Maine Winter Roads:
Salt, Safety, Environment and Cost

A Report by the Margaret Chase Smith Policy Center
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The views and opinions expressed in this report are solely those of the Margaret Chase Smith Policy Center and the individual authors. They do not represent those of Maine Department of Transportation or any other individual or organization that has provided information or assistance.

Road Salt Project Key Findings and Policy Recommendations

Key Findings

This section summarizes key findings from a yearlong study of the issues and practices in winter maintenance of Maine's roads. Please see the Executive Summary and the full report for additional details. Findings are grouped according to the major sections of the report.

Maine Winter Operations

- We estimate statewide expenditures for winter road maintenance in 2008-09 (state and municipal) at $98 million, or $76 per capita.
- We estimate that 490,000 tons of rock salt were purchased in 2008-09 in Maine. This is roughly 750 pounds for every Maine resident, or 21 tons per road mile.
- Sodium chloride (rock salt) is by far the most widely used chemical for snow and ice control. Significant amounts of sand, calcium chloride, and magnesium chloride are also used.
- Maine has approximately 23,450 miles of public roads which are maintained in winter by MaineDOT (18%) and the Maine Turnpike Authority (1%), as well as 488 municipalities, ten of Maine's counties and three reservations (81%).
- Anti-icing practices (preventing the bond of snow and ice to the road surface) are being widely adopted by state agencies across the U.S., using a variety of materials. MaineDOT, MTA, and some municipalities have incorporated anti-icing practices.
- The cost of municipal winter maintenance per lane mile varies. The municipality with the highest cost has a cost three times greater than that of the municipality with the lowest cost, reflecting differences in geographic conditions, maintenance practices, levels of service, and non-road winter maintenance (e.g., sidewalks and schools).

Corrosion

- All chloride salts contribute to corrosion; none is consistently shown to cause more corrosion than another in actual field conditions.
- No risk ranking of salts is possible. Climatic conditions, methods of use, and application rates may have more influence on corrosion than their chemical composition.
- Corrosion affects different metals and alloys differently and is also influenced by environmental factors such as moisture and temperature.
- Of deicing materials, sodium chloride has the greatest impact on steel in concrete. Calcium and magnesium chlorides chemically interact with cement paste in concrete to degrade it.
- All auto manufacturers have discontinued the use of hexavalent chromium, an effective corrosion preventative coating on brake lines and electrical components.

Mobility and Safety

- Using federal guidelines for the costs of injuries and deaths, Maine crash data show a 10 year average cost of $1.5 billion dollars annually for all crashes.
- The combination of young drivers and snow-covered roads is hazardous.
    - Drivers ages 16 to 17 are involved in 9% more winter-condition crashes than their share of crashes for all road conditions.
    - Drivers ages 18-19, 20-24 and 25-34 also have higher numbers of winter-condition crashes than expected, but not as many as 16 to 17 year olds.

    - Analysis by road category shows these higher numbers of crashes are concentrated on urban townways. On state highways there are fewer winter-condition crashes involving young drivers than expected.
- Drivers ages 65 to 74 have a smaller share of crashes in winter conditions than their share of crashes under all road conditions.
- Vehicle miles traveled in Maine (except for the last two years) has been steadily increasing.
- Drivers are exposed to fewer road conditions of snow and ice than a decade ago, and this has led to improved mobility.
- There are significantly fewer crashes in Maine than a decade ago, both during winter road conditions (snow, slush, ice) and during non-winter road conditions.
- In winter months (not conditions) between 1989 and 2008, the number of crashes has not been reduced when compared to crashes during the rest of the year. This is true for state highways as well as for all other roads.
- In winter months between 1989 and 2008, there is a significant reduction in the number of fatalities on state highways. This reduction does not occur on town roads and state-aid highways. This is consistent with our finding of a statistically significant decrease in fatalities on state highways since MaineDOT's anti-icing policy was implemented. It is unknown whether the anti-icing policy is the cause of the decrease.
- Colder temperatures with snowfall lead to large increases in daily crash totals. Temperatures below 25 degrees with a daily snowfall greater than one inch contribute to 127 additional crashes beyond the "average" day of 82 crashes.
- There are fewer crashes in extremely low temperatures with snowfall above 5 inches, possibly due to the lower number of drivers in these conditions.
- Data were not available to determine the level of vehicle travel during storm events.

Environment

- All of the chemicals used on roads end up in soil and water.
- Chloride salts degrade water quality, soil quality, and ecosystems. Specific effects vary by location.
- Long-term environmental effects, such as salt-contaminated groundwater wells, continue to be found along Maine's roads.
- Some environmental effects are short term; that is, they are seasonal and largely reversible.
- Although long-term effects of salt contamination in the environment are cumulative, they may be reversible. Recovery will take many years to decades after salt inputs stop.
- New policies are needed to encourage the use of chemicals and technologies that have fewer environmental effects than those of sand and salt.

Stakeholder Input

- Corrosion effects, though not rigorously documented, are real and widely felt in the transportation sector.
- Stakeholders express that roads in Maine are better than they used to be. The people who maintain our roads in Maine do a good job. Some people perceive the level of service to be higher than necessary on some roads.
- Stakeholder groups hold differing viewpoints and focus on issues that concern their group. There is no consensus on the relative importance of the consequences of the use of road salts.

- Stakeholders recognize the need for change and seem willing to work together on this issue. Some recommendations from stakeholders include more driver education for winter conditions, greater public awareness of this issue, and re-examining levels of service priorities except on state highways.

Policy Recommendations

Safe, passable roads in winter are necessary for commerce and mobility. Public works agencies and private contractors maintain our roads. Levels of service (how often and how quickly roads are cleared) are driven by public expectations (as expressed through local and state governments) and by available technologies. Winter road maintenance is funded by taxpayers. Chloride salts are currently the most effective and economical material for maintaining safe, passable winter roads. Salts corrode vehicles, affect infrastructure, and compromise water quality; these are the additional costs of winter mobility and safety. Level of service is a balance of the tradeoffs of safety, environmental impact, and cost.

Our recommendations address safety, water quality, and costs. Not all roads or regions of the state are the same; consequently, no one treatment method or level of service can be applied to all roads or all storms. There are, however, advances in technology and practice which can lead to reduced costs and reduced salt use. These advances should be pursued where feasible. Educating the public about the tradeoffs and costs of winter road maintenance is essential – effective change in policy and practice requires the participation of practitioners, elected officials and the general public. Educating young drivers about the risks of driving in winter storms can save lives.

Materials and Practices
Goal: maintain safety while reducing salt and sand use

- Do not limit the selection of materials available to maintain winter roads.
- Continue to improve practices to reduce salt and sand use.
- Continue, and expand, anti-icing practices at all levels. This includes expanding training for municipalities and private contractors.
- Identify municipal roads that are candidates for anti-icing vs. roads that require sand or special treatment.
- Encourage research and demonstration projects involving new materials, higher road-crown heights, porous asphalt, and other promising innovations for maintaining drivable roads in the face of winter storm conditions.

Budgetary Impact
Goal: identify efficiencies

- Improve record keeping by MaineDOT regions and by municipalities on material use by roadway segment. Enhance sharing of information in order to improve efficiencies statewide.
- Undertake a thorough inventory of municipal practices and accounting to identify possible efficiency gains.
- Investigate private contractor practices and training to identify possible efficiency gains.
- Based on information gathered, expand training at municipal and state levels.

- Investigate whether additional regional cooperation at the municipal level can lower winter maintenance costs, improve service, or both.

Environmental Protection
Goal: reduce salt use

- Reduce overall salt use through improved practices, new materials and equipment, and changes in levels of service.
- Review the levels of service in municipalities to see if some roads can have reduced salt application through lower service priorities, for example residential low-speed-limit neighborhoods.
- Identify state and local roads near sensitive environments which should receive reduced salt.
- Expand monitoring of salt loading in key areas to establish baseline data on water quality.
- Expand monitoring of the environmental impacts of deicing materials in urban areas, particularly parking lots, located near sensitive environments.

Corrosion
Goal: increase public awareness of preventative measures

- Investigate current best practices on corrosion prevention and vehicle maintenance for both fleet and private vehicles.
- Develop a public awareness campaign to encourage these practices across the transport industry and among the general public.

Driver Safety
Goal: increase driver safety

- Expand winter driving education for young drivers.
- Develop public awareness strategies to educate the public on winter road conditions and safe winter driving practices.
- Consider the cost effectiveness of requiring snow tires in winter.
- Incorporate more elements of winter-condition driving into state driver training and testing.

Public Education
Goal: increase public awareness of winter practices, costs, and environmental impacts

- Develop a public-awareness campaign about safe winter driving practices based on the increased risk of crashes in certain weather conditions.
- Develop a model public information campaign that can be used by state and local governments to make the public aware of road treatments, materials, and levels of service, as well as taxpayer and environmental costs.

Executive Summary

This report presents the results of a project by a research team from the University of Maine, in cooperation with the Maine Department of Transportation (MaineDOT), to examine the use of salts, equipment and personnel to control snow and ice on winter roads in Maine. The goal is to develop a common understanding among Maine residents of the relationships of cost, materials, research, policy priorities, and consequences.

In this report, we present background information on winter road maintenance, a description of current practices and policies in Maine, and summaries of the literature on environmental effects and corrosion. We examine winter road practices in other selected states and provinces. We base our analysis of safety, mobility and costs on state- and municipal-level data. To analyze road safety and the relationship between winter weather and crashes, we examined data from all police reported crashes from 1989-2008 in Maine. We used daily weather data from five weather stations throughout the state to measure the effect of precipitation, snow and temperature on road accidents and safety. We held meetings with stakeholders and conducted individual interviews to provide input to the project and for public outreach.

The State of Maine has 23,450 miles of public roadway, more miles per person than any other New England state. As a rural state, we have a relatively high per-resident cost for transportation maintenance and infrastructure. MaineDOT maintains approximately 4150 centerline miles in winter, 18% of the total roadway, which it divides into three categories of priority. The Maine Turnpike Authority maintains 109 centerline miles. The remainder of the mileage is maintained by Maine's municipalities and counties. Maine's 488 municipalities, 10 counties, and 3 reservations have winter road maintenance responsibility for 81% of the total road mileage. We estimate that clearing winter roads last year cost Maine (MaineDOT, MTA, municipal governments) $98 million dollars, or $76 per person. Change in winter road maintenance practices may provide an opportunity for cost savings. Any changes will need to be balanced with levels of service that the public has come to expect.

By far the most widely used chemical on winter roads in Maine is rock salt (sodium chloride) due to its cost-effectiveness and ease of handling. The total purchased in the state last year amounts to roughly 750 pounds for every Maine resident, or 21 tons per road mile. The resulting clear roads contribute to high levels of safety and mobility. There are fewer crashes on all roads under all conditions than a decade ago. Still, Maine accident data show a 10-year-average annual cost of $1.5 billion dollars. The youngest drivers have a disproportionately higher share of winter-condition crashes, specifically on urban townways. Elderly drivers have a disproportionately lower share of crashes in the same conditions. The consequences of road salt use show up in water quality, vehicle corrosion, and state and municipal budgets. Environmental data show increasing levels of chloride in fresh water throughout the Northeast. Anecdotal evidence shows that vehicle corrosion is widespread and costly.

Deicing is the winter road maintenance practice familiar to most people -- plowing the roads and applying a mixture of salt and sand to break the bond of ice with the pavement, improve traction and promote melting. Anti-icing is based on prevention -- an approach that requires greater attention to road and weather conditions than deicing. Anti-icing and pre-wetting policies have been shown to result in reduced plowing time, a reduction in abrasives use, a decrease in total

chemical use, and decreased maintenance costs. Anti-icing also means that the road returns to bare pavement faster than with deicing. This reduces time lost through travel delay and damage to cars and equipment due to abrasive use. Anti-icing has been gradually adopted by most northern state transportation agencies, including MaineDOT, the Maine Turnpike Authority and some municipalities in Maine.

There are primarily five types of chemicals available in North America for snow and ice control on roads. They all lower the freezing point of water. These are sodium chloride, or salt (NaCl), calcium chloride ($CaCl_2$), magnesium chloride ($MgCl_2$), potassium acetate (KA), and calcium magnesium acetate (CMA). Most ice-melting chemicals are based on these primary ingredients. Additives from agricultural processes are used as corrosion inhibitors. Sand is commonly used for traction on roads but it has no ice melting properties.

Each year, state Departments of Transportation in northern regions spend an average of 20% of their budgets on ice and snow removal. These expenses take the form of equipment, chemicals, training, repair, workers, and planning. Maintaining clear roads benefits local businesses, interstate transport, freight carriers, emergency vehicles, and the driving public. The application of road salts is effective at maintaining clear roadways and vehicle safety. It also has consequences for the environment, vehicles, infrastructure and budgets.

We estimate that approximately 490,000 tons of road salt were purchased statewide by all entities in Maine for 2008-09. Calcium chloride has long been used as an additive to road salt at lower temperatures to lower the freezing point. Magnesium chloride shares many performance characteristics with calcium chloride including its ability to retain moisture. MaineDOT uses magnesium chloride; the Maine Turnpike Authority and many municipalities use calcium chloride. Field tests show that performance among these chemicals varies with specific conditions. Chemical choice is often a matter of cost and availability.

Most of the available environmental research on deicers is for the commonly used salt (NaCl). There is ample evidence that salt is increasing in the aquatic environment in both the short term (months) and the long term (years). Winter road maintenance is a significant source of the total chloride loading to fresh waters. Short-term effects are directly related to the seasonality of salt use, with peak levels occurring in spring and fall. Several long-term studies find evidence of an increasing chloride trend. These studies found increases of 240 to 350% over several decades. Although most chloride is exported, some unknown amount accumulates in watersheds over time. Each year ten to twenty private wells in Maine are closed because of chloride. Once contaminated by high chloride levels, surface and ground water can take decades, if not longer, to recover. It will only recover after the source of chloride contamination is eliminated. Maintaining water quality in Maine for the long term will include reducing the amount of chloride that we put into the environment.

Abundant anecdotal evidence in Maine tells us that vehicle corrosion on cars and trucks is more prevalent than a decade ago. It affects family vehicles, commercial fleets, school buses, and government-owned road equipment. Bridges are subject to corrosion from road salts through impacts on exposed steel, concrete and the steel reinforcing within concrete. All deicers increase the number of freeze-thaw cycles, accelerating deterioration of concrete and pavement.

Corrosion causes damage to exposed metals and to vehicles. Of all the consequences of road salt, it is corrosion which elicits the most concern from the public and from industry.

From an extensive review of the published literature we conclude that it is not possible to rank chloride-based (sodium, calcium, magnesium) deicers for their impacts on vehicle corrosion when taking into account real-world conditions. The National Cooperative Highway Research Program (NCHRP) indicates that while all chlorides cause corrosion in the laboratory, the variation in field conditions (climate, temperature, road surface, speed, application rates, etc.) may determine differences among the chlorides. All of the common chlorides show high impact through atmospheric corrosion to metal, with calcium and magnesium chlorides higher due to their property of retaining moisture. Modern vehicles are composed of many metals and alloys; each responds differently to different road chemicals under different conditions. At the same time, vehicle manufacturers no longer use hexavalent chromium, a highly effective anti-corrosion coating for brake lines and electrical connectors. Its use has been discontinued because it is a proven carcinogen.

Our examination of crash data in Maine indicates that there are significantly fewer crashes reported during winter road conditions (snow, slush, ice) than a decade ago. In winter months (not conditions), however, the number of crashes has not been reduced compared to crashes during the rest of the year. This is true for state highways as well as for all other roads. For state highways there is even a slightly smaller reduction in winter month crashes compared to the rest of the year. However, if we look at fatalities, there is a significant reduction in the number of people killed on state highways. Town roads and state-aid highways have not seen a similar reduction. The clear-pavement policy means drivers are exposed to fewer conditions of snow and ice, and this has led to improved mobility. People get to their destinations more quickly and they probably cancel fewer winter-time trips because of inclement weather.

Older drivers are clearly underrepresented in crashes on snow- and ice-covered roads, compared to their share of crashes during other road conditions: 65 to74 year old drivers are significantly underrepresented in winter crashes by about 26% and drivers 75 years or older, by about 47%. The reason for this may be that elderly drivers may refrain from driving when roadway conditions are more risky. However, we do not know this with assurance since we lack data on miles driven by age group under different weather conditions.

On the other hand, 16 to 17 year old drivers are significantly overrepresented in winter crashes, by about 9%. This analysis compares their involvement in winter-related crashes to their share of crashes for all road conditions. There are also higher rates of winter crashes for the 18-19, 20-24 and 25-34 age groups. It is clear that the combination of young drivers and snow-covered roads is hazardous. An analysis by roadway category shows that this higher number of crashes is concentrated on urban townways. On state highways, teen drivers are actually underrepresented with respect to winter-road accidents. This may indicate that the MaineDOT is doing a good job maintaining the state highways during snowstorms, making them safer, or that teenagers are less likely to travel on state highways in winter weather conditions.

An analysis of weather parameters that influence the number of wintertime crashes shows that the presence of colder temperatures and snowfall account for the largest increase in daily crash

totals but hold a negative relationship with monthly fatality rates. Specifically, temperatures below 25 degrees and a daily snowfall greater than one inch contribute to 127 additional crashes compared to the "average" day of 82 crashes. However, crashes decrease in extremely low temperatures and snowfall above 5 inches, probably due to the decrease in the number of drivers in these conditions. Weekend days, and months with higher traffic volumes, increase the number of crashes by 40%. Regression results show a statistically significant decrease in crashes after MaineDOT's anti-icing policy was implemented but it is unknown whether this policy is the cause of the decrease because we are not able to control factors including the demographic characteristics of drivers, changes in roadways, safety improvements on vehicles (e.g., anti-lock brakes, stability control systems) and changes in rates of impaired driving.

We examined other states' and provinces' winter road maintenance practices to learn from their experience. The State of New Hampshire has a growing population and traffic density in the southern region. During a planned expansion of Interstate 93 the state formed a Salt Reduction Working Group and developed a Salt Reduction Plan for the area. Similar in climate to Maine, but with a larger population, Minnesota takes a more high-tech approach to winter road maintenance. A well-developed network of Road Weather Information Systems and Automatic Vehicle Location Maintenance Decision Support System contribute to Minnesota DOT's liquid anti-icing program.

In 1995 Canada initiated a five-year scientific assessment of road salts. In 2001 it concluded that road salts were affecting freshwater ecosystems, soils, vegetation and wildlife and recommended them for designation as toxic substances under the *Canadian Environmental Protection Act.* A multi-stakeholder working group developed a Code of Practice to guide development of voluntary salt management plans for road authorities using more than 500 metric tons of salts per year or maintaining roads near vulnerable ecosystems. Ontario's Ministry of Transportation uses a Road Weather Information System and an Advanced Vehicle Locator system that allow for the monitoring of salt usage and application rates through a computerized mapping system. Quebec became the first province to make winter tires mandatory in 2008 for all passenger vehicles and taxis registered in Quebec.

We have shared research findings with stakeholders in Maine and incorporated their feedback into this report. Stakeholder input comes in the form of interviews, stakeholder meetings and project advisory committee meetings. Although stakeholder groups hold differing viewpoints, all recognize the need for change and appear willing to work together to examine this issue in more detail and to participate in discussions of policy options. Recommendations from stakeholders include enhanced driver education for winter conditions and re-examining levels of service priorities except on state highways. All stakeholders, and the general public, have much to gain from increased public awareness of the issues surrounding road salts in Maine.