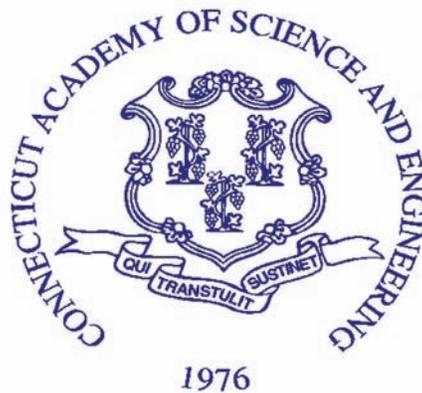


IMPROVING WINTER HIGHWAY MAINTENANCE: CASE STUDIES FOR CONNECTICUT'S CONSIDERATION

APRIL, 2006

A REPORT BY

THE CONNECTICUT
ACADEMY OF SCIENCE
AND ENGINEERING



FOR

THE CONNECTICUT DEPARTMENT OF
TRANSPORTATION

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This study was initiated at the request of the Connecticut Department of Transportation on April 25, 2005 . The project was conducted by an Academy Study Committee with the support of Lisa Aultman-Hall, PhD, Project Manager, and James Mahoney and Scott Zinke, Project Research Engineers. The content of this report lies within the province of the Academy's Transportation Systems Technical Board. The report has been reviewed by Academy Members Peter G. Cable, PhD, and Gale F. Hoffnagle. Martha Sherman, the Academy's Managing Editor edited the report. The report is hereby released with the approval of the Academy Council.

Richard H. Strauss
Executive Director

Disclaimer

The contents of this report reflect the views of the authors who are responsible for the facts and accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the Connecticut Department of Transportation or the Federal Highway Administration. The report does not constitute a standard, specification, or regulation.

IMPROVING WINTER HIGHWAY MAINTENANCE:
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IMPROVING WINTER HIGHWAY MAINTENANCE:
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EXECUTIVE SUMMARY

The traditional de-icing approach to winter highway maintenance, utilizing sand and salt¹, has been used in Connecticut for at least 35 years. De-icing is a strategy by which ice and/or compacted snow is removed from the roadway by either a chemical or mechanical means or both. These treatments are typically applied at a later stage of a winter storm and continued past the end of the storm.

Over the last decade, a large number of transportation agencies throughout the United States have turned their attention to improvements in winter highway maintenance operations to accomplish three critical goals: reducing costs, increasing safety and minimizing environmental impacts. In particular, the use of sand as an abrasive in winter highway maintenance is being reduced or eliminated in many jurisdictions. Sand has potentially negative human health impacts, limited traction at higher traffic volumes, and requires significant effort and cost to collect and dispose of in the spring season. Anti-icing is a non-mechanical process by which a chemical, usually salt brine², is applied to a roadway prior to or very early in a winter storm event. Pre-wetting is the process of mixing the salt or abrasives with a liquid chemical (usually salt brine or water) preceding application on-road. This mixing initiates the liquefaction or dissolving of the salt. Pre-wetting reduces the amount of bouncing and scattering that takes place when the material hits the roadway, thus reducing waste.

Case studies indicate that a coordinated management system based on quality weather data (including local forecasts, and in particular utilizing road weather information systems and forecasts, as opposed to atmospheric forecasts) and centered on a philosophy of anti-icing (including use of liquids such as salt brine and pre-wetting) can result in many positive winter highway maintenance benefits.

The case studies show that a shift in overall philosophy of winter maintenance from de-icing to anti-icing can result in almost complete elimination of sand and some increase in the use of salt. The monetary savings will most likely accrue from a significant reduction in spring clean-up. Safer road conditions were reported. No negative concerns about this transition in philosophy were raised by any individual interviewed for this study. Although salt has some negative environmental consequences associated with its use and is a concern of the Environmental Protection Agency (EPA), the elimination of or significant reduction in the use of sand will have positive environmental and potentially health benefits. Interviewees emphasized the need for a coordinated management system to maximize benefits, including new technology and equipment, increased information and communication systems, and continuous quality improvement.

¹ "Salt" used alone refers to sodium chloride (NaCl) unless otherwise specified.

² "Salt brine" refers to brine made with sodium chloride (NaCl), unless otherwise specified. NaCl is most commonly used in creating salt brine, but its use becomes ineffective at temperatures below 15°F. The use of salt brine at lower temperatures requires the use of salts other than NaCl. Furthermore, an adequate water supply is needed for any brine production.

The following actions are suggested for consideration by winter highway maintenance decision makers in Connecticut:

1. Implement the improved winter maintenance procedures being used extensively in other states and procure the modern equipment required to do so.
2. Implement variable application of materials by local area to increase efficiency in terms of material use; this will require the expanded use of advanced weather information systems and decision support systems.
3. Utilize basic education programs, the Connecticut Local Technology Assistance Program, coordination with police and other critical stakeholders, and the media, to achieve culture changes for the public and state highway maintenance crews.
4. Continually seek to improve winter maintenance operations by monitoring advances in procedures, materials, and technologies, both nationally and internationally.

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IMPROVING WINTER HIGHWAY MAINTENANCE:
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I: INTRODUCTION

Recently, many transportation agencies in the United States and Canada have been turning their attention to improving winter highway maintenance operations. This is because the two primary materials traditionally used in winter highway operations, sand and salt³ (NaCl), both have negative consequences, including environmental impacts. Many chemical alternatives to sand and salt have been investigated, but for the most part, are too costly for widespread implementation. Salt is corrosive and can cause problems with structural portions of the highway. It also can contaminate surface waters and drinking water supplies and damage plants. It builds up in the environment and there is evidence that some fresh water is locally becoming saline. However, sand also has serious environmental impacts including the sedimentation of waterways such as ponds and creeks. Of late, increasing attention to the significant health concerns, cost, safety, and clean-up costs of sand has motivated many agencies to move to a salt-preferred winter maintenance strategy.

Highway maintenance evolves over time and Connecticut recognizes the need to evaluate current procedures and identify possible areas for change. Furthermore, Connecticut, while using more sand than neighboring states, recognizes that other agencies have accrued benefits from changing winter maintenance procedures. Although, winter maintenance solutions involve equipment, management systems and materials, concern over the use of sand was the primary motivation of the Connecticut Department of Transportation (ConnDOT) in initiating this study with the Connecticut Academy of Science and Engineering.

The overall goal of this project is to provide suggestions to the State of Connecticut and to identify how improvements could be achieved in winter highway maintenance in Connecticut. These maintenance improvements should result in clearer highways and increased safety and/or reduced costs through changes of or reduction in materials used, reduced labor and equipment costs or efficiency improvements.

This report will present several case studies from other states and agencies to determine what alternatives Connecticut could employ to improve its overall winter highway operations, given the conditions that exist. The intention is to consider not just alternative chemicals and technologies, but also the overall winter maintenance system. This includes equipment, personnel, the decision-making process and data collection tools. To improve the current winter maintenance system in Connecticut with respect to safety, overall road conditions, cost and environmental impacts while reducing the use of sand and salt will require an integrated, system-wide solution. Preliminary research indicates that other states have found ways to overcome these challenges and to improve the overall effectiveness of their winter maintenance operations.

There are different processes and technologies that can be used to improve winter maintenance systems. This introductory section provides a brief definition of these methods as a foundation for understanding the case studies presented in subsequent chapters.

³ "Salt" used alone refers to sodium chloride (NaCl) unless otherwise specified.

Procedures

Three procedures are used commonly and merit definition here: anti-icing, de-icing and pre-wetting. Note that exact definitions vary between agencies and that these general descriptions are intended to simply establish the foundation for the remainder of the report.

Anti-icing is a non-mechanical process by which a liquid chemical, usually salt brine⁴, is applied to a roadway prior to or very early in a winter storm event. The chemical is applied to prevent bonding of snow and ice to the pavement surface by lowering the freezing point at which this occurs (Blackburn et al. 2004). It is intended to substantially reduce the amount of effort and material needed to achieve desirable road surface conditions during a winter storm. Salt brine or other chemicals such as calcium chloride (CaCl₂) or magnesium chloride (MgCl₂) are common materials used in anti-icing. In many cases, calcium chloride or magnesium chloride is used at colder temperatures (lower than the freezing point of the salt brine solution).

De-icing is a strategy by which ice and/or compacted snow is removed from the roadway by either a chemical or mechanical means or a combination of the two. This includes chemical treatments, such as salt, which are applied later in a winter storm and continued past the end of the storm. De-icing generally requires more materials and effort than anti-icing to achieve the same desirable road surface condition (Blackburn et al. 2004).

Pre-wetting is the process by which a liquid chemical (usually salt brine or water) is added to the salt prior to application to the road. This mixing pre-activates the salt to begin de-icing much faster than non-pre-wetted salt in its solid state (Environment Canada, 2005). Pre-wetting can occur at different points in the application process and different equipment options are used on the trucks. Pre-wetting reduces the amount of bouncing and scattering that takes place when the material hits the roadway. The city of Toronto's Department of Transportation Services states that application of solid crystal salt to the roadway can result in up to 40% of the material being lost in ditches and gutters (Environment Canada, 2005). They also found that pre-wetting reduces the amount of salt needed by 10-20%.

Materials

In addition to sand and salt, three other categories of materials used in winter highway maintenance are defined in this section: salt brine, alternative salts for very cold temperatures and alternative chemicals.

Salt brine is a liquid solution of salt, most commonly sodium chloride, and water. Salt brine is relatively commonly used by transportation agencies. In a liquid brine solution, the salt has already been activated, which means that upon contact with the road surface, it is already working to melt snow and ice. A high-speed brine stream is a delivery method which may differ from pre-wetting applications in the mixture and application techniques. In the use of brine, salt is not mixed with water immediately prior to application as it is in pre-wetting, but rather mixed, in most cases, at a central facility, where it is then loaded into a truck equipped with a tank. The trucks are outfitted with spray nozzles that dispense the brine on the roadway. Brine streams are often used as an anti-icing measure. In some locations, large tanker trucks

⁴ Salt brine" refers to brine made with sodium chloride (NaCl), unless otherwise specified.

are used in this process. ConnDOT conducted a study in the early 1980s (Kasinkas, 1982) and concluded that a definite savings can be realized through the use of the high-speed brine jets.

Other salts have been explored by different states and countries. Magnesium chloride and calcium chloride are commonly used for both anti-icing and de-icing because they are effective at lower temperatures, where sodium chloride does not work. Colorado, for example, makes use of two forms of magnesium chloride. One form is used in temperatures above 16°F and the other used in temperatures below 16°F. The form of magnesium chloride that is used for the lower temperature range is combined with a corn by-product, which lowers the freezing point of water. Both forms are reported to have little or no negative environmental impacts. Henault (2005) reports that the use of both calcium magnesium acetate (CMA) and potassium acetate (KA) are viable alternatives to traditional salt. The negative watershed ecosystem and drinking water impacts are significantly reduced when these two alternatives are used; however, they are considerably more expensive than traditional salt.

Other *chemical alternatives* make use of corn distillers' by-products as anti-icing and de-icing agents. These leftover by-products are produced from the distillation of corn-based products once ethanol has been extracted after fermentation. The manufacturers of these products claim they are cost effective, non-corrosive and environmentally friendly solutions (Morris, 2005; Magic Minus Zero™, 2005; Ice B'Gone®, 2005).

Management Plans

Several states and agencies have implemented different management plans to try to reduce the amount of material used for snow and ice control while maintaining the desired level of road surface performance. The New Hampshire Department of Transportation (NHDOT), for example, varies its application mixtures for ice and snow control materials on a per lane mile basis depending on traffic and weather conditions. Along with these recommendations, NHDOT documents proper material spreading practices, plowing operations and special attention for bridges. NHDOT also has a program which evaluates requests from local governing bodies for reduced salt or salt-free winter operations (New Hampshire Department of Transportation, 2005).

Toronto has implemented a Salt Management Plan (SMP) to reduce and regulate overall material usage (Environment Canada, 2005). Salt Management Plans are now in use nationwide in Canada. All provincial highway departments, large municipalities and county highway/road departments, in cooperation with Environment Canada⁵ and The Transportation Association of Canada, have developed SMPs and are operating under their winter maintenance plans accordingly.

Improved Weather Information Systems and Forecasts

The number of road weather information systems and traditional weather stations has been increasing in most states. Even though the resolution of digital forecasts from the National

⁵ The Department of the Environment, also referred to as Environment Canada, is the department of the government of Canada with responsibility for coordinating environmental policies and programs as well as preserving and enhancing the natural environment and conservation of wildlife. Environment Canada is the lead department within the federal government when it comes to cleaning up hazardous waste and oil spills. The department is also responsible for meteorology.

Weather Service has been increasing, many agencies have turned to private services to provide a detailed local forecast. Improved forecasts can play a role in reduction of winter maintenance materials by decreasing uncertainty and allowing for different maintenance strategies to be applied in different local areas. The FHWA is developing an expert system-based decision support system program called MDSS, or Maintenance Decision Support System (http://www.rap.ucar.edu/projects/rdwx_mdss/index.html), which recommends a road-specific treatment plan. The recommendations are based on weather forecasts, transportation network information and historic data.

II: WINTER HIGHWAY MAINTENANCE IN CONNECTICUT

The reduction of sand usage in Connecticut winter highway maintenance operations was a primary motivation for this study. It has been widely suggested that sand has little, if any, relative effect in terms of increasing the friction between the pavement and tires on high-speed roadways. This is due in part to traffic pushing and blowing sand from the travel lanes, as well as a scattering effect upon the sand's impact with the roadway. In high-volume, high-speed locations, the first few passing vehicles after application can cause most of the sand to be swept from the travel lane. The clean-up of sand after the winter season in Connecticut is also quite a substantial project, which includes sweeping, cleaning catch basins and dredging ponds and small bodies of water nearby and downstream of highways. There are also air quality implications with the use of sand. The United States Occupational Safety & Health Administration (OSHA) has published documentation linking increased breathing and lung health complications such as silicosis with the crystalline silica dust that can be generated from working with sand and other construction materials containing quartz. "Most crystalline silica comes in the form of quartz. Common sand can be as much as 100% quartz." (OSHA, 2005)

In addition to sand, ConnDOT uses salt in winter maintenance as a means of de-icing. Several detrimental environmental impacts have been linked to salt use. Water quality and surrounding vegetation suffer from repeated exposure to the compound. Salt is also corrosive to steel, making its use on bridge decks increasingly unfavorable. While use of salt may be necessary, it is generally accepted that efforts to minimize the amount used are essential and that the technologies and new application procedures exist to accomplish this goal.

Harsh winter weather combined with high traffic levels throughout numerous different microclimates in the relatively small state of Connecticut make development of optimal strategies for winter maintenance challenging. Furthermore, in addition to ConnDOT, there are 169 towns that are each responsible for local road winter maintenance. There is widespread agreement that the state needs cost-effective and high-efficiency snow and ice control along its roads and highways. In general, ConnDOT uses a single, statewide standard 7:2 sand/salt mixture for use on roadways. Some towns deviate from this standard. Also, ConnDOT uses only salt on the state's expressways/limited-access highways, and follows up later in a storm with the application of its standard sand/salt mixture on an as needed basis. Certainly, sand may be needed on snow pack to provide traction on less traveled roads, but this ratio may result in the overuse of sand in other situations.

Connecticut's microclimates make the use of this standard sand/salt ratio less effective in certain areas of the state than in others. There are 12 permanent surface temperature monitoring stations in the state. ConnDOT subscribes to a private service for road weather information in eight state zones. Decision makers for winter operations use the stations in Newington and Bridgeport, and sometimes a third in emergency situations, as these locations are considered the population centers of the state. They also represent the areas within the state with the highest levels of traffic. The key field variable used to determine when de-icing and/or sanding are necessary is the surface temperature of the pavement. The local supervisors of the 169 towns in

Connecticut make decisions for their own winter operations based on their local conditions or, in some cases, based on information provided by ConnDOT.

The state and local deployment of winter maintenance de-icing fleets represents a complex system. Many areas of the state have very congested traffic networks which inhibit the necessary winter maintenance operations. Although many states use pre-wetting routinely, ConnDOT does very little pre-wetting. This is due in part to equipment limitations, as only 28 of the 632 ConnDOT trucks are equipped with pre-wetting equipment. Connecticut uses very limited salt brine application, also due to equipment limitations. Currently, ConnDOT has salt brine capabilities at only 3 of its 32 maintenance garages, and they utilize 88 salt shed storage facilities that are located throughout the state. If the infrastructure for pre-wetting and production/application of salt brine were more available in Connecticut, it is likely that the amount of sand could be reduced significantly.

ADVANCING WINTER MAINTENANCE IN CONNECTICUT

The alternative methods defined in Chapter 1 are all known to ConnDOT and there is an overall intention to evaluate and use some of these options to improve winter maintenance systems. Indeed, ConnDOT Highway District 2 tested anti-icing procedures during the 2005-2006 winter season. However, Connecticut faces some challenges in optimizing and improving its winter maintenance operations and material usage that limit the widespread changes needed to accomplish reduced sand and salt usage. These limitations relate to personnel, equipment, climate and community.

Personnel

It is the conventional belief that the 7:2 sand/salt mixture currently used is adequate for winter maintenance. Most of Connecticut's winter maintenance workers have been trained to use this standard, which means any change would require retraining for all of those involved. Use of different mixtures at different times would require new decision-making processes and different procedures. This perceived barrier to change was not found to be significant in the case studies undertaken for this project.

Equipment

Because the same 7:2 sand/salt standard has been used for a relatively long period of time, changes are needed due to equipment limitations. With different mixtures or use of brine, new or modified trucks would be required. This represents a significant cost when considered for statewide implementation. Furthermore, since many garages, particularly in rural areas, use well water, they will not have the water capacity necessary to make brine.

Climate

There is significant variability in road surface temperature from area to area that reflects the state's many microclimates. Given the limited number of weather and surface monitoring stations in the state, it is difficult to determine if one local area might need more attention than another because of different conditions resulting from microclimate variations. Many agencies have to face the challenge of microclimates. This limitation does not directly affect the decision to use sand, salt or a combination of both, but it does mean more weather and road weather

data stations and systems are needed. Use of variable mixes from area to area and equipment that can change application rates along the road length are key ways to overcome this barrier.

Community

There are believed to be perceived psychological limitations within the community and motoring public. It was not uncommon for this to be the case before change was implemented in the case studies used in this report. The traditional use of sand, particularly the red sand often used in Connecticut, is viewed by the public as a sign that roads are safe. This may create a false sense of security among motorists. When weather is unfavorable, it is believed that the public wants to see sand on the road surface. Discontinuing the use of sand could create some unwarranted safety concerns with motorists, as traditional salts and other alternatives are not readily "seen." Furthermore, in a rather densely populated state such as Connecticut, officials worry that use of tanker trucks for the application of brine might result in significant public concern that "chemicals" were being spilled on the highways. There is no reason to believe that Connecticut residents are more alarmist than motorists in other states, so this concern may be overstated.

CONNECTICUT WINTER MAINTENANCE STRENGTHS

While limitations to the development of a completely new management system for winter maintenance do exist, Connecticut also has strengths when it comes to winter maintenance. For example, the salt storage sheds at the Connecticut maintenance garages are state of the art. The small size of the state itself might also be a strength, as a limited number of new technological devices such as weather stations or special trucks could be purchased and deployed statewide as needed. New truck systems as well as new application procedures and materials have been piloted in Connecticut recently. These include the following:

- Districts 2 and 3 tested a brine system, using two brine trucks in each district.
- District 2 experimented with a liquid product (Ice B'Gone®) that is used to pre-wet salt in a ratio of 8 gallons to 1 ton of salt; this pre-mixed product is composed of magnesium chloride and a carbohydrate-based material that reportedly lowers the freezing point of water, reduces the amount of salt required and has the added benefit of reducing corrosion.
- District 3 has used a standard ConnDOT sand/salt mixture that was pre-wetted with salt brine.

An additional strength is the decision, already made by ConnDOT, that all new trucks will be purchased with pre-wetting equipment that will facilitate current practices and ensure future flexibility.

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III: CASE STUDIES SITE SELECTION AND SUMMARY

The overall objective of this project was to evaluate methods that might improve the efficiency and effectiveness of winter highway maintenance in Connecticut. The study approach was developed in consultation with the Study Committee during its first meeting in the early summer of 2005. The group developed a consensus that the best way to identify potential changes and future directions for Connecticut was by performing case studies or interviews with several other agencies. In this way, it would be possible to consider not only the technical merit of different techniques but also to inquire about the management, data requirements, public relations, personnel management and training aspects of making improvements in the overall winter highway maintenance system. The Study Committee indicated that some agencies in other states had started experimenting with different systems more than a decade ago. Therefore, not only expert opinions could be gathered, but also measures of effectiveness and improvement.

The study research team developed a questionnaire with the input of the Study Committee (Appendix A). The case studies were chosen based on several criteria. It was considered desirable to speak with agencies on both state and local levels. A balance of urban and rural areas was sought. Both New England and non-New England areas were represented. The study research team attempted to include both agencies that had a long record of using innovative new technology in winter highway maintenance as well as those who were more recently trying to incorporate newer philosophies and technologies. While the team attempted to ensure that a range of new approaches was represented in the case studies, there were significant similarities in the approaches that agencies have found beneficial and adopted permanently.

The seven agencies selected for the case studies are listed in Table 1 and contact information can be found in Appendix B. Note that although area and population vary significantly, the average snowfall is similar for all areas. Also note that based on the information in Table 1, Connecticut seems to have a reasonable number of surface monitoring systems available for use for its size.

Agency	Pop (1000s)	Area (sq. mi.)	Lane Miles	Operations Subcontracted	Number of Surface Monitoring Stations	Average Annual Snowfall (in.) ¹
McHenry County, IL	300	600	550	0%	5	32
Maine DOT	1300	35,387	8,300	2%	6	78
Idaho Trans. Dept.	1400	83,574	11,600 (previous) 12,000 (current)	0%	36	48
East Hartford, CT	50	18	300	15%	0	45
Glastonbury, CT	32	53	220	0%	0	45
Toronto, Ontario	5000	240	9,352	75%	4	51
Iowa DOT	3000	56,276	25,000	0%	53	30
Connecticut DOT	3400	5,544	11,400	0-45% ²	12	37

¹ A fair, unbiased comparison of snowfall data is difficult to obtain for any group of regions, but especially for regions such as cities, counties, and states, which vary by size. The values in this table (except for Toronto and McHenry County) are taken from the National Climatic Data Center's (www.ncdc.noaa.gov/oa/ncdc.html) 30-year average data (1971-2000) that are based on every weather station operated by the National Oceanic and Atmospheric Administration (NOAA). The number of weather stations in our study areas varied from none to over 100. This table contains the average of all weather stations in the given region. The Toronto average is taken from Environment Canada. Because NOAA station records were normalized by state, it was difficult to determine which of all the numerous Illinois NOAA weather monitoring stations were located in McHenry County. For this reason, the Marengo-Union Chamber of Commerce value was used. ALL SNOWFALL NUMBERS IN THIS TABLE SHOULD BE TREATED AS ESTIMATES.

² Contractors used only when necessary.

Table 1: Case Study Agencies

The interviews were conducted mainly by telephone, although email questionnaire replies were also accepted when this was the preference of the respondent. The Iowa case study was based

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on the workshop presentations of Iowa state personnel at the Eastern Winter Maintenance Symposium held in Hartford, Connecticut, September 7-8, 2005.

Table 2 contains a summary of agencies that use anti-icing and pre-wetting procedures. The management practices and equipment vary among case studies and even within a case study area. However, all locations use anti-icing. All use pre-wetting, except Glastonbury, where a liquid agricultural by-product is used.

Agency	Pre-wetting?	Prewetting Materials	Anti-icing?	Anti-icing Materials
McHenry County, IL	Yes	Own Blend	Yes	Blend
Maine DOT	Yes	Salt Brine, CaCl, MgCl	Yes	Salt Brine, MgCl, CaCl
Idaho Trans. Dept.	Yes	CaCl, MgCl	Yes	CaCl
East Hartford, CT	Yes	ClearLane®	Yes	Pre-wetted NaCl
Glastonbury, CT	No	N/A	Yes	ClearLane®
Toronto, Ontario	Yes	NaCl Brine	Yes	NaCl Brine
Iowa DOT	Yes	NaCl Brine	Yes	NaCl Brine
Connecticut DOT	No	N/A	No	N/A

Table 2: Summary of Prewetting and Anti-icing Practices

Direct comparison of savings is difficult, but Table 3 indicates the tons of material per lane mile for each agency reported before and after the change in maintenance philosophy. It should be understood that the number and type of snowstorms vary between locations and by year. Note that a direct comparison of material savings is not easy, especially for Idaho, as they have acquired additional lane miles and experienced changes in public demand for improved road conditions and thus changed their level of service provision. All agencies showed benefits from their changes in procedures in terms of usage of sand or abrasives per lane mile (the exact time and types of changes are outlined in the subsequent chapters). However, the change in use of salt varies considerably. Certainly, Connecticut's salt use would increase if ConnDOT adopted an anti-icing or brine-based program. However, equipment and procedures to ensure a minimal increase are possible, as illustrated by a subset of the case studies.

Agency	Current Usage				Previous Usage			
	Abrasives		NaCl		Abrasives		NaCl	
	Tons	Ton/lane-mi	Tons	Ton/lane-mi	Tons	Ton/lane-mi	Tons	Ton/lane-mi
McHenry County, IL	0	0	8k	14.5	15k	27	12k	22
Maine DOT	50k	6	80k - 105k	9.6-12.7	500k	60	75k	9
Idaho Trans. Dept.	641k ¹	53	29k ¹	3	404k ¹	34	18k ¹	1.5
East Hartford, CT	0	0	4k	14	6k	20	2k	7
Glastonbury, CT	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Toronto, Ontario	0	0	143k	15	13k	1.4	159k	17
Iowa DOT	23k ²	1	185k ²	8	100k ²	4	100k ²	4
Connecticut DOT	485k ²	43	107k ²	9	N/A	N/A	N/A	N/A

Note 1: Level of service and mileage changes in this time period attribute to increase in materials

Note 2: Based on 5 year average

Table 3: Material Usage Before and After Program Changes

IV: CASE STUDY: McHENRY COUNTY, ILLINOIS

McHenry County (approximate population 300,000), northwest of Chicago on the northern border of Illinois, maintains 550 lane miles of roadway over an area of approximately 600 square miles (Figure 1). This somewhat suburban area is well populated and experiences higher traffic volumes, and might be considered to have a similar development pattern to many areas in Connecticut. None of the county's winter maintenance is contracted to private companies. Ed Markison, assistant maintenance superintendent of McHenry County, was interviewed after the research team read an article entitled *Fixed Anti-Icing Spray Boosts Winter Maintenance* in the August 2005 issue of *Better Roads*® (Pyde, 2005). The article illustrates the advanced weather monitoring systems used by McHenry County in everyday winter operations. McHenry County began using pavement-specific weather forecasting systems by Surface Systems Incorporated (SSI) as a means of improving the efficiency of their winter operations. This system provided several detailed weather forecasting services to the county, including: atmospheric condition monitoring, frost warnings, meteorologist consultation and most importantly, a 24-hour pavement temperature prediction.

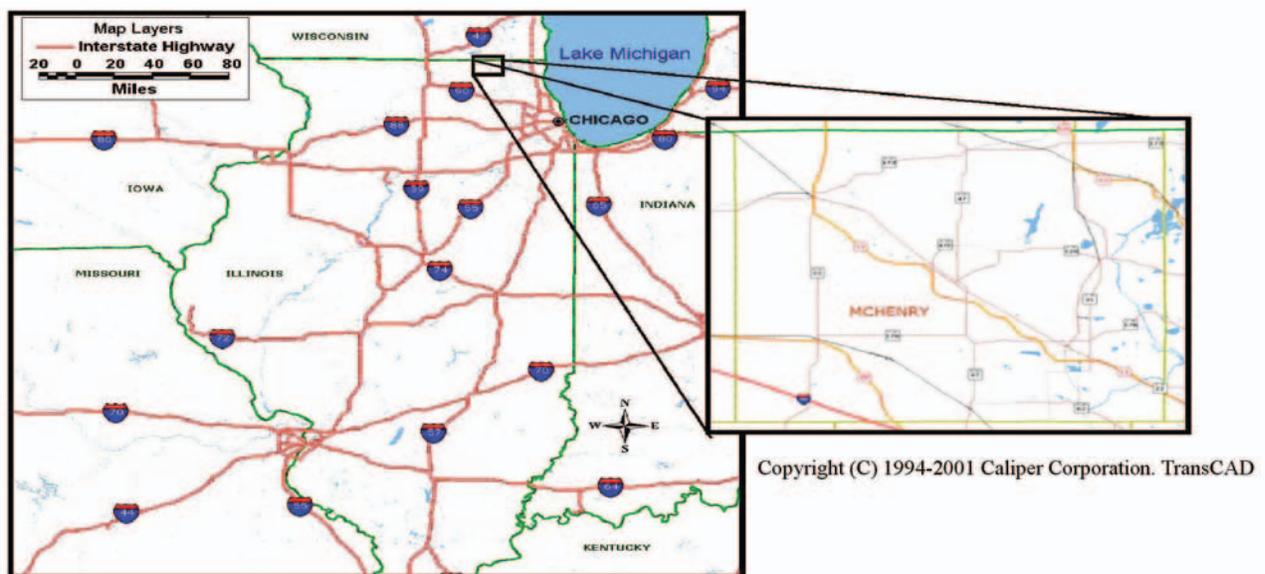


Figure 1: Location of McHenry County, Illinois

In 1993, when the population in the county was under 183,000, McHenry County began to seek ways to minimize the use of abrasives to save on material and labor costs; they have since stopped all use of abrasives. Prior to 1993, they used sand and salt mixtures and were not anti-icing or using Road Weather Information Systems (RWIS). By 2005, the population in McHenry County had increased to 300,000 and, due to this increase, McHenry County was changed from a Highway Department to a Division of Transportation by the State of Illinois.

The alternatives that were considered in the early 1990s were calcium chloride and a corn by-product material known as Liquid Corn Salt and Ice Ban®. McHenry County Division of Transportation did try a cane molasses by-product with magnesium chloride called

ClearLane®. At first, only calcium chloride was used for pre-wetting; however, after some experimentation, McHenry County developed their own blend of materials for de-icing, pre-wetting of solid materials, and anti-icing. Currently this blend contains 85% salt brine, 10% Geo-Ice® (a beet by-product that has only been added in the last few years) and 5% calcium chloride. This blend, which the county dubbed "Supermix," is generated on site using only a single blend house which the county constructed. When used in pre-wetting, the blend is mixed 10 gallons per ton in the vehicle to ensure fully wetted material. The county's continuing efforts to improve efficiency, which include ongoing training of winter operations crews, better automated equipment and the use of Supermix, have resulted in a reduction in the amount of salt used of 1,000 tons per year over each the last four years (2002-2006), with current salt use being approximately 8,000 tons per year. Over time, the county has also accrued savings with other materials, including calcium chloride. The county was using 22,521 gallons of calcium chloride during the 2003-2004 winter season and during the 2004-2005 winter season was able to reduce this amount to 2,704 gallons. Cost savings associated with materials as well as clean-up of abrasives are also quite evident. Some of the most significant savings resulted from the fact that when the use of abrasives was eliminated, no clean-up was required. The county has plans to incorporate additional anti-icing tankers in its fleet in order to expand its anti-icing activities.

Since the Good Roads article was written in 2005, McHenry County has implemented an anti-icing program and further updated their weather forecasting system(s). In addition to the advanced SSI weather monitoring system, they are now also using a new system called Meteorlogix Weather Sentry Transportation Edition, which offers RoadCast®. RoadCast® is a new addition to Meteorlogix this year (2005-2006) and makes forecasts without the use of sensors in the road surface. Meteorlogix is a specialist weather forecasting service provided via telephone, facsimile, password-protected web page or direct to an agency's surface temperature prediction system. A full range of services are available including hourly predictions of road surface, dew point and air temperatures, road surface condition or state, precipitation type, cloud cover, wind speed and direction etc. While the details of the particular meteorological surface condition prediction systems tested by McHenry County are not specifically of interest here, it is of note that the county continually tries to improve not only their operations but their information for winter maintenance activities. McHenry County is using four selected points throughout the county (one in each corner) as surface temperature RoadCast® prediction points, a relatively large number for this small area.

In addition to advanced computerized tools, intuition is still used in decision making in McHenry County. The basic television forecast is still used as a weather monitoring tool. A strong relationship with the sheriff's department also provides timely information on specific trouble spots as they are encountered by the department's vehicles. All of these sources of information are used as a means of deciding an intelligent course of action in a winter event.

Changes in winter maintenance were implemented with the support of the county engineer, the county transportation committee and the county board. The public was informed about the anti-icing program, but no prior notice was given to inform the public that the use of abrasives had stopped. The public has not expressed any major concerns. Training for the maintenance workers was conducted very informally, with the crews learning the new techniques and materials as changes occurred. The county is proactive in trying new techniques and also in disseminating their experiences, as evidenced by articles in Better Roads© and the American Public Works Association (APWA) Reporter©.

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The case of McHenry County illustrates that both material and labor costs for winter maintenance can be significantly reduced through use of new products and new methods. Furthermore, the cooperation of decision makers and the maintenance team is essential for success.

McHenry County has made continual changes over the last decade, including proactive strategies using anti-icing and intelligent weather monitoring systems. The county has combined advanced technology and management systems with traditional knowledge and the participation of a diverse team. There is an expectation that continual improvements will be always undertaken in winter maintenance. The success of this culture in McHenry County suggests that to be effective, new programs in Connecticut should have the ability to change; equipment and facilities must be able to be used for different materials or chemicals, but also management systems must be able to incorporate the increasing volume of information from new system deployments such as road weather information systems or intelligent forecasting. In short, a system – and an expectation – of continuous improvement must ideally be established.

V: CASE STUDY: MAINE DEPARTMENT OF TRANSPORTATION

Brian Burne and Cliff Curtis of the Maine Department of Transportation (MaineDOT) were interviewed via email questionnaire and telephone for this study. MaineDOT is responsible for 8,300 lane miles of highway over 35,387 square miles (Figure 2). The population of Maine is approximately 1,275,000. MaineDOT contracts approximately 2% of its winter maintenance out to private companies. This is generally done in areas that can handle a lower level of service or that are very remote for access by MaineDOT's crews from DOT garages. Unless the crews are pre-treating (anti-icing), Maine uses weather forecasts, radar, communication from New Hampshire, and local law enforcement with the goal of calling out crews approximately one hour before a storm starts. Weather forecasts trigger anti-icing operations, but in the case of de-icing, surface conditions trigger the actual application of materials. MaineDOT uses six weather monitoring stations throughout the state.

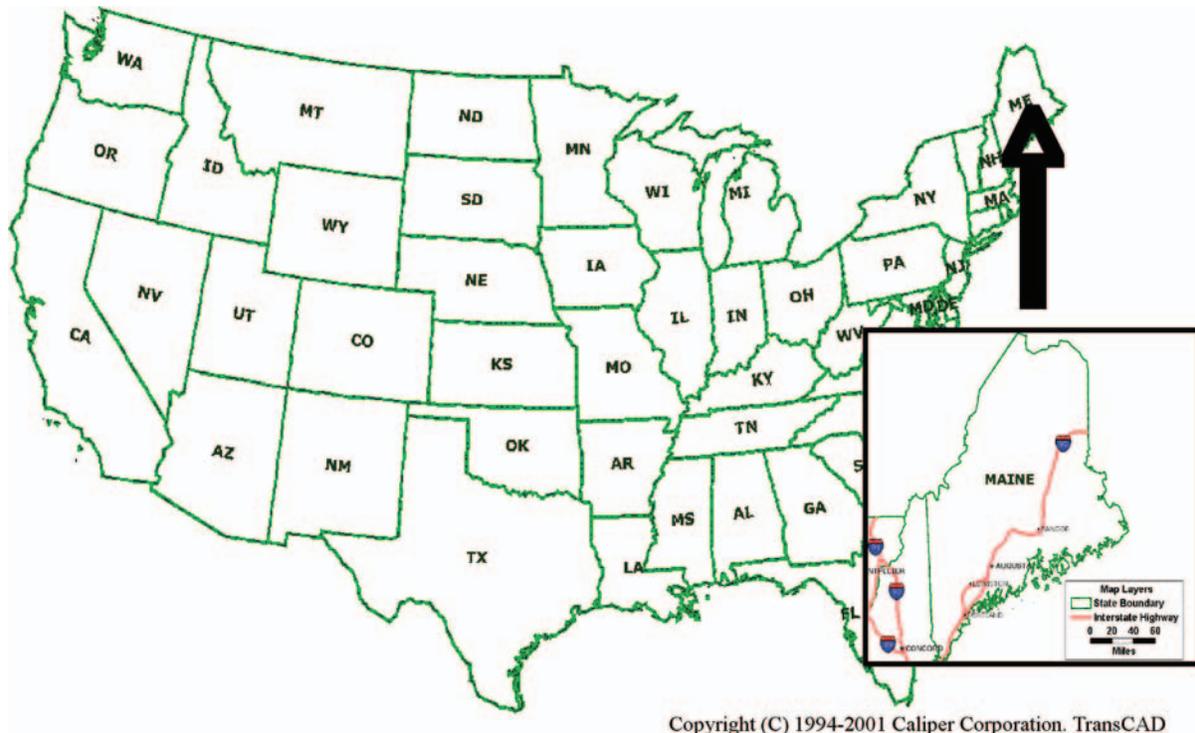


Figure 2: Location of the State of Maine

MaineDOT began to seek new ways and means to mitigate material usage in the late 1990s in the southern part of the state. Due to their success, these changes have gradually spread to the northern parts of the state. The motivation for seeking new methods was cost savings, reduction of materials used, and a desire to achieve a higher level of service on roadways in a shorter period of time during a winter weather event. Overall, a movement to anti-icing instead of solely de-icing was the focus of the improvement efforts. Maine pre-treats with salt brine

for certain select storms. Despite the success of the overall system currently implemented, MaineDOT continues to experiment with different processes and chemicals, but remains committed to an overall anti-icing philosophy as the basis for their improvements.

MaineDOT currently uses between 80,000 and 105,000 tons of salt and about 50,000 tons of abrasives annually, depending on the severity of the winter storms and weather. They use salt brine for pre-treating roads; magnesium chloride and calcium chloride for pre-wetting in colder temperatures. They encourage pre-wetting with magnesium chloride and calcium chloride when pavement temperatures are below 20°F, and encourage salt brine for pre-wetting above 20°F. They encourage the use of sand at temperatures below 15°F.

There was full management support when the anti-icing practice was introduced to the state; however, there were some environmental concerns regarding well claims. Occasional political issues involving some citizens who wanted to see more sand used on the roadways were also encountered. Training was conducted both formally and informally. Most of the maintenance crews initially objected to the changes; however, they are now strong supporters of the new practices. Maine proactively seeks to inform the public of their winter practices and justify the decreased use of sand and abrasives through the dissemination of informational materials such as those created by the Salt Institute (Appendix C). MaineDOT has a Community Services division that continually educates the local towns on anti-icing and MaineDOT practices.

MaineDOT has not conducted a comprehensive evaluation of their new programs; however, maintenance work reports used to track valuable information from crews have been used to gauge savings and improvements. Maine's salt costs have increased slightly since the switch to anti-icing, however, savings have accrued from reduced winter sand use, snow pack removal, and sand clean-up costs in the spring. Before the switch to anti-icing, MaineDOT was using about 500,000 tons of abrasives; that figure has now been reduced to approximately 50,000 tons.

Although the rural/urban development patterns and winter weather in Maine differ significantly from those in Connecticut, Maine's experience provides valuable guidance. The material savings are evident based on the approximate 90% reduction in sand usage since the switch to anti-icing. Moreover, the change in attitude of the maintenance crews illustrates that the effort to change the mindset of the winter maintenance teams is worthwhile and can occur relatively quickly once the new procedures are successful. MaineDOT's experience also demonstrates the value of having management support to drive these changes as well as the importance of having an effective mechanism to educate townships, localities and the public of new practices.

VI: CASE STUDY: CITY OF TORONTO, CANADA

The Greater Toronto Area (GTA) sits on the northwest shore of Lake Ontario (Figure 3) and encompasses approximately 11,000 lane miles (18,000 lane-kilometers) over 240 square miles (640 square kilometers) of urban and suburban development. The GTA has a population of approximately 5,000,000. The study research team interviewed Gary Welsh, general manager, transportation services for the city of Toronto, via telephone. Approximately 75% of the city's winter maintenance is contracted out to private companies and the city (upon notification) can deploy more than 120 maintenance vehicles in 5 minutes.

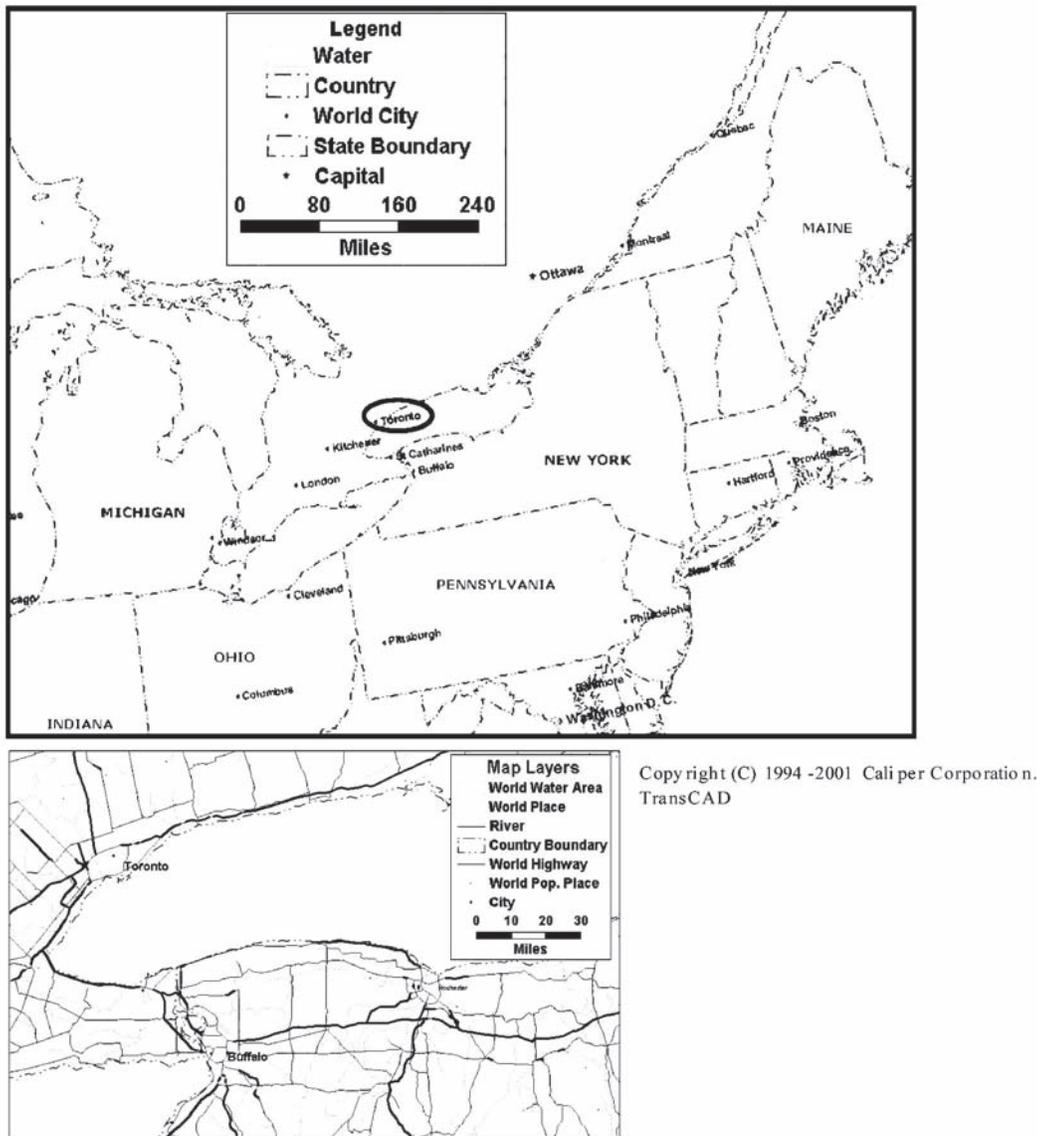


Figure 3: Location of Toronto, Ontario, Canada

Toronto utilizes weather forecasting services to inform of winter maintenance needs. There are four Road Weather Information System (RWIS) sites throughout the city which provide information including the ability to monitor the surface temperature of the pavement.

In 2001, change in Toronto's winter road maintenance system was motivated primarily by advocacy from environmental groups. As a result, city officials sought a proactive response to growing public concern about the city's salting and salt management practices. The city developed what has been termed the Toronto Salt Management Plan (Environment Canada, 2005). This plan was developed during an eight-month period and outlines all of the regulations regarding the use, storage, and application of salt. This plan includes detailed regulations, including requirements such as electronic controls on all spreading equipment and storage of salt and blends inside buildings on impermeable floors. In addition, deliveries must be made in dry weather using tarped trucks. The plan also requires that salt be pre-wetted on a truck as it is being applied to the road. This practice pre-activates the salt and prevents much of the salt from bouncing and scattering to ditches and gutters alongside the roadway. Environment Canada⁵ reports that up to 40% of solid salt material can be lost to the roadside due to the bouncing and scattering effect (Environment Canada, 2005). The city now uses 143,000 tons (130,000 metric tons) of salt annually and does not use sand at all. Before these changes the city was using 186,000–285,000 tons of salt.

Although this new salt plan is now in full implementation, some additional products for de-icing are still being explored and evaluated for effectiveness in Toronto. These exploratory materials, including agricultural by-products from sugar beets and corn, are added to other de-icing materials to lower the freezing point of water for de-icing in very cold weather.

Salt is also used for anti-icing in Toronto. At temperatures below 5°F, the city will not anti-ice because it loses effectiveness in such cold temperatures. Sometimes, however, the city will add agricultural by-products such as those mentioned above to lower the freezing point of water for anti-icing in very cold weather.

The implementation of the salt management plan did not generate much objection since it was the result of public and political forces in the first place. The plan had the complete backing of the city of Toronto, as well as Environment Canada, because it was so proactive. The city developed formal training for both city and contracted crews with the assistance of the Salt Institute, American Association of State Highway and Transportation Officials (AASHTO) and the Ontario Road Salt Management Group (ORSMG).

Limited formal evaluations have taken place. The program is deemed successful because of the 10% overall decrease in spending for winter maintenance, improved road conditions and the fact that the number of complaints received by the city from road users has decreased considerably. The city is continuously looking for ways to increase the efficiency of its winter maintenance program. Other savings and improvements include the use of 15,500 fewer tons (14,000 metric tons) of salt in the 2003-2004 season than in 2001-2002 and a 35-50% decrease in salt spread on local roads since the introduction of the Salt Management Plan.

The savings realized by the city of Toronto suggest that long-term and low-cost solutions can not only mitigate overusage of winter snow and ice control materials, but also can mitigate environmental impact and criticism from environmental advocacy groups. It was through

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the modification of its winter ice and snow control processes (Salt Management Plan) that the city was able to decrease spending and salt usage while improving the overall safety of the roadways and reducing the impact of salts and chlorides on the environment. Certainly some of the success of the plan may be attributed to education programs for workers as well as the creation of a comprehensive document, which outlines the full range of the management system that was intended for the road program.

VII: CASE STUDY: EAST HARTFORD, CONNECTICUT

The Town of East Hartford, Connecticut, which is close to the center of the state (Figure 4) maintains approximately 300 lane miles over an area of only 18 square miles. The population of this town is approximately 50,000 people. The town sits approximately 60 feet above sea level in the Connecticut River Valley. The study research team interviewed Billy Taylor, East Hartford's director of public works, via telephone. East Hartford contracts out about 15-20% of its winter

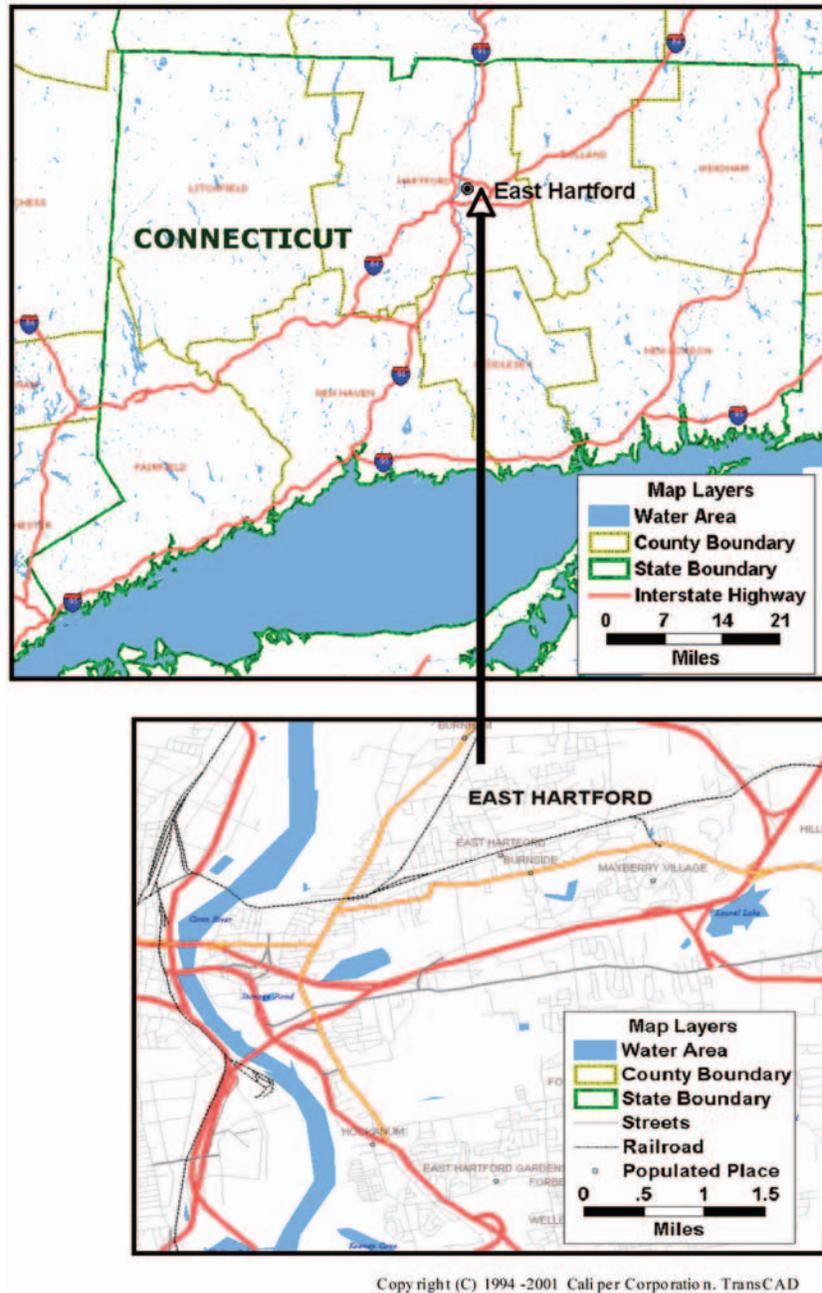


Figure 4: Location of East Hartford, Connecticut

maintenance to private companies. This occurs only during the larger storm events. For smaller storms and winter events, the work is undertaken internally by the town's crews and equipment.

East Hartford utilizes weather forecasts and simple observation as well as a weather forecasting service to send alerts via facsimile or telephone to trigger maintenance action for a winter storm or weather event.

East Hartford began reducing sand use in the winter of 2001–2002 and has since eliminated all use of sand. This change was motivated by the determination that other chemicals and materials could achieve a higher level of service and do so more effectively than sand. In addition to reduced application costs of using only salt, the elimination of sand reduced spring clean-up costs considerably. Proactive anti-icing was the only alternative measure considered during this period. No products or equipment were field tested for anti-icing. The decision to utilize anti-icing technology and eliminate sand use was based solely on an extensive review of literature. East Hartford currently uses approximately 4,000 tons of salt per year, depending on the severity of the winter. East Hartford also uses a commercial freezing point depressant chemical for anti-icing and pre-wetting of salt during winter storm events when temperatures are generally expected to be lower than freezing throughout a storm, but uses straight salt when the temperatures are generally projected to be around freezing. The town does not make or use salt brine.

When East Hartford public works officials informed the mayor's office of their interest in switching from the use of abrasives, they encountered no opposition. However, the Department of Public Works' maintenance staff did express reluctance at the idea of anti-icing alone, without the use of sand. After the first storm, the crews were convinced that the sand was not necessary for winter ice and snow control. The crews were not trained extensively in the new approach; however, they take a day each fall to calibrate the spreaders and watch training videos. The public was only notified of the new winter maintenance practices and elimination of sand via a written narrative on the town's website. Complaints from road users dropped off tremendously after the changes were implemented, and in fact the town now gets compliments on how efficiently their department takes care of the roads during winter months.

No comprehensive formal evaluation of the East Hartford program has been undertaken. The finding that improvement was achieved was reached simply by visual observation that the new methods worked better and that road surfaces were clearer. The greatest savings, although not quantified, are believed to be due to the reduction in the cost and effort of spring sand clean-up. The department is considering future changes including an upgrade of its equipment fleet and the use of salt brine for anti-icing.

Eliminating sand from the winter maintenance system has brought clearer road surfaces to East Hartford. Public and crew opposition was not significant. Minimal educational effort was used for both the public and public works crews. The changes have resulted in reduced costs. This case study is important because it illustrates that change is feasible within the public policy and public opinion atmosphere of Connecticut. Furthermore, new winter maintenance techniques and change have the potential to be accepted at both the state and local levels.

VIII: CASE STUDY: GLASTONBURY CONNECTICUT

The information in this case study was provided Eric Hood, physical services operations manager of the town of Glastonbury, Connecticut. The town is approximately 53 square miles and the agency maintains 220 miles of roadway (Figure 5). Glastonbury switched to use of ClearLane®, which is a manufactured blend of liquid magnesium chloride, a patented corrosion inhibitor and a green dye, for the 2005-2006 winter season. The product is applied as much as two hours before a storm's arrival. Plowing is not undertaken until approximately 6 inches of snow have accumulated. Because the liquid material prevents bonding between the asphalt and the snow/ice, the crews have noticed easier clean-ups.

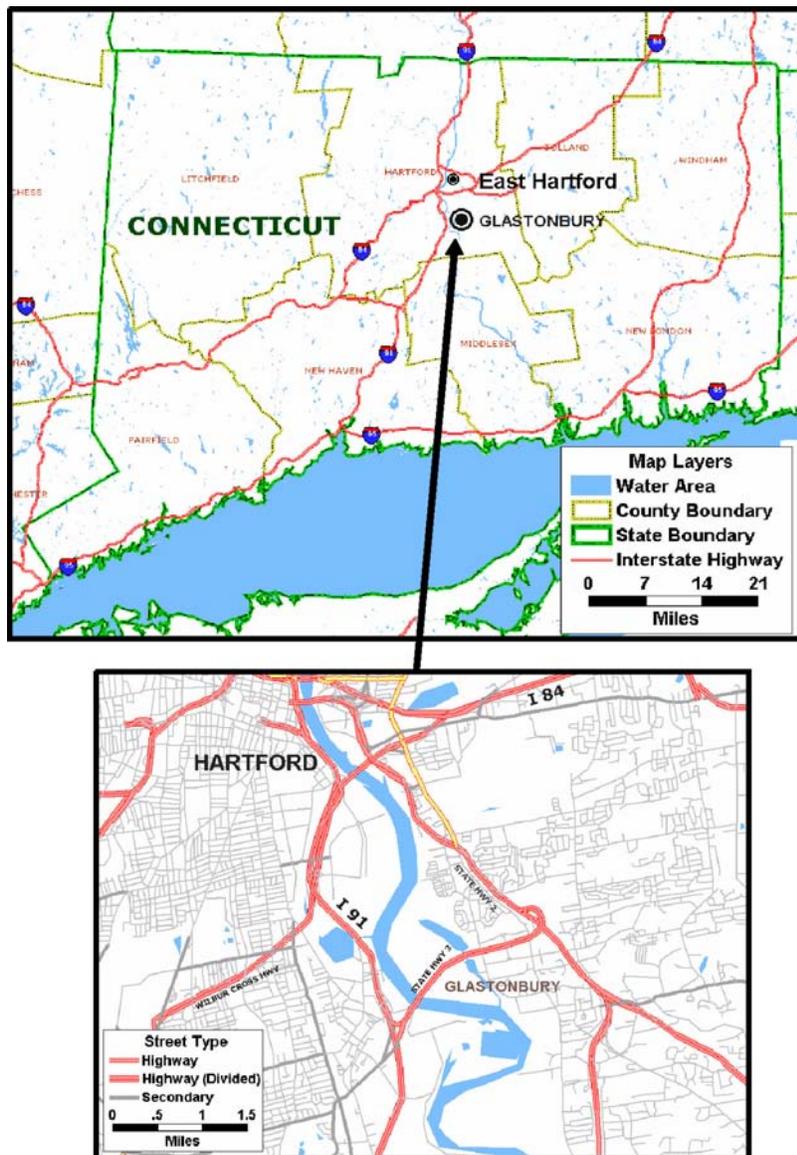


Figure 5: Location of Glastonbury, Connecticut

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The town was motivated by a desire to reduce road sand to as close to zero as possible in order to reduce catch basin clean-up and sweeping in the spring. This sweeping work had been conducted by two town-owned sweepers, as well as two sweepers provided by an outside contractor for a two-week period. They expect to eliminate the need for the contracted sweepers due to the change material usage. The town wanted to stop having their operators chasing the snow, but instead be ahead of it to improve both the operators' safety and the safety of the motoring public. The town hoped to eliminate the use of liquid calcium chloride and to use less total material to maintain the roads on the theory that less material would result in less fuel usage. While less ClearLane® material is required, it costs more per ton than either sand or salt.

Initially there was concern that if residents did not see sand, they would be concerned, or that the green dye in the product would alarm them. Instead the town has received compliments on how good the roads have been following a winter storm/event. The town hosted a "Winter Operations Round-up" event to discuss use of the material with their crews. The crew support was very positive.

Finally, changes in management procedures that reduce material use will save money. The town of Glastonbury provided the following approximate current material costs: ClearLane® - 60.18/ton, sand - \$17/cubic yard, salt - \$49-54/ton and liquid calcium chloride - \$0.88/gallon.

IX: CASE STUDY: IDAHO TRANSPORTATION DEPARTMENT

The state of Idaho stretches from the northern borders of Nevada and Utah north to the Canadian border (Figure 6). The Idaho Transportation Department (ITD) is responsible for approximately 12,000 lane miles over 83,600 square miles; none of the maintenance is contracted out. The elevation ranges from 710 feet to 12,600 feet above sea level. This wide range of elevations results in numerous different winter weather scenarios, from mild precipitation/frost-prone areas to areas subject to very dangerous winter weather where snowfall accumulations can be as much as 2 feet over the course of a night. The maintenance crews face significant challenges keeping the roads clear and safe, despite the low population density.



Figure 6: Location of State of Idaho

The study research team interviewed Bryon Breen, assistant state maintenance engineer, via telephone, to gain insight into Idaho's winter strategies. There is no single action trigger in Idaho as far as when winter maintenance will occur due to the variability of conditions throughout the state. Some areas of the state rely simply on weather forecasts, while others rely on custom pavement condition and weather forecasting services. Some areas of Idaho need routine maintenance simply to combat frost conditions. There are 36 dedicated Road Weather Information Systems (RWIS) throughout the state and ITD is contemplating adding more.

ITD began anti-icing in the mid 1990s, motivated by significant research, a desire to reduce the amount of abrasives used and a desire to provide a higher level of service for a longer period of time. In anti-icing, ITD uses liquid magnesium chloride. ITD treats some roads with very small amounts of the compound prior to a winter event or frost warning. Because only small doses are used, multiple applications are often necessary to keep the concentration high enough so that freezing does not occur during storms with a lot of precipitation. When the magnesium chloride is used as a pretreatment in frost-prone areas, it can keep the road free of frost for up to four days per application so long as no precipitation takes place.

ITD also still uses sand in a mixture with 5%-10% salt. The usages average out to approximately 397,000 tons of sand per year and 30,000 tons of salt. Solid materials are pre-wetted using both magnesium chloride and calcium chloride depending on the area of the state in question. Calcium chloride is the material of choice for the coldest regions. No salt brine is used by ITD for anti-icing, de-icing or pre-wetting. National Cooperative Highway Research Program (NCHRP) Synthesis 344 (Congier 2005) reports that the state reduced abrasives by 83% and labor hours by 63% as a result of changing to anti-icing procedures. These figures are based on a comparison of the 1997-2000 averages (following the change in winter operations) to the prior period of 1992-1997.

The only real opposition to the chemical usage comes from truck owners, whose trucks suffer corrosion caused by the magnesium chloride on the roadways. The only training of the crews was very informal and took place within each individual district of the state because each faces different challenges. As decreases in sand use took place, there were no significant concerns from the public regarding the road maintenance. No specific effort was made to encourage local agencies to adopt the new methods of snow and ice control.

There is a large range of elevation differences and microclimates throughout Idaho and, while Idaho is much larger than Connecticut, the need to allow different areas to proceed independently, given their climate situation, might be applicable here. Idaho has had to research and find different ways to cope with several different problems. The range of climate and road conditions in Idaho also illustrates that anti-icing is a flexible tool that can be used in many circumstances. While the chemicals used might vary with temperature, the proactive nature of this measure for any road, when used properly, provides significant benefit.

X: CASE STUDY: IOWA DEPARTMENT OF TRANSPORTATION

Iowa is located in the Midwest (Figure 7) and consists of 56,276 square miles of largely rural areas. The information contained in this case study was adapted from a workshop presentation by Dennis Burkheimer, Iowa Department of Transportation's (Iowa DOT) winter operation administrator, at the Eastern Winter Maintenance Symposium in September 2005, as well as from telephone interviews with Burkheimer and Jim Dowd, winter operations research analyst for Iowa DOT. The theme of the conference presentation was that improvements in snow and ice removal need not be expensive or high tech.



Figure 7: Location of State of Iowa

Iowa has more land mass than Connecticut, but is divided into only six districts. Within these districts, the state has approximately 1,200 personnel and 110 maintenance facilities. The relatively harsh winters lead to an annual highway winter maintenance budget of approximately \$35 million. Up until the mid-1990s, Iowa used a 50/50 mix of sand and salt for de-icing.

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In 1993, Iowa started its anti-icing program and today has approximately 1.6 million gallons of storage capacity statewide. Of the department's fleet of 898 snowplows, 97% are equipped with pre-wetting capabilities and 185 trucks are equipped with equipment for anti-icing operations. Trucks used for anti-icing range from 1,000 gallon slip-in units to 5,000 gallon tankers. Iowa uses salt or calcium chloride depending on the temperature. Magnesium chloride is not used by Iowa DOT due to the harsh effects on the dolomite limestone used in Iowa's concrete pavements. The injection of calcium chloride into the salt brine in different percentages to be able to reduce the temperature for successful anti-icing is being continuously researched. Iowa DOT now uses about 185,000 tons of salt annually, 8,000,000 gallons of salt brine and 23,000 tons of abrasives. They attribute cost savings to reduced clean-up of abrasives and an overall reduced number of hours of operation. Figures 8 and 9 illustrate the significant decrease in

Statewide Salt and Abrasive Use Compared with Snowfall

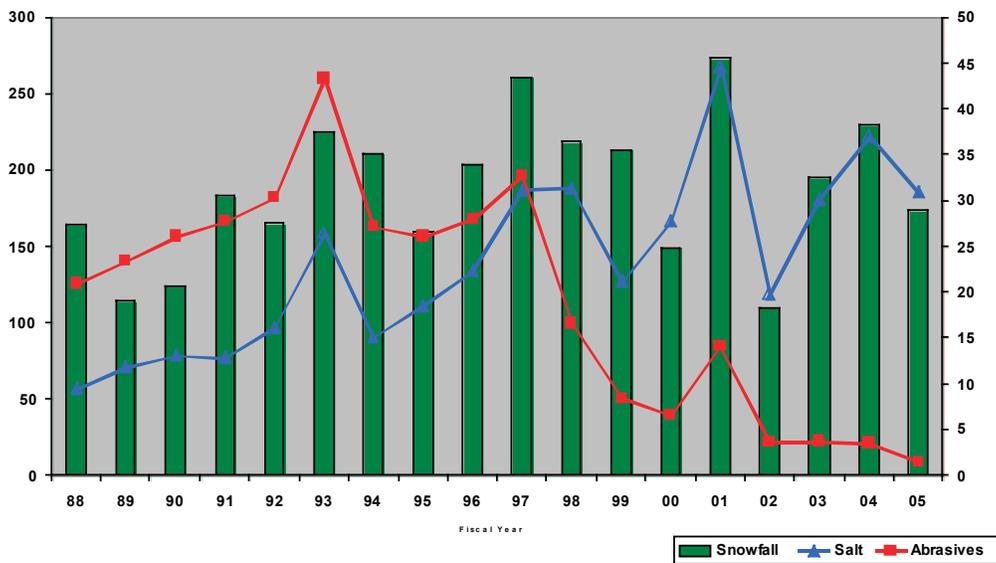


Figure 8: Iowa Material Use and Snowfall (Source: Iowa DOT, 2006)

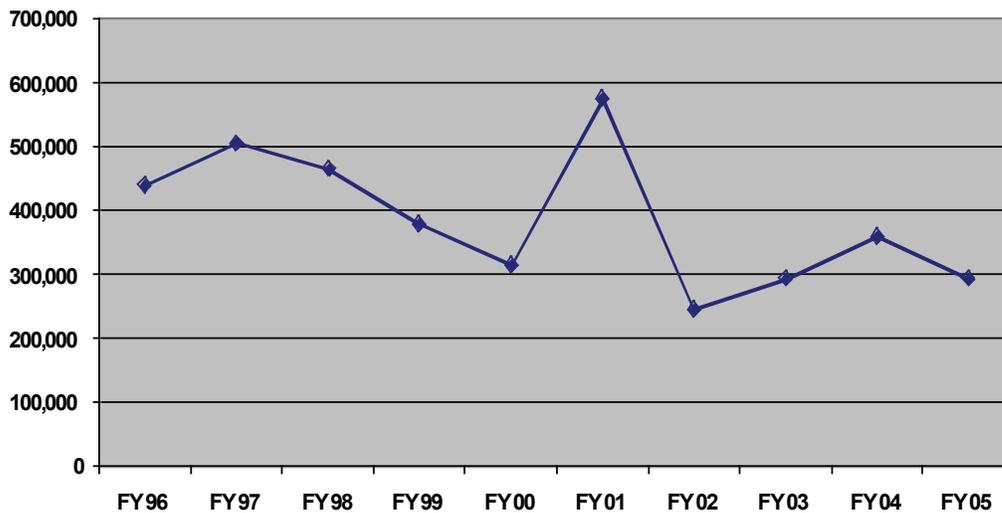


Figure 9: State Winter Maintenance Hours (Source: Iowa DOT, 2006)

abrasive use and work hours and the slight increase in salt use since the new practices were implemented. Figure 8 also illustrates how material usage varies with snowfall and from winter to winter. This greatly complicates the explicit calculation of measures of effectiveness.

At the time of the conversion, Iowa DOT issued numerous press releases and participated in numerous radio and TV shows in order to educate the public. Yet 15 years later, they still receive some questions about the use of liquids. They made a particular effort to educate the police, who in turn served as informal educators. Iowa DOT now hosts a joint expo with the cities and counties; joint crew, mechanic and supervisory training also is undertaken. While the cities and counties do vary, many of the local agencies are now also using anti-icing approaches for maintenance. The expo sponsors a "Build a Better Mousetrap" contest to encourage innovation and in-house inventions from within the city, county and state crews.

It should be stressed that early salt brine systems were very unsophisticated. Brine makers in particular can start small and adaptation to existing equipment can be accomplished in-house. For example, Iowa used relatively small slip-in tanks to start. Iowa DOT maintenance garages internally designed and constructed many units, in some cases from military surplus equipment. A large variety of spreaders and nozzle designs, including ones that are speed sensitive, have been built and experimented with. Rubber sheeting and other methods have been used to direct the distribution of material. Iowa has now moved to the use of tanker trucks, which have been successful at anti-icing over 100 lane miles before being re-filled. However, when they utilize the ability of tanker trucks to do three lanes at once, some public opposition has been noted. Bridge decks are targeted for treatment in the afternoon to avoid freezing frost the next morning. Frost-related crashes have been reduced as a result of this change in practice.

Beyond anti-icing, Iowa DOT has also moved to passive snow and ice control. Drifting of snow is a major challenge in Iowa. Snow fencing of wood, plastic, or even standing corn is used to prevent drifting of snow onto highways. This has proved very successful and very cost effective. Experimentation with a vortex generator to accelerate snow and move it away from ramp areas continues.

Iowa is also very active in promoting and assisting in the development and use of road weather information system technology. Iowa currently gathers weather information from 53 RWIS stations throughout the state. These stations however, are not used solely by Iowa DOT. Iowa DOT has granted use of the RWIS information to the cities, towns and general public by providing internet access (<http://www.dotweatherview.com>) to virtually the same weather information that is available to Iowa DOT. Having attained savings based on the changes in technology, operations and materials, Iowa DOT now sees the Maintenance Decision Support System (MDSS) as the next tool to help improve winter maintenance operations. This is in part motivated by the fact that the pavement temperature before, during and after a storm plays a large role in determining the best maintenance strategy. This information is not available from typical weather forecasts or weather stations.

XI: SYNTHESIS OF FINDINGS AND IMPLICATIONS FOR CONNECTICUT

The case studies conducted here included both state and local agencies, in both rural and urban areas. In the last decade, all of these agencies have moved to minimal sand usage and use of more salt, in many cases in the form of salt brine. The change in procedures from predominantly de-icing to anti-icing has been found to correspond with clearer and safer roads. There has been minimal, if any, negative response from maintenance crews or the public. Because salt also has negative environmental effects, efforts to optimize its use have been undertaken. These efforts include road weather information systems and forecasts (as opposed to atmospheric forecasts), and equipment that allows variable material distribution. The application rate should be varied along the length of a road or by area as well as from storm to storm. The financial investment and effort to update winter maintenance procedures in other states have created savings in operating costs in a relatively short period of time.

Connecticut's winter maintenance practices are outdated compared to neighboring states and the case studies undertaken in this project. Connecticut is using more sand than its neighbors and the associated health concerns and spring clean-up costs make this very undesirable. There is the potential that sand can be almost completely eliminated. The strong, consistent message from all of the case studies is that the state of Connecticut should consider moving to anti-icing and eliminate sand to the extent possible. The use of liquids (pre-wetting with either brine or a manufactured commercial ice and snow control product), while still presenting environmental concerns, is believed to be preferable for today's winter highway maintenance. Switching to the use of salt alone has the added benefit that trucks can make longer runs before returning to the garage (in some cases twice as long), resulting in fuel savings and improved response time. ConnDOT should consider if their rate of equipment replacement is adequate for the conversion to the suggested winter maintenance practices and, if not, consideration should be given to adopting a replacement schedule that provides for statewide implementation of such practices.

The following approaches are suggested to improve winter maintenance operations within Connecticut.

- Implement the improved winter maintenance procedures being used extensively in other states and procure the modern equipment required to do so. As of June 30, 2006, approximately 55% of ConnDOT's snow and ice equipment fleet will have surpassed its life expectancy. New and retrofitted equipment needs to include variable application rate technology to ensure minimum salt usage, especially given the EPA's concern regarding the effect of salt on groundwater and surface water quality. Based on the age and capabilities of existing equipment, a large-scale equipment replacement and retrofit is needed in order to update the state's winter maintenance procedures. This retrofit may require special financing. Other states have created dedicated special funds for this purpose, and this could be considered.
- Implement variable application of materials by local area to increase efficiency in terms of material use; this will require the expanded use of advanced weather information

systems and decision support systems to effectively manage winter maintenance operations throughout the state's many microclimates. Efficiency in terms of material reduction can be attained by using only what is necessary in a localized area. Furthermore, road weather, not the atmospheric weather as provided by most weather services, is needed. Use of specialized road weather information services could be expanded.

- Utilize basic education programs, the Connecticut Local Technology Assistance Program, coordination with police and other critical stakeholders, and the media to achieve culture changes for the public and state highway maintenance crews. There are leading agencies within Connecticut, including East Hartford, Glastonbury, Hartford, Manchester, Montville, and West Hartford, that have effectively changed their long-established winter maintenance operations with positive results. Utilizing these in-state leaders, widespread education programs for town and state crews could be pursued. The Connecticut Local Technology Assistance Program newsletter is one existing avenue for facilitating the dissemination of information. Coordination with police and other critical stakeholders is necessary. The use of media and other resources for widespread public education may be needed, but the case studies were mixed on whether this was required.
- Continually seek to improve winter maintenance operations by monitoring advances in procedures, materials, and technologies, both nationally and internationally. The use of an AASHTO training program, Anti-Icing/Road Weather Information Systems (AI/RWIS) Computer-Based Training (CBT), was recommended by respondents in several case studies.
- Connecticut has the opportunity for leadership in the field of winter highway maintenance operations if the changes in procedures are accompanied by a deliberate data collection and tracking effort before, throughout the transition period, and after, so that benefits can be precisely quantified. This data should include material use, snow information and crash information. For various understandable reasons, other agencies have not done an adequate job of this.

APPENDIX A

INTERVIEW QUESTIONS ASKED TO THE REPRESENTATIVES FOR EACH CASE STUDY

1. How many lane miles is your agency responsible for?
2. Approximately how many square miles is this area?
3. Given a winter storm event, what is your agency's trigger for maintenance action?
4. How many surface and/or weather monitoring stations does your agency use?
5. When did your agency start to seek a way to minimize sand and/or salt use?
6. What factors motivated this?
7. What alternatives did you consider?
8. Did you field-test any procedures, equipment or products?
9. On average, how many tons of NaCl does your agency currently use?
10. On average, how many tons of abrasives does your agency currently use?
11. Does your agency use pre-wetting as a mechanism for activating NaCl?
12. What materials does your agency use in pre-wetting?
13. Does your agency use NaCl brine for anti-icing or de-icing?
14. What level of management or political support did you have?
15. Did you conduct training - formal or informal? Was there concern among staff with the new changes?
16. Do you have future plans for additional changes?
17. If a state agency, how did you involve local agencies?
18. How did you evaluate new programs?
19. Did cost influence your choices and if so, what kind of savings have you incurred, if any?
20. If your agency has eliminated or partially eliminated the use of sand, what kinds of information or education (if any) was offered to the public to account for their concerns?
21. Is any percentage of your winter operations contracted to private companies? If so, what percentage? How has this influenced any of your decisions regarding methods of ice and snow control?
22. How do different temperatures influence the approach you take when a winter event takes place

APPENDIX B CONTACT INDIVIDUALS FOR CASE STUDIES

1. McHenry County, Illinois.
 - Ed Markison, Assistant Maintenance Superintendent

2. Maine Department of Transportation.
 - Brian Burne, Highway Maintenance Engineer
 - Cliff Curtis, Assistant Highway Maintenance Engineer

3. Toronto, Ontario, Canada.
 - Gary Welsh, General Manager, Transportation Services

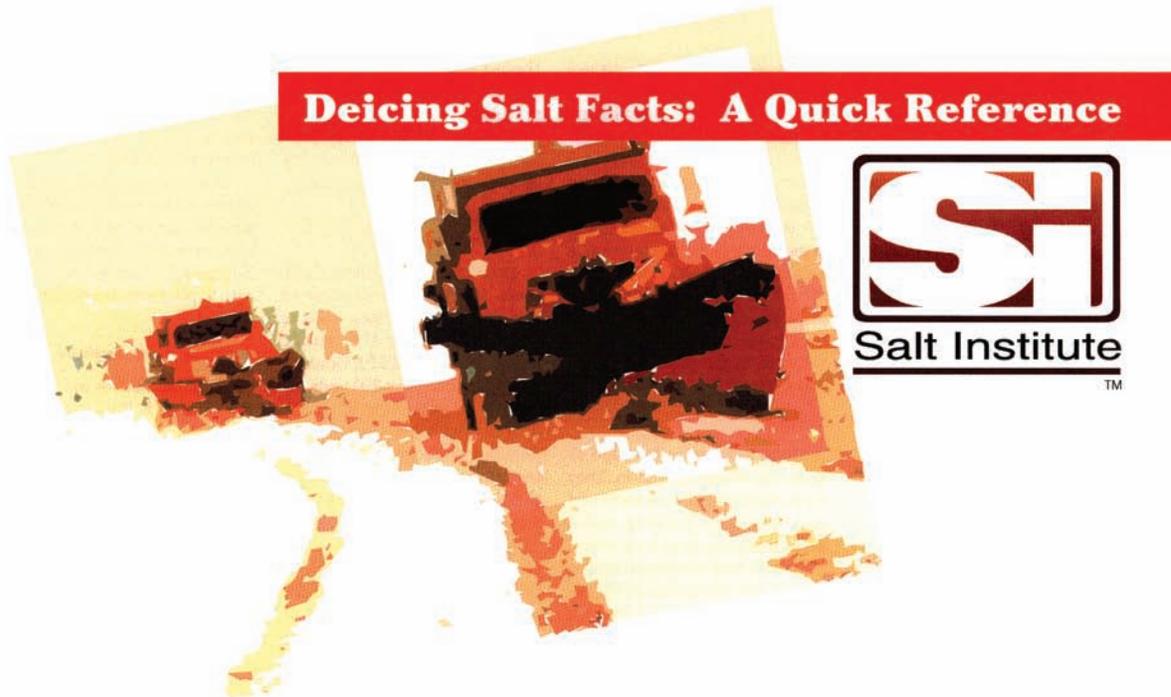
4. East Hartford, Connecticut
 - Billy Taylor, Director of Public Works

5. Idaho Transportation Department
 - Bryon Breen, Assistant State Maintenance Engineer

6. Iowa Department of Transportation
 - Dennis Burkheimer, Winter Operations Administrator
 - Jim Dowd, Winter Operations Research Analyst

7. Town of Glastonbury, Connecticut
 - Eric Hood, Physical Services Operations Manager

APPENDIX C INFORMATIONAL BROCHURES ("DE-ICING SALT FACTS") (Courtesy of the Salt Institute)



Salt was first used in the 1930s in snow and ice control. It wasn't until the sixties that its use became widespread after winter maintenance personnel learned of its effectiveness.

Today, salt is a necessary and generally accepted part of the winter environment. It provides safety and essential mobility for motorists, commercial vehicles and police, fire and other emergency vehicles. Without it, there would often be hazardous conditions and even chaos. Yet its use has brought criticism, sometimes justified in the past when it was used to excess.

Criticism is unjustified when it is used properly and does not present environmental harm. However, there are those who would like to see it banned and replaced with less effective materials for various reasons, including effects on the environment and salt's contribution to corrosion.

The purpose of this fact sheet on deicing salt is to answer some

of the questions often asked about salt use and bring together in one reference useful information about the use and storage of deicing salt.

Why Is Salt Used?

Salt is used as the principal deicer because it is the most available and most cost-effective safe deicer. It is plentiful in the earth and the sea. The primary type used is rock salt that is mined from the earth. Solar salt, which is evaporated by the sun from seawater or Great Salt Lake water, is also used. Some 10 million tons of deicing salt is used each year in the U.S. and about 3 million in Canada.

In today's highly mobile society, it is imperative to remove hazardous conditions created by snow and ice as quickly as possible and to keep roads open to guarantee essential mobility in winter. That makes a deicer necessary. Sometimes, salt is used alone when there is ice or too little snow to plow, mostly it is used in conjunction with snowplows.

Salt is used to keep snow and ice from bonding to the pavement and to allow snowplows to remove accumulations quickly and efficiently.

How Does Salt Work?

When salt is applied to ice and snow it creates a brine that has a lower freezing temperature than the surrounding ice or snow.

Salt is the ideal deicing material because

- It is readily available
- It is the least expensive deicer
- It is easy to store and handle
- It is easy to spread
- It is non-toxic and harmless to skin and clothing
- It is harmless to the environment when used and stored properly

Why Not Use Alternatives?

Alternative deicers are just not practical. Those that are as effective as salt are too expensive and have limited availability. Some have a very detrimental effect on the environment, and on pavements. According to a report on

the technical, environmental and economic aspects of highway deicing salts by the National Conference of State Legislatures, "Several alternatives to deicing salts have been investigated or tried, but they tend to be too expensive, damaging to highway structures, more toxic than deicing salts or not as effective. The alternatives include other deicing chemicals, pavement heating systems, mobile thermal deicing systems and mechanical equipment." Despite the futile search that has gone on for years for alternatives as effective, as inexpensive and as safe as salt, the search continues.

Abrasives are often cited as practical alternatives, but they have limitations. Disadvantages of abrasives are that they cannot melt snow and ice, offer only temporary traction, are covered up by new snow, large quantities and frequent applications are necessary and they must be cleaned up at great expense. It is essential to use some salt with abrasives in order to keep the abrasive stockpile from freezing.

Straight salt is more efficient and more economical. Used sensibly, it is the best means of pro-

APPENDIX C INFORMATIONAL BROCHURES (CONTINUED)

viding safe roads in winter by itself or in conjunction with plowing, depending on the situation.

Sensible Salting

Sensible Salting emphasizes getting the most out of every application of deicing salt, maintaining the safest roads possible in the most economical way while protecting the environment.

A good Sensible Salting program should include

- Personnel training
- Good equipment
- Calibration of spreaders
- Use of automatic controls
- Adequate, covered storage
- Proper maintenance around storage areas
- An awareness of safeguarding the environment by all who use salt.

It is essential that salt be spread properly, using only the amount needed to do the job at hand. However, timing is essential. Getting it down early will prevent snow and ice from bonding to the road surface. Salt application rates range from 300 pounds to 800 pounds per two-lane mile, depending on storm conditions.

Salt can be applied in a windrow or full width, but generally it should be spread no wider than the truck spreading it. Brine formed by salt and water will run to other parts of the road and be spread by traffic. Plowing operations should be timed to allow maximum melting. Salt reaction time is usually 20 to 30 minutes.

The best snow and ice control operation can be reduced to a mediocre, or even poor operation, if it doesn't have good equipment. Automatic controls are recommended for spreaders to make sure the correct amount of salt is being spread at all times. Regardless of whether automatic or manual controls are used, they should be calibrated before the snow season starts. Poorly maintained and uncalibrated controls are often responsible for excessive salt use.

Storage

Good storage facilities are vital to any winter operation. They must have sufficient capacity and good cover, preferably under roof. Stockpiles must be covered to prevent loss of material and to protect the environment. Where environmental problems are caused by salt, 80 percent of the time they are the result of poor storage. Outside stockpiles should be on impermeable pads. There must be proper drainage to keep the salt dry and protect the surrounding area, another part of environmental protection.

Types of temporary covering include tarpaulin, polyethylene, polyurethane, polypropylene or rubberized polyethylene.

The types of permanent-roofed structures for salt storage are too numerous to mention. More frequently agencies are laccessing storage needs with aesthetics and community involvement in mind, they want to be a good neighbor.

The Salt Institute maintains a list of several nationally-recognized manufacturers of buildings.

Sufficient maneuvering space for delivery trucks and loading operations should be provided.

Environmental Protection

Deicing salt can pollute if misused. If not properly used or stored, it could get into wells or groundwater. The U.S. Public Health Service and EPA Drinking Water Standards set 250 parts per million (ppm) chloride as the limit in drinking water, based on esthetics; that is, where one might begin to notice a taste. There is no recommended restriction by these agencies for sodium.

Most sources of drinking water naturally contain levels of sodium. However, most of us get very little sodium in our daily diets from water. If deicing salt is properly stored and utilized, it contributes little if any sodium to drinking water sources. Where deicing salt might contribute to the rise in sodium levels of drinking water supplies, relocation of stockpiles and sometimes changes in road drainage patterns can be made. Local wells and water supplies in the vicinity of salt storage should be monitored for sodium levels. There are many cities that have naturally high sodium levels in their water, though, where no deicing salt is ever used. Some persons on severely restricted sodium diets may be required by their physicians to drink bottled water in areas where high sodium levels are found in water supplies.

A Michigan DOT study released in December, 1993 concluded that sodium chloride provides the best deicing qualities with minimum long term environmental and economic impact. Natural scientists from the University of Michigan determined that even heavy use of roadway salt flushes through waterways with little long-term environmental impact.

Excessive salt from any source can be damaging to certain plants and trees when spray or runoff leaves sodium in the soil or on the surface of the plants. The sodium is eventually flushed from the soil

by rain. However, some agencies with plants and trees near salt runoff use gypsum to loosen the soil and hasten the sodium removal by natural flushing.

Most highway and street departments now plant salt-tolerant grasses, shrubs and trees along highways and drainage areas. However, for safety reasons they avoid planting trees close to roads.

Anti-Caking Agents

Certain additives are put into salt to keep it from caking. The most frequently used is sodium ferrocyanide, also known as Yellow Prussiate of Soda (YPS). Another is ferric ferrocyanide, also known as Prussian Blue. They are added in amounts of 50 to 100 ppm.

YPS is approved by the Food and Drug Administration as an anti-caking additive in table salt based on exhaustive tests wherein no evidence of toxicity was demonstrated at levels considerably higher than those used in highway deicing salts.

Prussian Blue is also used in household bluing, blueprints, blue-black ink and carpenter's chalk. It is also non-toxic to animal and plant life.

Corrosion

One of the major criticisms of salt is that it contributes to corrosion of metal. The basis of much of the environmental concern about salt can be traced to salt's acceleration of the corrosion of vehicles.

However, cars will rust even where deicing salt is not used, particularly in warm coastal areas and in wet climates. Automobile companies have intensified efforts to protect cars from corrosion by special dipping processes, use of aluminized waxes, zinc-rich primers, galvanized steel and greater use of other non-corrosive metals and plastics. In addition, some give the assembled cars an anti-corrosion treatment. Extended warranties by the major auto companies are now offered against rust perforation of automobiles.

However, no matter how good anti-rust methods are, car owners have a responsibility to help pro-

Severity of accidents reduced by 30%

8 times the accidents without deicing

Fastest and most efficient snow and ice removal

2

Deicing Salt Facts: A Quick Reference

APPENDIX C INFORMATIONAL BROCHURES (CONTINUED)

tect their cars from corrosion by touching up nicks and scratches, waxing frequently and washing cars regularly, even in winter.

A Utah Department of Transportation study found that corrosion is not limited to areas that use deicing salt, and that even in these areas, at least 50 percent of the corrosion is a result of factors not related to deicing salt.

Corrosion inhibitors are being tried and tested in salt. Laboratory tests seem to indicate that corrosion inhibiting salts work. Several agencies are presently using corrosion inhibiting salt.

Bridge Deck Corrosion

Bridge deck corrosion has been a problem in the snow belt areas. Research on the subject is an ongoing process. Various anti-corrosion methods have been tried or are now available. The method offering the most promise for old bridge decks is cathodic protection, where a small reverse current halts the rusting process. Epoxy-coated reinforcing bars and air-entrained concrete and/or high-density concrete are used in the construction of new deck surfaces.

Potholes

Salt has often been blamed for causing potholes. Potholes are caused by water entering the grade below the surface of the road and then freezing. This freezing cause the road surface to heave. Thawing leaves a cavity or weakened spot beneath the surface. Traffic then causes the surface to collapse into the cavity creating a pothole. Salt can cause surface spalling of poor concrete or scaling of non-air-entrained concrete. It has no bad effects on asphalt or the air-entrained concrete that is available today for road building.

Salt Bans

There have been several efforts over the years to ban the use of deicing salt. In the early seventies they were tried in Burlington, Concord, Woburn and Winchester, Massachusetts. The longest ban was in Burlington for three winters, but all bans were eventually rescinded. Two Rivers, Wisconsin, Oklahoma City and Tulsa,



Oklahoma had more recent experiences with salt bans. All were quickly rescinded.

Economic Benefits of Salting

Not everyone realizes all of salting's benefits. Consider these statistics:

A study by Paul J. Claffey, an independent consulting engineer, presented to the Highway Research Board (now Transportation Research Board), published in 1972, concluded that the roughness of road ice and slippage of wheels can result in an average one third more fuel consumption and as much as 50 percent more on just two inches of snow.

In a 1976 report, *Benefits and Costs in the Use of Salt to Deice Highways*, by The Institute for Safety Analysis (TISA), Washington, DC, using 1976 prices and rates, the use of deicing salt;

- reduces loss in wages due to lateness to work by 7.6 billion dollars,
- results in savings due to wage loss because of work absenteeism by 3 billion dollars,
- reduces production losses by 7 billion dollars,
- reduces losses in goods shipment by 600 million dollars,
- results in the saving of 370 million to 1.2 billion gallons of fuel,

- results in an economic payback for just 20 snow days of 18 to 1 (18.4 billion dollar savings against a 1 billion dollar cost, including purchase, application and damaging effects).

A study, *Accident Analysis of Ice Control Operations*, released in 1992 by Marquette University's Department of Civil and Environmental Engineering concluded that "As a winter maintenance service, de-icing pays for itself within the first 25 minutes after the first hour that salt is spread on two-lane highways. . . . Then, during the first four hours after the hour of application of salt, the direct road user benefits were \$6.50 for every \$1.00 spent on direct maintenance costs for the operation." The study found that costs related to accidents, including medical expenses, emergency services, workplace costs, travel delay, property damage, and administration and legal expenses decrease by 88 percent after application of deicing salt.

Use of salt, in conjunction with a good plowing program, is the fastest and most efficient means of snow and ice removal. The use of abrasives requires at least seven times more material to treat a given distance of roadway. Therefore, it takes seven loads and seven round trips to the loading point, compared to just one for salt, resulting in a greater use of fuel, increased manpower and more time to treat roads dur-

ing a storm. Studies by the Salt Institute have determined that a loaded salt truck, spreading at the generally accepted rate of 500 pounds per two-lane mile for general storm conditions, can treat a 22.5 mile stretch of roadway, traveling a total of 45 miles. A sand truck requires seven loads, must travel a total distance of 187 miles to treat the same section of road and that truck requires four times more fuel. In more ways than one, salt used in snow and ice control contributes to energy savings.

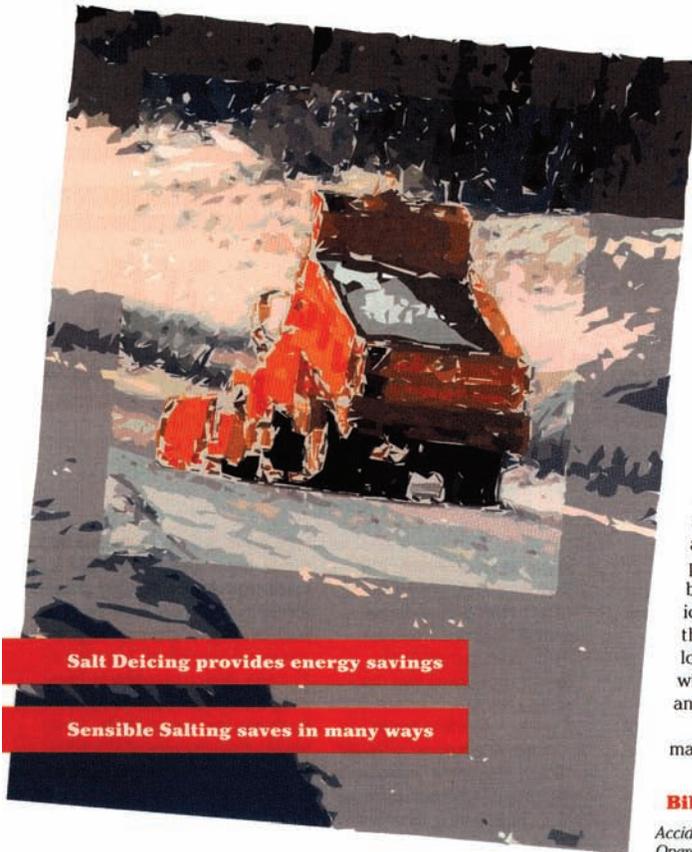
Lifesaving Benefits of Deicing Salt

The same Marquette University cited above concluded that;

- the total number of accidents is 8 times higher before deicing than after on a two-lane roadway (4.5 times higher for multi-lane freeways),
- the number of accidents involving injuries is 9 times higher before application (7 times higher for multi-lane freeways),
- the severity of accidents is reduced by 30 percent after application.

Although no specific statistics are available on the effects of storm-clogged roads on the delivery of emergency service (ambulance, fire, rescue and police), common sense tells us that response times are drastically affected by snow and ice covered streets. Consider the number of times you have heard the call go

APPENDIX C INFORMATIONAL BROCHURES (CONTINUED)



Salt Deicing provides energy savings

Sensible Salting saves in many ways

out over radio and television for volunteers with 4-wheel drive vehicles to transport medical professionals, deliver meals and medical supplies to the elderly and disabled, and otherwise fill in for needed public services affected by storms.

Summary

Salt is an essential part of the winter environment and its use is accepted by a great majority of the motoring public. It is one of the major weapons in the battle against snow and ice. It is used to provide safety and essential mobility on roads in winter. Salt is the most plentiful and most inexpensive deicer that is both efficient and safe. It is easy to handle. It is non-toxic to man and animals and will not harm the environment when properly used.

Sensible Salting requires careful application of salt, good spreading equipment, calibration of spreaders, preferably use

of automatic controls, adequate covered storage, proper maintenance around storage areas and an awareness by all who use salt of the need to protect the environment.

Much environmental criticism can be traced to concern over salt's contribution to auto corrosion. However, auto companies are producing more corrosion-resistant vehicles and there are good methods for protecting bridges, old and new, against corrosion.

Anti-caking agents used in salt are non-toxic. One agent is the same as approved by the FDA for use in table salt.

Despite what some people think, salt does not cause potholes. It has no detrimental effect on asphalt or air-entrained concrete, which is used in today's road building. Neglected bridge decks and those constructed

without protected reinforced steel are susceptible to corrosion.

A number of salt bans were put into effect in various places since the early 1970s, but all were eventually rescinded, several after the very first snow or ice storm.

Salt's benefits far outweigh any detrimental effects. The benefit-to-cost ratios is about 18 to one. Salt saves lives in reducing accidents, reducing response time to medical and other emergencies, provides energy savings by removing snow and ice quickly and reduces the size of economic losses that would otherwise mount up with snow and ice left on streets.

Sensible Salting saves in many ways.

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*Literature available from the Salt Institute

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www.saltinstitute.org/40.html
www.saltinstitute.org/snowfighting



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APPENDIX C
INFORMATIONAL BROCHURES ("SALT VS. ABRASIVES")

SALT VS ABRASIVES

FOR SNOW AND ICE CONTROL



Salt Institute

APPENDIX C INFORMATIONAL BROCHURES (CONTINUED)

INTRODUCTION

The primary purpose of any snow and ice control program is to provide safe and passable roads and streets as soon as possible during a storm and to clear them of ice and snow quickly and efficiently once the storm is over.

To the snow and ice control professional, this means providing a reasonable and *acceptable* level of service. The level of service will depend on many factors—budget, equipment, policy, politics and what motorists demand. Motorists do not expect July driving conditions in January, but they do expect reasonable safety for winter driving.

Providing an acceptable level of service with manpower and machines alone isn't always possible. It takes something else. Salt, in most instances. Although plowing is generally the first line of defense, unless the snowfall is light, spreading salt simultaneously with plowing is often done. Regardless, salting is often required as a followup operation. Many times salt is the only snowfighting weapon to use, such as with light snow accumulations and ice.

Sometimes an abrasive, such as sand or cinders, is used. But the abrasive can only provide temporary traction, something salt also does as it starts the melting action. Salt can melt snow and ice and with larger accumulations prevent it from bonding to the pavement.

It is these and other important differences in the effectiveness of salt and abrasives that this publication addresses.

ADVANTAGES OF SALT

Salt was first used to treat snow- and ice-covered roads in the mid 1940s, but its use didn't begin in earnest until the fifties. Use increased as more agencies became aware of the higher level of service salt could provide and as the North American road system expanded. Today, just about every jurisdiction in the North American

Bare pavement results where salt was sensibly applied.



snow belt is using salt to make roads safer in winter. Also, just about everywhere salt is used, it is being used prudently.

ROAD SURFACE EFFECT

Plowing can't remove all snow from roads, and what it can't remove will soon turn to hazardous hardpack bonded to the pavement by traffic if salt is not used early. With bonded hardpack, salt is essential in order to melt it or loosen it so it can be plowed off. It takes more than the salt that is mixed with abrasives to do the job. Straight salt will penetrate the hardpack for effective plowing, often with only one application. Using an abrasive does nothing but provide a temporary aid to traction, while vehicles pack the snow even harder.

What happens after the hardpack is finally gone? Salt goes into solution and is removed from the road surface in diluted runoff, leaving a quick-drying, safe pavement. Abrasives remain, some on the road, some on the shoulders and some in scuppers, drains and storm sewers, where clogging can occur. But the abrasives remaining on the road surface diminish the safety of the dry pavement by causing a skidding hazard of their own. Particularly with sand, the ball-bearing-like effect can be hazardous for turning and stopping vehicles, especially for motorcycles. Abrasives, then, have a safety-impeding aftereffect. Salt does not.

ENVIRONMENTAL CONCERNS

One concern about salt is that when salt brine is allowed to run off into lakes and ponds it could increase the chloride level, threatening marine life, or could increase the sodium level in some water supplies. The fact is, when salt is used sensibly, there are no significant increases in chloride levels, and the incidences of damage to marine life are negligible.



Storm drain clogged by abrasives.

Any increase in the sodium level of groundwater usually is temporary and decreases when diluted by rainfall. Much has been said and written about sodium in water, but the amount of sodium supplied by drinking water in relation to the total sodium in the daily diet is insignificant and usually not of concern, even for most people on sodium-restricted diets. No more than 5%, and in most instances less than 1%, of daily sodium intake comes from drinking water.

Dilution by melting snow and rainfall quickly diminishes most effects of salt on the adjacent environment. If sodium buildup in the soil is of concern, often the application of gypsum can loosen the sodium-compacted soil by replacing the sodium with calcium and allowing the sodium to leach out.

Effects of salt on environmentally sensitive areas can be avoided by directing brine runoff to less sensitive areas, salting sensibly, or, if need be, using an alternative decicer.

Abrasives can have an effect on the environment by smothering grasses and causing the silting of streams and lakes, a condition detrimental to marine and plant life and to the stream or lake itself by altering it or impeding flow.

The salt spread on streets and roads for snow and ice control seldom results in detrimental effects on the environment if spreaders are properly calibrated to regulate spreading to known rates. However, the improper storage of salt, that is, in uncovered stockpiles or on open ground without the benefit of an impermeable pad, has been primarily responsible for the relatively few cases of drinking water contamination by salt.

Snow and ice control agencies have greatly improved their salt storage, often with the help of the Salt Institute. The preferable way to store salt is under roof on an impermeable pad, such as bituminous concrete, with a proper drainage and collection system for brine

COVER PHOTO—*Bare pavement roadway remains snow-packed when*

APPENDIX C INFORMATIONAL BROCHURES (CONTINUED)

that forms from salt spilled around storage areas.

Most agencies have improved their personnel training, often with the help of the Salt Institute's Sensible Salting seminars, which emphasize calibration of spreaders, good salt storage and proper salt application for the judicious use of salt to protect the environment.

The advantages of salt over abrasives now should be evident. The chart compares the use of salt and abrasives.

SUMMARY

Salt and abrasives have different functions in snow and ice control; salt is a deicer and abrasives are merely a traction aid. Nevertheless, some agencies use only straight salt, while others use abrasives in snow and ice situations. It is not difficult to compare the effectiveness of these two snow and ice control materials.

The main concern about salt use is the potential corrosive effect on vehicles and bridge decks. However, it must not be overlooked that all abrasives are mixed with some salt to keep the abrasives from freezing.

It is important to note, however, that the auto manufacturers have made great strides in reducing susceptibility of their vehicles to rust and corrosion. After-purchase anti-corrosion treatment of autos also is helpful. Corrosion inhibiting methods are now being used in building new bridges and protecting existing ones. The knowledge and the materials to minimize salt's side effects are available, and are being used in many cases, to construct corrosion-resistant bridges and reconstruct existing bridges. Also, the corrosion process can be halted in existing bridges by cathodic protection. These protections, coupled with proper care of vehicles by owners and proper maintenance of bridge decks, will significantly diminish the corrosion factor.

With the precautionary measures available for the use of snow and ice control materials, in the final analysis, cost and effectiveness are the only meaningful factors to compare salt and abrasives. It doesn't take more than that to realize that salt is the material to use for the greatest economy, efficiency, level of service and safety for motorists.

ults where salt was applied. Note that abrasives were applied at upper right.

COMPARISON TABLE

SALT	ABRASIVE
Melts snow and ice	Can't melt snow and ice
Gives temporary traction	Gives temporary traction
Sharply reduces potential skidding period	Prolongs potential skidding period
Prevents bonding of ice and snow to pavement	Can't prevent bonding of ice and snow to pavement
Keeps snow mealy and plowable even when it's too cold for melting	Can freeze into snowpack or get covered by snow and become useless
Not as visible to motorists	More visible to motorists
Costs more to purchase	Costs less to purchase
Requires no mixing with other materials	Entails cost of mixing with some salt to prevent freezeup
Requires no cleanup	Clogs storm sewers, scuppers, drains and gutters, thereby requiring costly and lengthy cleanup operations
Doesn't interfere with road drainage	Builds up on road shoulders and interferes with proper road drainage
Contributes to corrosion if vehicles and bridges are not properly maintained or bridges are not properly constructed	Contributes to corrosion by holding moisture and from salt content
Does not damage paint or glass on vehicles	Pits windshields and chips paint when thrown about by vehicle wheels, exposing bare body metal to corrosion
Leaves road surface clear	Remains on road surface and can create ball-bearing effect on which wheels can skid after pavement is dry
Can damage some types of vegetation close to roads only when used in excess	Can smother roadside grasses when not cleaned up
Less costly in long run by requiring less material, plowing, equipment and manpower, and no cleanup	More costly in long run by requiring more material, plowing, equipment and manpower, plus extensive cleanup
More effective overall	Less effective overall



APPENDIX C INFORMATIONAL BROCHURES (CONTINUED)

WINTER MAINTENANCE LITERATURE AVAILABLE FROM THE SALT INSTITUTE

Benefits and Costs in the Use of Salt to Deice Highways, a study by Robert Brenner, Ph.D. and Jack Moshman, Ph.D. The Institute for Safety Analysis, Washington, DC, November 1976, 140 pp.

Benefits and Costs of Road Salting, a pocket-size summary of the Brenner and Moshman report. Salt Institute, 1976, 16 pp.

Calibration Chart, card for use in calibrating spreaders. One side for recording calibration figures, other side explains steps. Salt Institute, 1978, 5 x 7-inch card.

Comparative Cost Analysis, a form to compare the cost of using straight salt and an abrasive/salt mix. Salt Institute, 1982. Form CCA-82.

Deicing Salt Facts, a quick reference fact sheet covering common questions asked about deicing salt, including storage, environmental protection, corrosion and potholes. Salt Institute, 1977, 4 pp.

Facts You Should Know About Effects of Deicing Salt on the Environment, a review of National Cooperative Highway Research Program Report No. 91. Supplement to *APWA Reporter*, January 1971, 16 pp.

Highway Digest, a newsletter about highway uses of salt, published twice a year. Salt Institute, 4 pp.

Road Salt and Your Environment, consumer booklet on salt's benefits to the motoring public and its minimal environmental side effects. Salt Institute, 1971, 8 pp.

Salt and the Environment, a more detailed look at the potential effects of deicing salt, if overused, on plants, trees and grasses, and water supplies; also discusses corrosion to autos and bridge decks, damage to pavement and problems caused by other deicers. Salt Institute, 1980, 12 pp.

Salt Storage Handbook, a guide for handling and storing deicing salt, with dozens of storage ideas. Salt Institute, revised 1979, 20 pp.

Salt vs. Abrasives, a comparison of the advantages and disadvantages of salt and abrasives for snow and ice control. Salt Institute, 1985, 4 pp.

Sensible Salting Program, a brochure explaining the program and the special Sensible Salting seminar for snowfighters. Salt Institute, 1985, 6 pp.

The Snowfighter's Handbook, a manual for winter maintenance that includes planning, equipment scheduling, maintenance, special plowing and spreading problems and environmental considerations. Salt Institute, revised 1982, 20 pp.



Salt Institute

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The Salt Institute is a non-profit association supported by the world's major salt producers. Its activities include research, information and educational services, member services, government relations and field services for users of salt.

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