30	no vid	81	18:47:16	0	100	230	1	12	0	0	18:50:01	3.18	0a	1	0	1	0	1	0.93	-1	6.75	6.75
458	4-Mar-99	Sand Mix	0	8	570	0.0%	0.00	-6.61		-1.3	0	14:12:08	no vid	12	14:11:17	28.5	28.5	0	0	0	0	0	14:15:01	0.00	0	0	0	0	0	0	0.00	-1	2.25	2.25
459	4-Mar-99	Sand Mix	0	11	570	34.4%	0.34	-4.54		-3.22	0	14:17:16	no vid	12	14:17:01	0	0	0	0	0	0	0	14:20:01	2.51	1	1	0	0	0	0	0.42	-1	2.25	2.25
464	6-Mar-99	6%NAAC	8	8	130	42.8%	0.43	-7.07	5:12:01	-3.73	N/A		no vid	33	5:12:08	0	0	0	3	0	0	0	5:15:01	3.12	1	0	0	1	0	0	0.18	-1	-6.75	6.75
469	6-Mar-99	6%NAAC	8	9	130	83.3%	0.83	-7.58	5:13:35	-4.83	N/A		no vid	33	5:13:36	0	0	0	3	0	0	0	5:15:00	6.08	2	1	0	1	0	0	0.10	-1	-6.75	6.75
467	6-Mar-99	dry salt	3	11	130	71.9%	0.72	-7.64	5:17:43	-5.07	99		no vid	33	5:17:16	0	0	0	0	0	0	0	5:20:01	5.25	2	1	2	1	0	0	0.52	-1	-6.75	6.75
465	6-Mar-99	dry salt	3	11	130	63.6%	0.64	-8.09	6:26:03	-6.3	99		no vid	33	6:26:57	130	130	130	0	0	0	0	6:30:01	4.64	1	1	1	0	1	0	-0.14	-1	-5.5	5.5
462	6-Mar-99	Sand Mix	0	8	570	29.7%	0.30	-8.49		-4.43		10:32:08	no vid	42	10:32:08	130	130	0	0	0	0	0	10:35:01	2.17	1	0	0	1	0	0	-1.10	-1	-1.5	1.5
468	6-Mar-99	Sand Mix	0	9	350	76.1%	0.76	-9.64		-5.93		10:33:36	no vid	42	10:33:36	130	130	0	0	0	0	0	10:35:00	5.56	0a	1	0	1	0	1	0.73	-1	-5.5	1.5
466	6-Mar-99	Sand Mix	0	11	570	71.7%	0.72	-9.14		-5.45		10:37:16	no vid	42	10:37:16	260	260	0	0	0	0	0	10:40:01	5.23	0a	1	0	1	0	1	0.66	1	-1.5	1.5
460	6-Mar-99	Sand Mix	0	8	570	10.0%	0.10	-9.92		-5.93		16:12:08	no vid	42	16:12:08	171	301	0	0	0	0	0	16:15:01	0.73	0a	1	0	1	0	0	0.12	1	4.25	4.25
461	6-Mar-99	Sand Mix	0	9	570	19.4%	0.19	-9.81		-5.67		16:13:36	no vid	42	16:13:36	171	301	0	0	0	0	0	16:15:00	1.42	0a	1	0	1	0	1	1.32	1	4.25	4.25
463	6-Mar-99	Sand Mix	0	11	570	31.7%	0.32	-10.37		4.08		16:17:16	no vid	42	16:17:16	171	301	0	0	0	0	0	16:20:01	2.31	0a	1	0	1	0	1	0.36	1	4.25	4.25
470	7-Mar-99	Sand Mix	0	8	450	0.0%	0.00	-9.97		4.08	0	18:07:08	no vid	0	18:07:39	0	0	0	0	0	0	0	18:10:01	0.00	0	0	0	0	0	0	0.00	1	6	6
471	7-Mar-99	Sand Mix	0	9	450	0.0%	0.00	-7.49		7.54	0	18:08:36	no vid	0	18:08:24	0	0	0	0	0	0	0	18:10:01	0.00	0	0	0	0	0	0	0.00	-1	6	6
473	7-Mar-99	Sand Mix	0	10	450	24.4%	0.24	-8.42		-2.23	0	18:10:56	no vid	0	18:10:58	0	0	0	0	0	0	0	18:10:01	1.78	0	1	1	0	0	1	1.03	1	6.25	6.25
472	7-Mar-99	Sand Mix	0	11	450	0.0%	0.00	-10.14		4.42	0	18:12:16	no vid	0	06:12:12 PM	0	0	0	0	0	0	0	18:15:01	0.00	0	0	0	0	0	0	0.00	1	6.25	6.25
474	18-Jan-00	sand mix	0	1a	570	41	0.41	-2.2098	20:56:45	-8.64617	na	na	1	110	20:40	0	0	0	0	0	0	0	na	1.50	na	na	1	0	0a	1	1.67	na	9	9
475	18-Jan-00	prewet sand mix	12	2a	570	44	0.44	-3.3802	20:58:49	-8.206	na	na	1	110	20:43	0	0	0	1	6	0	0	na	1.61	na	na	0a	1	2	1	0.00	na	9	9
476	18-Jan-00	prewet sand mix	12	3a	570	48	0.48	-4.4911	20:59:50	-8.32183	na	na	1	110	20:46	0	0	0	2	0	6	0	na	1.75	na	na	1	0	0a	1	0.99	na	9	9
477	18-Jan-00	sand mix	0	4a	370	42	0.42	-3.9015	21:12:09	-8.4145	na	na	1	110	21:00	0	0	0	0	0	0	0	na	1.53	na	na	0a	1	2	1	0.60	na	9.25	9.25
478	18-Jan-00	prewet sand mix	12	5a	370	52	0.52	-4.7218	21:15:10	-8.727	na	na	1	110	21:07	0	0	0	1	6	0	0	na	1.90	na	na	0a	1	2	1	1.91	na	9.25	9.25
479	18-Jan-00	prewet sand mix	12	6a	370	55	0.55	-4.3383	21:16:38	-9.0745	na	na	1	110	21:10	0	0	0	2	0	6	0	na	2.01	na	na	0a	1	0a	1	1.06	na	9.25	9.25
485	19-Jan-00	prewet salt	5	3a	130	50	0.5	1.713	7:37:57	na	na	na	0	110	7:37:30	0	0	0	2	0	6	0	na	1.83	0a	1	0a	1	0a	1	2.88	1	-4.25	4.25
484	19-Jan-00	prewet salt	5	3	130	63	0.63	1.302	7:38:14	na	na	na	0	110	7:37:48	0	0	0	2	0	6	0	na	2.30	0a	1	0a	1	0a	1	1.77	-1	-4.25	4.25
483	19-Jan-00	prewet salt	5	2a	130	60	0.6	-3.216	7:38:57	na	na	na	0	110	7:38:32	0	0	0	2	0	6	0	na	2.19	0a	1	0a	1	0a	1	1.63	0	-4.25	4.25
482	19-Jan-00	prewet salt	5	2	130	63	0.63	0.892	7:39:32	na	na	na	0	110	7:39:05	0	0	0	2	0	6	0	na	2.30	0a	1	0a	1	0a	1	1.77	1	-4.5	4.5
481	19-Jan-00	dry salt	3	1a	130	50	0.5	-0.543	7:40:56	na	na	na	0	110	7:40:36	0	0	0	0	0	0	0	na	1.83	0a	1	0a	1	0a	1	1.16	1	-4.5	4.5
480	19-Jan-00	dry salt	3	1	130	60	0.6	3.148	7:43:49	na	na	na	0	110	7:43:30	0	0	0	0	0	0	0	na	2.19	0a	1	0a	1	0a	1	0.00	1	-4.5	4.5
486	20-Jan-00	sand mix	0	1	370	87	0.866	-1.569	7:10:34	na	na	na	1	150	7:10:04	0	0	0	0	0	0	0	na	3.16	0a	1	0a	1	0a	1	0.00	1	-4.75	4.75
487	20-Jan-00	sand mix	0	1a	370	80	0.8	-3.415	7:13:08	na	na	na	0	150	7:12:38	0	0	0	0	0	0	0	na	2.92	0a	1	1	1	0a	1	0.00	1	-4.75	4.75
488	20-Jan-00	prewet sand mix	12	2	370	87	0.866	-5.26	7:14:27	na	na	na	0	150	7:13:57	0	0	0	1	6	0	0	na	3.16	1	1	0a	1	0a	1	0.00	1	-4.75	4.75
489	20-Jan-00	prewet sand mix	12	2a	370	77	0.766	-4.235	7:15:00	na	na	na	0	150	7:14:30	0	0	0	1	6	0	0	na	2.80	2	1	0	1	0a	1	0.00	1	-4.75	4.75
490	20-Jan-00	sand mix	0	3	570	67	0.666	-4.44	7:15:25	na	na	na	0	150	7:14:55	0	0	0	0	0	0	0	na	2.43	3	0	2	0	3	0	0.00	1	-4.75	4.75
491	20-Jan-00	sand mix	0	3a	570	80	0.8	-6.081	7:15:55	na	na	na	0	150	7:15:25	0	0	0	0	0	0	0	na	2.92	1	1	0a	1	0	1	0.00	1	-4.75	4.75
492	20-Jan-00	prewet sand mix	12	4	570	93	0.933	-4.645	7:16:33	na	na	na	0	150	7:16:03	0	0	0	1	6	0	0	na	3.41	0a	1	0a	1	0a	1	0.00	1	-4.75	4.75
493	20-Jan-00	prewet sand mix	12	4a	570	63	0.633	-6.286	7:18:15	na	na	na	0	150	7:17:45	0	0	0	1	6	0	0	na	2.31	2	0	0a	1	0a	0	0.00	-1	-4.75	4.75
494	23-Jan-00	sand mix	0	1a	570	61	0.608888889	0.687	20:56	-8.067	na	na	?	100	?	0	0	0	0	0	0	0	na	2.22	na	na	0a	1	0a	1	0.00	1	9	9
495	23-Jan-00	sand mix	0	2a	570	16	0.155555556	0.482	20:58	-10.29	na	na	?	100	?	0	0	0	0	0	0	0	na	0.57	na	na	3	0	2	1	-0.32	-1	9	9
496	23-Jan-00	prewet sand mix	12	3a	570	10	0.077777778	0.072	20:59	-8.206	na	na	?	100	?	0	0	0	2	0	6	0	na	0.28	na	na	3	0	2	0	-0.59	-1	9	9
497	23-Jan-00	prewet sand mix	12	4a	570	42	0.422222222	-0.543	21:01	-0.543	na	na	?	100	?	0	0	0	2	0	6	0	na	1.54	na	na	0a	1	0a	1	0.55	-1	9	9
498	23-Jan-00	prewet sand mix	12	5a	570	68	0.677777778	-0.543	21:05	-9.735	na	na	?	100	?	0	0	0	5	0	0	0	na	2.47	na	na	1	1	0a	1	0.00	-1	9	9
499	23-Jan-00	prewet sand mix	12	6a	570	98	0.983333333	-0.543	21:06	-10.29	na	na	?	100	?	0	0	0	5	0	0	0	na	3.59	na	na	0a	1	1	1	0.00	-1	9	9
500	3-Feb-00	dry salt	3	1a	130	97	0.97	-1.979	5:31	-5.427	na	na	2	20	5:19	0	0	0	0	0	0	0	na	3.54	0a	1	0a	1	0a	1	2.00	-1	-6.5	6.5

APPENDIX D. DART Database

Event	Date	Material	Material Code	Site	Rate kg/2lnkm (X6)	Initial Snow Cover % (X1)	Initial cover fraction	Air Temp (X2)	Air Temp Time	Surface Temp (X3)	Precip @ Application (X4)	Precip Sensor Time	Snowfall	DaySnow	Time Applied	Prior 4 hrs	Prior 6hrs	Prior 12hrs	Prewet Matereial	NaCl Prewet % Rate	Other Prewet % Rate	DLA	Time of analyzed frame	Initial Cover (m)	Trend, 2 hr	Effect, 2 hr	Trend, 1 hr	Effect, 1 hr	Trend, .5 hr	Effect, .5 hr	MR m/hr	Air Temp trend	hours from noon (hr)	abs value from noon
501	3-Feb-00	dry salt	3	2a	130	98	0.98	-3.58533	5:33	-5.8438	na	na	2	20	5:22	0	0	0	0	0	0	0	na	3.58	0a	1	0a	1	0a	1	1.70	1	-6.5	6.5
502	3-Feb-00	prewet salt	4	3a	130	100	1	-3.41467	5:34	-5.53511	na	na	2	20	5:25	0	0	0	1	6	0	0	na	3.65	1	1	0a	1	0a	1	0.00	1	-6.5	6.5
503	3-Feb-00	prewet salt	4	4a	130	98	0.98	-3.8506	5:36	-5.7606	na	na	2	20	5:30	0	0	0	1	6	0	0	na	3.58	0a	1	2	1	2	1	0.00	1	-6.5	6.5
504	3-Feb-00	prewet salt	4	5a	130	98	0.98	-3.989	5:39	-6.12183	na	na	2	20	5:36	0	0	0	1	6	0	0	na	3.58	0a	1	2	1	2	1	1.70	1	-6.25	6.25
505	3-Feb-00	dry salt	3	6a	130	100	1	-3.996	5:40	-5.816	na	na	2	20	5:39	0	0	0	0	0	0	0	na	3.65	0a	1	1	1	0a	1	2.07	1	-6.25	6.25
506	3-Feb-00	dry salt	3	1a	130	35	0.35	2.533	21:23	-4.454	na	na	1	50	21:05	0	0	0	0	0	0	0	na	1.28	0a	1	na	na	na	na	?	1	9.5	9.5
507	3-Feb-00	prewet salt	5	2a	130	11	0.105555556	-0.338	21:25	-4.593	na	na	1	50	21:08	0	0	0	2	0	6	0	na	0.39	3	0	na	na	na	na	0.00	1	9.5	9.5
508	3-Feb-00	prewet salt	5	3a	130	14	0.14	2.123	21:26	-4.454	na	na	1	50	21:11	0	0	0	2	0	6	0	na	0.51	0a	1	na	na	na	na	0.00	0	9.5	9.5
509	3-Feb-00	prewet salt	5	4a	130	23	0.227777778	-0.748	21:29	-4.176	na	na	1	50	21:16	0	0	0	2	0	6	0	na	0.83	2	1	na	na	na	na	0.00	1	9.5	9.5
510	3-Feb-00	dry salt	3	5a	130	27	0.272222222	0.072	21:32	-3.62	na	na	1	50	21:23	0	0	0	0	0	0	0	na	0.99	2	1	na	na	na	na	0.00	-1	9.5	9.5
511	3-Feb-00	prewet salt	5	6a	130	34	0.344444444	-0.338	21:34	-3.898	na	na	1	50	21:26	0	0	0	2	0	6	0	na	1.26	0a	1	na	na	na	na	?	-1	9.5	9.5
512	3-Feb-00	prewet salt	5	7a	130	50	0.5	-2.389	21:38	-4.315	na	na	1	50	21:31	0	0	0	2	0	6	0	na	1.83	1	1	na	na	na	na	0.00	1	9.75	9.75
513	3-Feb-00	dry salt	3	8a	130	28	0.277777778	-0.543	21:41	-5.149	na	na	1	50	21:34	0	0	0	0	0	0	0	na	1.01	0a	1	na	na	na	na	0.00	1	9.75	9.75
514	3-Feb-00	dry salt	3	8b	130	29	0.294444444	2.123	21:42	-3.898	na	na	1	50	21:36	0	0	0	0	0	0	0	na	1.07	0a	1	na	na	na	na	0.00	-1	9.75	9.75
515	3-Feb-00	dry salt	3	9a	130	38	0.383333333	0.482	21:43	-4.454	na	na	1	50	21:38	0	0	0	0	0	0	0	na	1.40	0a	1	na	na	na	na	?	1	9.75	9.75
516	3-Feb-00	dry salt	3	9b	130	50	0.5	0.072	21:44	-4.454	na	na	1	50	21:40	0	0	0	0	0	0	0	na	1.83	1	1	na	na	na	na	0.00	-1	9.75	9.75
517	3-Feb-00	dry salt	3	10a	130	24	0.244444444	0.482	21:46	-4.176	na	na	1	50	21:42	0	0	0	0	0	0	0	na	0.89	2	1	na	na	na	na	0.00	1	9.75	9.75
518	3-Feb-00	dry salt	3	10b	130	41	0.411111111	1.507	21:47	-4.454	na	na	1	50	21:43	0	0	0	0	0	0	0	na	1.50	0a	1	na	na	na	na	0.80	-1	9.75	9.75
519	9-Feb-00	prewet salt	5	1	130	80	0.8	-0.338	7:06:06	-2.231	na	na	0	40	7:05:36	0	0	0	2	0	6	0	na	2.92	na	na	0a	1	0a	1	2.48	1	-5	5
520	9-Feb-00	prewet salt	5	1a	130	97	0.966	0.482	7:09:04	-2.647	na	na	0	40	7:08:34	0	0	0	2	0	6	0	na	3.53	na	na	2	1	0a	1	0.00	1	-4.75	4.75
521	9-Feb-00	prewet salt	7	2	130	87	0.866	2.943	7:10:57	-2.231	na	na	0	40	7:10:27	0	0	0	4	0	0	0	na	3.16	na	na	0a	1	0a	1	2.21	1	-4.75	4.75
522	9-Feb-00	prewet salt	7	2a	130	77	0.766	3.968	7:11:48	-1.536	na	na	0	40	7:11:18	0	0	0	4	0	0	0	na	2.80	na	na	0a	1	0a	1	3.32	-1	-4.75	4.75
523	9-Feb-00	prewet salt	5	3	130	70	0.7	3.558	7:12:25	-2.092	na	na	0	40	7:11:55	0	0	0	2	0	6	0	na	2.56	na	na	0a	1	0a	1	2.12	0	-4.75	4.75
524	9-Feb-00	prewet salt	5	3a	130	77	0.766	4.379	7:13:12	-3.481	na	na	0	40	7:12:42	0	0	0	2	0	6	0	na	2.80	na	na	0a	1	0a	1	1.92	-1	-4.75	4.75
525	9-Feb-00	prewet salt	5	4	130	80	0.8	4.379	7:14:00	-2.092	na	na	0	40	7:13:30	0	0	0	2	0	6	0	na	2.92	na	na	0a	1	0	0	2.04	0	-4.75	4.75
526	9-Feb-00	prewet salt	5	4a	130	90	0.9	3.763	7:16:41	-2.092	na	na	0	40	7:16:11	0	0	0	2	0	6	0	na	3.29	na	na	0a	1	0a	1	0.00	na	-4.75	4.75
527	9-Feb-00	prewet salt	5	5	130	90	0.9	4.584	7:18:54	-2.231	na	na	0	40	7:18:24	0	0	0	2	0	6	0	na	3.29	na	na	0a	1	0a	1	0.00	na	-4.75	4.75
528	9-Feb-00	prewet salt	5	5a	130	70	0.7	2.943	7:21:04	-2.37	na	na	0	40	7:20:34	0	0	0	2	0	6	0	na	2.56	na	na	0a	1	0a	1	0.00	na	-4.75	4.75
529	9-Feb-00	prewet salt	5	6	130	93	0.933	3.763	7:21:33	-1.814	na	na	0	40	7:21:03	0	0	0	2	0	6	0	na	3.41	na	na	0a	1	0a	1	0.00	na	-4.75	4.75
530	9-Feb-00	prewet salt	5	6a	130	87	0.866	3.968	7:22:53	-2.092	na	na	0	40	7:22:23	0	0	0	2	0	6	0	na	3.16	na	na	0a	1	0a	1	0.00	na	-4.75	4.75
531	11-Feb-00	prewet sand	12	1	570	73	0.733	-4.03	7:51:23	-7.511	na	na	1	150	7:50:53	0	0	0	1	6	0	0	na	2.68	0a	1	0a	1	na	na	1.23	1	-4.25	4.25
532	11-Feb-00	prewet sand	12	1a	570	57	0.566	0.892	7:55:35	-6.261	na	na	1	150	7:55:05	0	0	0	1	6	0	0	na	2.07	1	1	0a	1	na	na	0.00	-1	-4	4
533	11-Feb-00	prewet sand	12	2	570	50	0.5	0.072	8:00:21	-6.677	na	na	1	150	7:59:51	0	0	0	1	6	0	0	na	1.83	0a	1	0a	1	na	na	0.00	-1	-4	4
534	11-Feb-00	prewet sand	12	2a	570	57	0.566	-1.979	8:01:25	-6.677	na	na	1	150	8:00:55	0	0	0	1	6	0	0	na	2.07	1	1	0a	1	na	na	0.00	-1	-4	4
535	11-Feb-00	prewet sand	12	3	570	43	0.433	-1.774	8:02:12	-6.122	na	na	1	150	8:01:42	0	0	0	1	6	0	0	na	1.58	1	1	0a	1	na	na	0.00	-1	-4	4
536	11-Feb-00	prewet sand	12	3a	570	50	0.5	-3.004	8:03:04	-7.233	na	na	1	150	8:02:34	0	0	0	1	6	0	0	na	1.83	0a	1	3	0	na	na	0.00	-1	-4	4
537	11-Feb-00	prewet sand	12	4	670	60	0.6	-1.774	8:04:13	-6.955	na	na	1	150	8:03:43	0	0	0	1	6	0	0	na	2.19	0a	1	0a	1	na	na	0.00	-1	-4	4
538	11-Feb-00	prewet sand	12	4a	670	60	0.6	-0.954	8:06:59	-6.261	na	na	0	150	8:06:29	0	0	0	1	6	0	0	na	2.19	0a	1	0a	1	na	na	0.97	-1	-4	4
539	11-Feb-00	prewet sand	12	5	770	30	0.3	-3.825	8:09:41	-6.261	na	na	1	150	8:09:11	0	0	0	1	6	0	0	na	1.10	0a	1	3	0	na	na	-0.14	1	-3.75	3.75
540	11-Feb-00	prewet sand	12	5a	770	57	0.566	0.277	8:12:20	-4.732	na	na	1	150	8:11:50	0	0	0	1	6	0	0	na	2.07	0a	1	0a	1	na	na	0.00	-1	-3.75	3.75
541	11-Feb-00	prewet sand	12	6	770	60	0.6	-3.62	8:12:57	-4.454	na	na	1	150	8:12:27	0	0	0	1	6	0	0	na	2.19	2	1	0	0	na	na	1.01	0	-3.75	3.75
542	11-Feb-00	prewet sand	12	6a	770	57	0.566	1.713	8:14:40	-5.01	na	na	1	150	8:14:10	0	0	0	1	6	0	0	na	2.07	0a	1	3	0	na	na	0.00	-1	-3.75	3.75
543	13-Feb-00	dry salt	3	1a	90	100	1	-3.255	6:58	na	na	na	1	20	6:30	0	0	0	0	0	0	0	na	3.65	0a	1	0a	1	na	na	0.00	-1	-5	5
544	13-Feb-00	dry salt	3	2a	90	91	0.91	-3.25	7:00	na	na	na	1	20	6:33	0	0	0	0	0	0	0	na	3.32	0a	1	0a	1	na	na	0.00	-1	-5	5
545	13-Feb-00	dry salt	3	3a	90	100	1	-3.278	7:01	na	na	na	1	20	6:36	0	0	0	0	0	0	0	na	3.65	1	0	0a	1	na	na	0.00	-1	-5	5
546	13-Feb-00	dry salt	3	4a	90	58	0.58	-3.251	7:03	na	na	na	1	20	6:41	0	0	0	0	0	0	0	na	2.12	3	0	3	0	na	na	0.00	-1	-5	5
547	13-Feb-00	dry salt	3	5a	130	58	0.58	-4.709	7:07	na	na	na	1	20	6:48	0	0	0	0	0	0	0	na	2.12	3	0	3	0	na	na	0.00	1	-5	5
548	13-Feb-00	dry salt	3	6a	170	68	0.68	-4.41	7:08	na	na	na	1	20	6:51	0	0	0	0	0	0	0	na	2.48	2	1	2	1	na	na	0.00	1	-5	5
549	13-Feb-00	dry salt	3	7a	210	38	0.38	-4.163	7:12	na	na	na	1	20	6:54	0	0	0	0	0	0	0	na	1.39	3	0	2	1	na	na	0.00	1	-4.75	4.75
550	13-Feb-00	dry salt	3	8a	210	32	0.32	-3.935	7:14	na	na	na	1	20	6:56	0	0	0	0	0	0	0	na	1.17	2	1	2	1	na	na	0.20	-1	-4.75	4.75
551	13-Feb-00	dry salt	3	8b	210	40	0.4	-4.192	7:15	na	na	na	1	20	6:58	0	0	0	0	0	0	0	na	1.46	2	1	2	0	na	na	0.22	1	-4.75	4.75
552	13-Feb-00	dry salt	3	9a	210	48	0.48	-3.903	7:16	na	na	na	0	20	7:00	0	0	0	0	0	0	0	na	1.75	2	1	2	1	na	na	1.29	-1	-4.75	4.75
553	13-Feb-00	dry salt	3	9b	210	48	0.48	-4.116	7:17	na	na	na	0	20	7:02	0	0	0	0	0	0	0	na	1.75	2	1	2	1	na	na	0.64	1	-4.75	4.75
554	13-Feb-00	dry salt	3	10a	130	60	0.6	-4.317	7:20	na	na	na	0	20	7:04	0	0	0	0	0	0	0	na	2.19	1	0	0a	1	na	na	1.99	1	-4.75	4.75
555	13-Feb-00	dry salt	3	10b	130	67	0.67	-4.325	7:21	na	na	na	0	20	7:07	0	0	0	0	0	0	0	na	2.45	1	1	0a	1	na	na	2.39	1	-4.75	4.75
557	19-Feb-00	prewet salt	5	1a	85	73	0.733	na	na	na	na	na	0	50	20:19:04	0	0	0	2	0	6	0	na	2.68	0a	1	2	1	3	0	1.76	na	8.25	8.25
558	19-Feb-00	prewet salt	5	2	85	77	0.766	na	na	na	na	na	0	50	20:20:34	0	0	0	2	0	6	0	na	2.80	2	1	2	1	3	0	1.45	na	8.25	8.25
559	19-Feb-00	prewet salt	5	2a	85	63	0.633	na	na	na	na	na	0	50	20:21:14	0	0	0	2	0	6	0	na	2.31	0a	1	2	1	3	0	1.40	na	8.25	8.25
560	19-Feb-00	prewet salt	5	3	130	83	0.833	na	na	na	na	na	0	50	20:21:46	0	0	0	2	0	6	0	na	3.04	0a	1	0a	1	0	0	2.16	na	8.25	8.25
561	19-Feb-00	prewet salt	5	3a	130	90	0.9	na	na	na	na	na	0	50	20:22:21	0	0	0	2	0	6	0	na	3.29	0a	1	0a	1	0a	1	0.00	na	8.25	8.25
562	19-Feb-00	prewet salt	5	4	130	77	0.766	na	na	na	na	na	0	50	20:23:11	0	0	0	2	0	6	0	na	2.80	1	1	0a	1	0a	1	3.77	na	8.5	8.5
563	19-Feb-00	prewet salt	5	4a	130	100	1.0	na	na	na	na	na	0	50	20:25:09	0	0	0	2	0	6	0	na	3.65	0a	1	0a	1	0a	1	2.11	na	8.5	8.5
556	19-Feb-00	prewet salt	5	1	85	83	0.833	na	na	na	na	na	0	50	na	0	0	0	2	0	6	0	na	3.04	0a	1	0a	1	0	0	3.27	na	8.25	8.25
564	2-Mar-00	prewet salt	5	1	50	70	0.7	5.814	6:43:58	0.688	na	na	0	30	6:42:58	0	0	0	2	0	6	0	na	2.56	na	na	0a	1	0a	1	3.40	-1	-5.25	5.25
565	2-Mar-00	prewet salt	5	1a	50	40	0.4	2.123	6:44:39	0.41	na	na	0	30	6:43:39	0	0	0	2	0	6	0	na	1.46	na	na	0a	1	0	0	0.86	-1	-5.25	5.25
566	2-Mar-00	prewet salt	5	2	90	75	0.75	6.224	6:45:57	0.271	na	na	1	30	6:44:57	0	0	0	2	0	6	0	na	2.74	na	na	0a	1	0a	1	2.31	-1	-5.25	5.25
567	2-Mar-00	prewet salt	5	2a	90	30	0.3	5.199	6:46:32	0.688	na	na	0	30	6:45:32	0	0	0	2	0	6	0	na	1.10	na	na	2	1	3	0	0.38	-1	-5.25	5.25
568	2-Mar-00	prewet salt	5	3	90	30	0.3	4.379	6:46:58	0.688	na	na	0	30	6:45:48	0	0	0	2	0	6	0	na	1.10	na	na	2	1	3	0	0.00	-1	-5.25	5.25
569	2-Mar-00	prewet salt	5	3a	90	90	0.9	1.713	6:47:29	0.966	na	na	1	30	6:46:29	0	0	0	2	0	6	0	na	3.29	na	na	2	1	3	0	3.75	-1	-5.25	5.25
570	2-Mar-00	prewet salt	5	4	130	63	0.633	3.968	6:48:11	0.271	na	na	1	30	6:47:11	0	0	0	2	0	6	0	na	2.31	na	na	2	1	3	0	0.00	-1	-5.25	5.25
571	2-Mar-00	prewet salt	5	4a	130	95	0.95	-0.954	6:49:56	0.132	na	na	2	30	6:48:56	0	0	0	2	0	6	0	na	3.47	na	na	0a	1	0a	1	2.69	-1	-5.25	5.25
730	16-Jan-01	dry salt	3	1	130	100	1	0	7:00:00	0	0	na	1	.	5:54	130	0	170	0	0	0	0	na	3.65	0a	1	0a	1	0a	1	1.83	0	-4	4
731	16-Jan-01	dry salt	3	4	130	100	1	0	7:00:00	0	0	na	1	.	6:08	130	0	170	0	0	0	0	na	3.65	0a	1	0a	1	0a	1	1.83	0	-4	4
732	16-Jan-01	dry salt	3	5	130	NO DATA	NO DATA	0	7:00:00	0	0	na	1	.	6:11	130	0	170	0	0	0	0	na	na	0a	1	0a	1	0a	1	na	0	-4	4
733	16-Jan-01	dry salt	3	6	130	100	1	0	7:00:00	0	0	na	1	.	6:17	130	0	170	0	0	0	0	na	3.65	0a	1	0a	1	0a	1	2.03	0	-3.75	3.75
735	24-Jan-01	prewet salt	4	4	130	100	1	-2	18:00:00	-1.8	1	na	3	.	17:05	mix	0	0	1	15	0	0	na	3.65	0a	1	0a	1	0a	1	0.61	0	7	7
737	24-Jan-01	prewet salt	4	6	130	100	1	-2	18:00:00	-1.8	1	na	3	.	17:18	mix	0	0	1	15	0	0	na	3.65	0a	1	0a	1	0a	1	0.73	0	6.45	6.45
734	24-Jan-01	dry salt	3	1	130	100	1	-2	18:00:00	-1.8	1	na	3	.	18:25:00	mix	0	0	0	0	0	0	na	3.65	0a	1	0a	1	0a	1	0.98	0	8.25	8.25
736	24-Jan-01	prewet salt	4	5	130	NO DATA	NO DATA	-2	18:00:00	-1.8	1	na	3	.	NO DATA	mix	0	0	1	15	0	0	na	3.65	0a	1	0a	1	0a	1	na	0	na	na
738	26-Jan-01	prewet salt	12	1	70	100	1	-4	21:00:00	-3.8	1	na	1	.	22:09	0	0	0	2	0	5	0	na	3.65	1	0	1	0	0a	1	1.46	-1	12	12
739	26-Jan-01	prewet salt	4	4	70	100	1	-4	21:00:00	-3.8	1	na	1	.	22:23	0	0	0	1	15	0	0	na	3.65	1	0	1	0	0a	1	1.83	-1	11.8	11.8
740	26-Jan-01	prewet salt	4	5	70	100	1	-4	21:00:00	-3.8	1	na	1	.	22:26	0	0	0	1	15	0	0	na	3.65	1	0	1	0	0a	1	1.83	-1	11.5	11.5

APPENDIX D. DART Database

Event	Date	Material	Material Code	Site	Rate kg/2lnkm (X6)	Initial Snow Cover % (X1)	Initial cover fraction	Air Temp (X2)	Air Temp Time	Surface Temp (X3)	Precip @ Application (X4)	Precip Sensor Time	Snowfall	DaySnow	Time Applied	Prior 4 hrs	Prior 6hrs	Prior 12hrs	Prewet Matereial	NaCl Prewet % Rate	Other Prewet % Rate	DLA	Time of analyzed frame	Initial Cover (m)	Trend, 2 hr	Effect, 2 hr	Trend, 1 hr	Effect, 1 hr	Trend, .5 hr	Effect, .5 hr	MR m/hr	Air Temp trend	hours from noon (hr)	abs value from noon
741	26-Jan-01	prewet salt	4	6	70	100	1	-4	21:00:00	-3.8	1	na	1	.	22:31	0	0	0	1	15	0	0	na	3.65	1	0	1	0	0a	1	1.83	-1	11.5	11.5
742	27-Jan-01	prewet salt	12	1	70	100	1	-5	3:00:00	-6	1	na	1	.	4:09	70	0	0	2	0	5	0	na	3.65	0	0	0	0	0	0	0.81	-1	-6	6
743	27-Jan-01	prewet salt	4	4	70	100	1	-5	3:00:00	-6	1	na	1	.	4:23	70	0	0	1	15	0	0	na	3.65	0	0	0	0	0	0	0.39	-1	-5.75	5.75
744	27-Jan-01	prewet salt	4	5	70	100	1	-5	3:00:00	-6	1	na	1	.	4:26	70	0	0	1	15	0	0	na	3.65	0	0	0	0	0	0	0.39	-1	-5.75	5.75
745	27-Jan-01	prewet salt	4	6	70	100	1	-5	3:00:00	-6	1	na	1	.	4:31	70	0	0	1	15	0	0	na	3.65	0	0	0	0	0	0	0.39	-1	-5.5	5.5
746	8-Feb-01	dry salt	3	1	130	100	1	-4	4:00:00	-4	1	na	0	.	3:39	0	0	0	0	0	0	0	na	3.65	0	0	0	0	0	0	0.37	-1	-6.33	6.33
747	8-Feb-01	dry salt	4	4	130	100	1	-4	4:00:00	-4	1	na	0	.	4:41	0	0	0	0	0	0	0	na	3.65	0	0	0	0	0	0	0.33	-1	-5.33	5.33
748	8-Feb-01	dry salt	4	5	130	100	1	-4	4:00:00	-4	1	na	0	.	4:45	0	0	0	0	0	0	0	na	3.65	0	0	0	0	0	0	0.37	-1	-5.25	5.25
749	8-Feb-01	dry salt	4	6	130	100	1	-4	4:00:00	-4	1	na	0	.	4:50	0	0	0	0	0	0	0	na	3.65	0	0	0	0	0	0	0.37	-1	-5.15	5.15
751	9-Feb-01	dry salt	3	4	130	100	1	3	23:00:00	0	1	na	3	.	22:35	0	0	130	0	0	0	0	na	3.65	0	0	0	0	0	0	0.10	-1	12.5	12.5
752	9-Feb-01	dry salt	3	5	130	100	1	3	23:00:00	0	1	na	3	.	22:39	0	0	130	0	0	0	0	na	3.65	0	0	0	0	0	0	0.10	-1	12.66	12.66
753	9-Feb-01	dry salt	3	6	130	100	1	3	23:00:00	0	1	na	3	.	22:44	0	0	130	0	0	0	0	na	3.65	0	0	0	0	0	0	0.10	-1	12.75	12.75
750	9-Feb-01	dry salt	3	1	130	100	1	3	23:00:00	0	1	na	3	.	23:09	0	0	130	0	0	0	0	na	3.65	0	0	0	0	0	0	0.30	-1	13	13
754	11-Feb-01	sand	1	1	na	100	1	-11	3:00:00	-11	1	na	3	.	4:59	170	170	240	0	0	0	0	na	3.65	0	0	0	0	0	0	0.52	-1	-5	5
755	11-Feb-01	sand	1	4	na	100	1	-11	3:00:00	-11	1	na	3	.	5:13	170	170	240	0	0	0	0	na	3.65	0a	1	0	0	0	0	0.54	-1	-4.75	4.75
756	11-Feb-01	sand	1	5	na	100	1	-11	3:00:00	-11	1	na	3	.	5:16	170	170	240	0	0	0	0	na	3.65	0a	1	0	0	0	0	0.54	-1	-4.75	4.75
757	11-Feb-01	sand	1	6	na	100	1	-11	3:00:00	-11	1	na	3	.	5:22	170	170	240	0	0	0	0	na	3.65	0a	1	0	0	0	0	0.52	-1	-4.34	4.34
759	17-Feb-01	mix	0	4	270	100	1	-7.1	4:00	-5.5	1	na	3	.	4:39	170	170	240	0	0	0	0	na	3.65	0	0	0	0	0	0	na	0	-5.25	5.25
760	17-Feb-01	mix	0	6	270	100	1	-7.1	4:00	-5.5	1	na	3	.	4:44	170	170	240	0	0	0	0	na	3.65	0	0	0	0	0	0	na	0	-5.25	5.25
758	17-Feb-01	prewet mix	12	1	270	100	1	-7.1	4:00	-5.5	1	na	3	.	6:04	170	170	240	2	0	5	0	na	3.65	0a	1	0	0	0	0	0.67	0	-4	4
761	21-Feb-01	mix	0	1	na	100	1	-8	4:00	-8	1	na	2	.	5:24	0	170	0	0	0	0	0	na	3.65	0a	1	0	0	0	0	0.81	-1	-4.5	4.5
762	21-Feb-01	mix	0	4	na	100	1	-8	4:00	-8	1	na	2	.	5:36	0	170	0	0	0	0	0	na	3.65	0a	1	0	0	0	0	0.38	-1	-4.5	4.5
763	21-Feb-01	mix	0	5	na	100	1	-8	4:00	-8	1	na	2	.	5:40	0	170	0	0	0	0	0	na	3.65	0a	1	0	0	0	0	0.37	-1	-4.25	4.25
764	21-Feb-01	mix	0	6	na	100	1	-8	4:00	-8	1	na	2	.	5:45	0	170	0	0	0	0	0	na	3.65	0a	1	0	0	0	0	0.41	-1	-4.25	4.25
766	23-Feb-01	sand	1	4	na	100	1	-5	3:00	-5	1	na	3	.	1:35	0	0	0	0	0	0	0	na	3.65	0	0	0	0	0	0	0.52	-1	-8.5	8.5
767	23-Feb-01	sand	1	5	na	100	1	-5	3:00	-5	1	na	3	.	1:39	0	0	0	0	0	0	0	na	3.65	0	0	0	0	0	0	0.41	-1	-8.5	8.5
768	23-Feb-01	sand	1	6	na	100	1	-5	3:00	-5	1	na	3	.	1:44	0	0	0	0	0	0	0	na	3.65	0	0	0	0	0	0	0.46	-1	-8.25	8.25
765	23-Feb-01	sand	1	1	na	100	1	-5	3:00	-5	1	na	3	.	4:49	0	0	0	0	0	0	0	na	3.65	0a	1	0a	1	0	0	0.61	-1	-5	5
769	27-Feb-01	dry salt	3	1	130	100	1	-4	6:06	-3	1	na	3	.	5:30	0	0	0	0	0	0	0	na	3.65	0a	1	0a	1	0	0	0.56	1	-4.5	4.5
770	27-Feb-01	dry salt	3	4	130	100	1	-4	6:06	-3	1	na	3	.	6:12	0	0	0	0	0	0	0	na	3.65	0a	1	0a	1	0	0	0.67	1	-3.75	3.75
771	27-Feb-01	dry salt	3	5	130	100	1	-4	6:06	-3	1	na	3	.	6:15	0	0	0	0	0	0	0	na	3.65	0a	1	0a	1	0	0	0.52	1	-3.75	3.75
772	27-Feb-01	dry salt	3	6	130	100	1	-4	6:06	-3	1	na	3	.	6:20	0	0	0	0	0	0	0	na	3.65		1	0a	1	0	0	0.52	1	-3.75	3.75
773	28-Feb-01	prewet salt	5	1	130	100	1	-9.5	1:40:00	-5.5	1	na	3	.	4:30	0	0	0	2	0	5	0	na	3.65	0a	1	0a	1	0	0	0.61	1	-5	5
774	28-Feb-01	prewet salt	4	4	130	100	1	-9.5	1:40:00	-5.5	1	na	3	.	5:35	130	0	0	1	15	0	0	na	3.65	0a	1	0a	1	0	0	0.33	1	-4.5	4.5
775	28-Feb-01	prewet salt	4	5	130	100	1	-9.5	1:40:00	-5.5	1	na	3	.	5:38	130	0	0	1	15	0	0	na	3.65	0a	1	0a	1	0	0	0.33	1	-4.5	4.5
776	28-Feb-01	prewet salt	4	6	130	100	1	-9.5	1:40:00	-5.5	1	na	3	.	5:44	130	0	0	1	15	0	0	na	3.65	0a	1	0a	1	0	0	0.33	1	-4.25	4.25
777	1-Mar-01	prewet 30/70 mix	12	1	130	75	0.75	-7	21:00	-5	1	na	2	.	19:39	170	0	0	2	0	5	0	na	2.74	0a	1	0a	1	0	0	0.52	0	7.17	7.17
778	1-Mar-01	prewet 30/70 mix	4	5	130	5	0.05	-7	21:00	-5	1	na	1	.	19:56	170	0	0	1	15	0	0	na	0.18	0a	1	0	0	0	0	1.15	0	8	8
779	1-Mar-01	prewet 30/70 mix	4	6	130	10	0.1	-7	21:00	-5	1	na	1	.	20:02	170	0	0	1	0	0	100	na	0.37	0a	1	0	0	0	0	0.97	0	8	8
780	5-Mar-01	prewet mix	12	1	130	100	1	-5	18:00	-5	1	na	3	.	18:02	0	0	0	2	0	5	0	na	3.65	0	0	0	0	0	0	0.21	-1	8	8
781	5-Mar-01	prewet mix	4	4	130	100	1	-5	18:00	-5	1	na	3	.	18:17	0	0	0	1	15	0	0	na	3.65	0	0	0	0	0	0	0.20	-1	8.25	8.25
782	5-Mar-01	prewet mix	4	5	130	100	1	-5	18:00	-5	1	na	3	.	18:20	0	0	0	1	15	0	0	na	3.65	0	0	0	0	0	0	0.18	-1	8.17	8.17
783	5-Mar-01	prewet mix	4	6	130	100	1	-5	18:00	-5	1	na	3	.	18:25	0	0	0	1	0	0	100	na	3.65	0	0	0	0	0	0	0.19	-1	8.5	8.5
784	11-Mar-01	prewet mix	4	4	270	100	1	1	4:00	0	1	na	3	.	4:28	0	0	0	1	15	0	0	na	3.65	0	0	0	0	0	0	0.33	1	-5.5	5.5
785	11-Mar-01	prewet mix	4	5	270	100	1	1	4:00	0	1	na	3	.	4:31	0	0	0	1	15	0	0	na	3.65	0a	1	0a	1	0a	1	0.52	1	-5.5	5.5
786	11-Mar-01	prewet mix	4	6	270	100	1	1	4:00	0	1	na	3	.	4:36	0	0	0	1	0	0	100	na	3.65	0a	1	0a	1	0a	1	0.61	1	-5.5	5.5
572	dec 23 97	dry salt	3	1	130	80	0.8	-2	0:07:30	-3	na	na	2		23:55	0	0	0	0	0	0	0	na	2.92	3	0	na	na	na	na	0.00	0	-12	12
574	dec 23 97	dry salt	3	2	130	90	0.9	-2	0:08:15	-3	na	na	2		23:55	0	0	0	0	0	0	0	na	3.29	3	0	na	na	na	na	0.00	0	-12	12

APPENDIX E. Example Analysis Of The DART Database

Purpose

To compare the effectiveness of dry and pre-wet road salt in removing snow from a highway surface.

Method

Effectiveness was compared by sorting the database into classes of similar weather and surface conditions, defining a measurement criterion, and comparing the percentage of cases in each group which met the criterion.

Criterion variable: success in ½ hour, where success=1 for cases in which snow cover decreased within ½ hour after salt application and success=0 for cases in which snow cover did not decrease within that time.

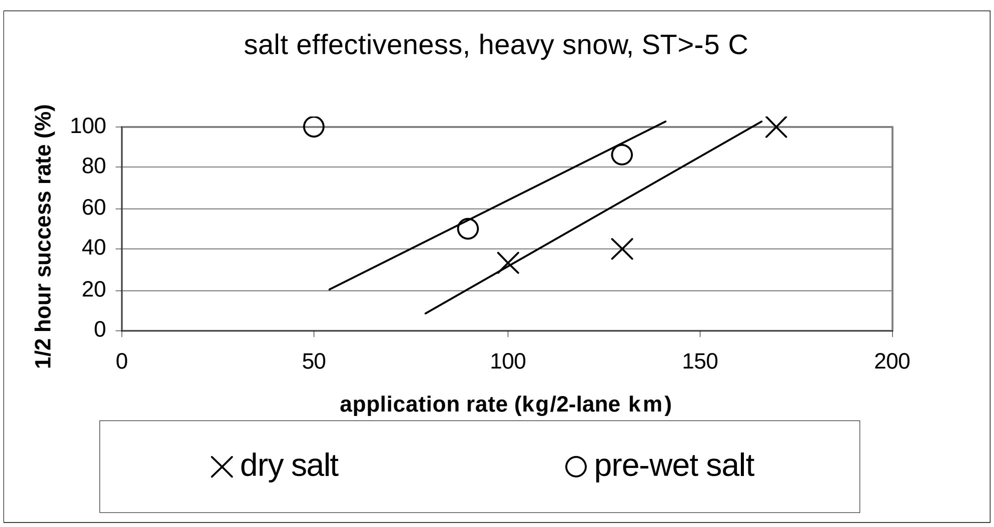
Classes into which data were sorted:

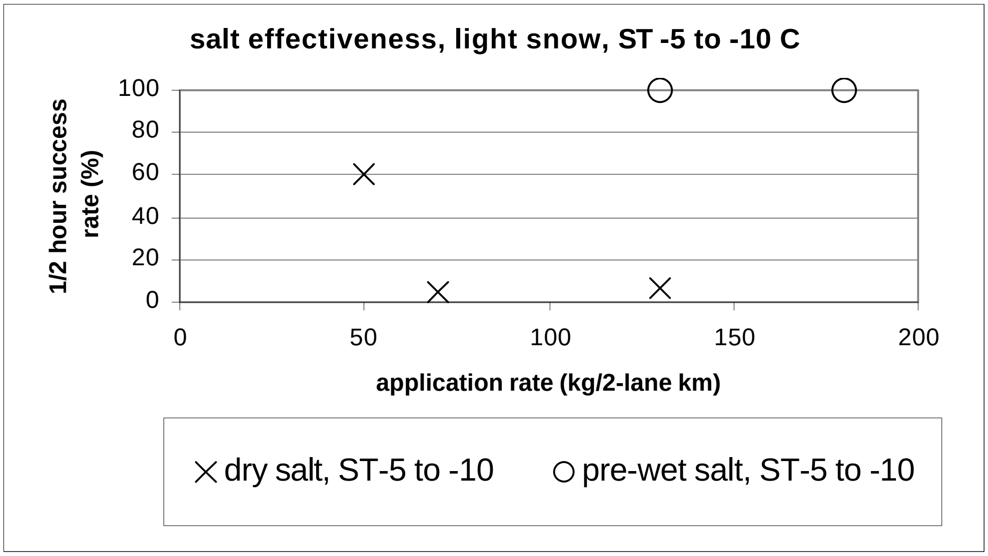
Daily snowfall>0 and <=25 mm (light snow) and surface temp. >=-5 and <=-10^{o}C
Daily snowfall>0 and <=25 mm (light snow) and surface temp. <-10^{o}C
Daily snowfall >25 mm (heavy snow) and surface temperature >=-5^{o}C

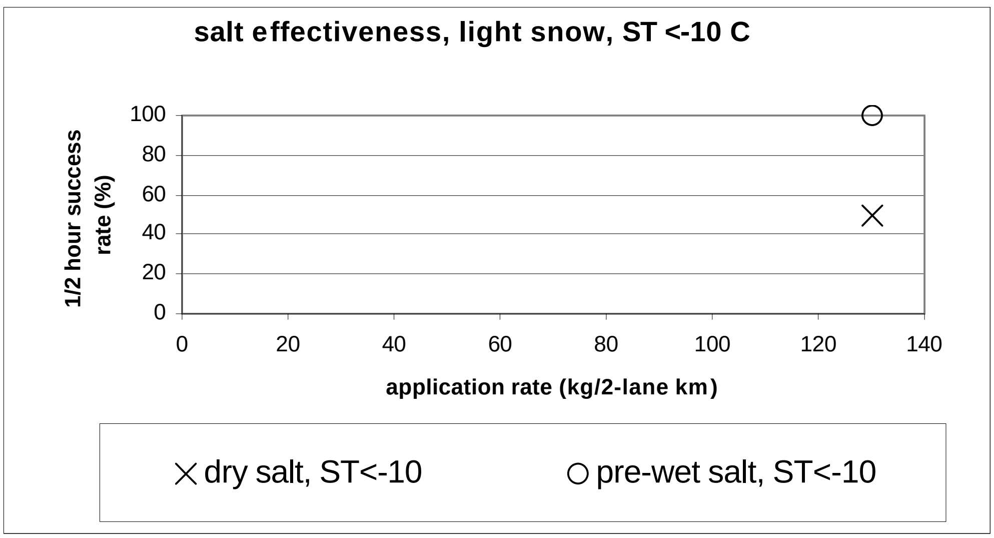
For each environmental condition, cases were split by dry vs pre-wet salt and by application rate (50, 70, 100, 130, 170 kg/2-lane km, where 1 kg/2-lane km=1.77 lb/lane mile). The number of cases where success=1 were tabulated in each class and divided by the total cases in that class to express the success rate as a %. The success rate was plotted against application rate.

Results

Sorting produced 17 valid cases light snow at –5 to –10^{o}C, 3 cases for light snow at <-10^{o}C and, 7 cases for heavy snow at >=-5^{o}C. Pre-wet salt was more effective than dry salt in all cases.




salt effectiveness, light snow, ST -5 to -10 C
1/2 hour success rate (%)
100
80
60
40
20
0
0
50
100
150
200
application rate (kg/2-lane km)
dry salt, ST-5 to -10
pre-wet salt, ST-5 to -10


salt effectiveness, light snow, ST <-10 C
1/2 hour success rate (%)
100
80
60
40
20
0
0
20
40
60
80
100
120
140
application rate (kg/2-lane km)
dry salt, ST<-10
pre-wet salt, ST<-10