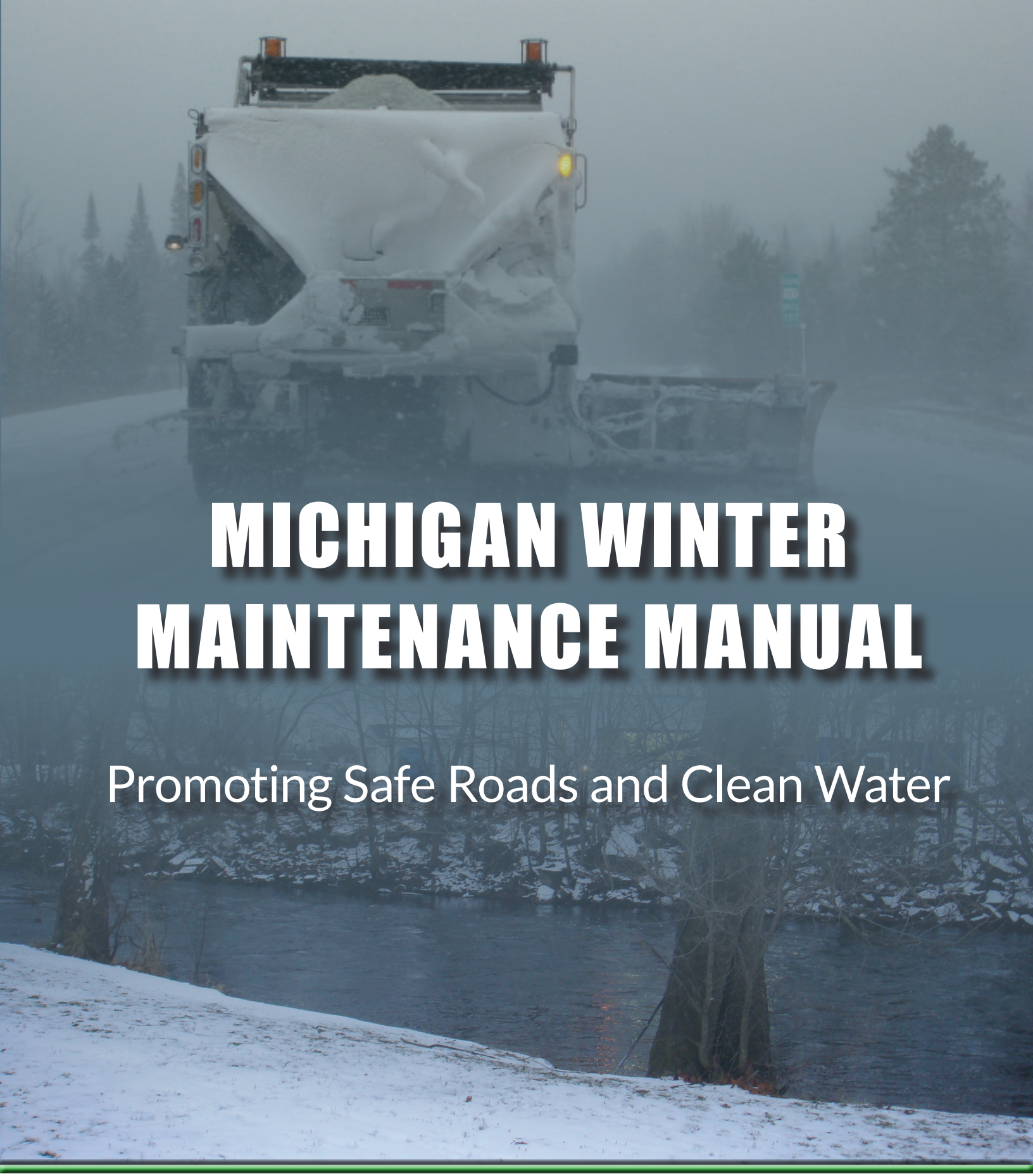


MICHIGAN WINTER MAINTENANCE MANUAL

Promoting Safe Roads and Clean Water

Applying knowledge to improve water quality
Great Lakes Regional Water Program
A Partnership of USDA NIFA & Land Grant Colleges and Universities

MICHIGAN STATE UNIVERSITY | Extension

Acknowledgments

This manual is dedicated to the protection of Michigan's natural resources and the winter maintenance professionals who have the opportunity to protect them. *Michigan Winter Maintenance Manual – Promoting Safe Roads and Clean Water* is based on the *Minnesota Snow and Ice Control Field Handbook for Snowplow Operators, Second Revision* published by the Minnesota Local Road Research Board in 2012.

Thank you to the following sponsors and participants for their valuable input in the production of this document. Final interpretation is the responsibility of the authors.

Project Funding
Great Lakes Regional Water Program This material is based upon work supported by the USDA-NIFA under award No. 2012-48691-20334

Project Management
Lois Wolfson - Specialist, Michigan State University Inst of Water Research
Faye Sleeper - Co-Director, University of Minnesota Water Resources Center
Rebecca Power - Co-Director, Great Lakes Regional Water Program
University of Wisconsin-Extension

Project Leader
Connie Fortin - President, Fortin Consulting, Inc.

Manual Authors and Manual Development
Connie Fortin, Fortin Consulting, Inc.
Nancy Mulhern, Fortin Consulting, Inc.

Extension Liaison
Carlos Garcia-Salazar - Educator, Michigan State University Extension

Publication Date
2013

Technical Expert Committee:

Sustainable Salting Solutions, LLC

Mark Cornwell, Team Leader, Sustainable Salting Solutions LLC
Dave Barr, ADC Solutions
Mark Crouch, Michigan Department of Transportation
Tim Croze, Michigan Department of Transportation
Rob Doletzky, Universities-Facilities, University of Michigan
Dave Drullinger, Michigan Department of Environmental Quality
Ron Fadoir, Oakland County Water Resources Commission
James Fountain, Knapheide Truck Equipment Company
Amy Frankmann, Michigan Nursery Landscape Association
Chuck Fritz, City of Novi MI
Matt Kapp, Michigan Farm Bureau
Wayne Kukuk, Michigan Department of Environmental Quality
Ron Lacasse, City of East Lansing MI
Mike McCann, Snow Plow Group Inc.
Robert Pigg, Michigan Department of Agriculture and Rural Development
Matt Pratt, Michigan Department of Transportation
Mary Schulz, Michigan Local Government Benchmark Consortium
Dan Sommerville, Michigan Environmental Council
Ken Stanton, Universities-Facilities, Grand Valley State University
Roger Thelen, Universities-Facilities, Michigan State University
Brian Wendling, Drain Commissioner, Saginaw County
Matt Wiktorowski, City of Novi MI
Herm Witte, Witte Lawn Maintenance

Other Contributors:

Andrew Bahrou, Department of Environmental Quality
Andy Conroy, Department of Environmental Quality
Mark DeVries, McHenry County Illinois
Matt Goddard, Department of Environmental Quality
Darryl Heide, Road Commission for Oakland County
Brad Knight, Road Commission for Oakland County
Amy Kohlhepp, Michigan Department of Environmental Quality
Dawn Roush, Michigan Department of Environmental Quality
Laura Young, Michigan State University

Production:

Michigan State University

Editing:

University of Minnesota, Water Resources Center

Contact:

Institute of Water Research, Michigan State University at
www.iwr.msu.edu/miwintermaintenance
(517) 353-3742

Table of Contents

List of Figures

Purpose of this Manual

The purpose of this manual is to help winter maintenance professionals achieve their goals of providing safe roads through sustainable winter maintenance practices and policies. As a maintenance professional involved in your organization's winter maintenance program, your daily actions are critical components of its success.

Not only are you tasked with providing continued public safety on roads, parking lots and sidewalks during winter storm events, but the choices you make can greatly affect the ability of your organization to provide these services in a cost-effective manner. The actions you take can also make the difference between adding to or reducing the amount of salt, sand and other pollutants presently entering drains, creeks, streams and lakes throughout Michigan.

The over-application of deicing materials can have a detrimental effect on surface water, groundwater and drinking water quality. Studies have also shown that the over-application of deicing materials can contribute to habitat degradation in our local creeks**,** streams, and lakes and in vegetated areas near roadways. This has a negative effect on fish and other wildlife living in these areas. The use of deicing materials is being increasingly regulated, and discharge limits are being applied under federal and state storm water regulations.

This manual is designed to provide you with Best Management Practices (BMPs) and other information that can assist you and your organization in making sound decisions around your winter maintenance duties. The goal of this manual is help you establish procedures that will maintain the desired level of service while reducing the amount of deicing materials that are being applied. It will also help your organization comply with strict federal and state storm water regulations.

We hope that reading this manual will increase your knowledge of the equipment, materials and application processes that are used in winter maintenance operations. Reviewing this manual in your organization can provide an opportunity for further discussion between you, your coworkers, supervisors and managers on how to improve efficiency, while reducing the use of de-icing materials and increasing protection of the environment.

Throughout the manual you will find environmental tips shown with a fish symbol. These tips will help you reduce environmental impacts.

Throughout the manual you will find cost-saving tips shown with a dollar symbol. These tips will allow you to maximize your efficiency and save money.

Michigan Roads: Where Economics and Environment Meet

The business of winter maintenance rests in the very capable hands of people like you.

As the industry evolves, it is important for you to stay current in your knowledge and understanding of the issues that drive winter maintenance. We are beginning to understand the serious corrosion and environmental harm caused by the deicing materials used in winter maintenance. With the advent of better equiment and alternative deicers, we have great opportunity for cost savings as well for a lessening of the environmental impacts of winter maintenance.

By following the BMPs discussed in this manual, you can both meet the needs of your customers and protect the freshwater systems that surround your roads.

The use of more sophisticated deicing materials and equipment with more flexibility may have higher cost assosiated with them up-front. These costs can be recovered, however, by reducing your salt usage and minimizing the need for some of your post-winter maintenace activities such as curb sweeping and catchbasin cleaning. These chemicals and equipment can also help improve your level of service.

By demonstrating a strong return on investment (ROI), you will increase public support for your efforts. By taking time to educate the public on your winter maintenance policy and methods, you can foster a positive and cooperative relationship with them.

In order to help public agencies be careful stewards of taxpayer dollars, the Clear Roads pooled study created an interactive tool kit that helps agencies calculate the cost/benefit ratio of selected winter maintenance technologies. This tool kit can be found on the Clear Roads website at www.clearroads.org.

There are other costs associated with the use of deicing materials that commonly are not included in most organizations' ROI assessment. These uncounted costs include repairing damage to infrastructure. Using less salt on the roadways can save all taxpayers money by reducing the corrosion of maintenance equipment, personal vehicles and bridges, and by limiting the degradation of road surfaces.

Estimates of damage to infrastructure, automobiles, vegetation, human health and the environment from deicing materials range from $803 to $3300 per ton of road salt used, according to several research reports (see figure 1 and citations below).

The True Cost of Road Salt: It Really Adds Up!

Item	Cost
Material (salt) $55/ton[1]	$55/ton
Labor and Equipment to apply salt[2]	$100/ton
Damage from use of salt[3]	$800 - $3300/ton
Total cost:	$955 - $3455/ton

Figure 1: Estimates of Costs for Using Road Salt

Sources: MDOT (2013), Vitaliano (1977) and Murray et. al (1992) as cited in a draft, "The Real Cost of Road Salt Use for Winter Maintenance in the Twin Cities Metropolitan Area of Minnesota," prepared for the Minnesota Pollution Control Agency by Carolyn Dindorf and Connie Fortin, January 21, 2013.

Figure 2: Great Lakes Drainage Area

In addition to having safe roads and reducing the immediate and long-term winter maintenance costs, your customers are also interested in protecting Michigan's lakes and rivers. As "The Great Lakes State," Michigan has an abundance of water bodies, with the Great Lakes and approximately 11,000 inland lakes, as well as streams and wetlands. These should be preserved as the valuable and irreplaceable natural resources that they are.

Lake Michigan and the other Great Lakes represent 20 percent of the world's fresh surface water. The Great Lakes, along with the rivers, channels, and lesser lakes feeding or draining them, constitute the largest surface freshwater system on Earth!

Michigan residents rely on this freshwater for personal, agricultural and business uses. Tourism is important to the state of Michigan as it is one of our leading industries. Our fresh, clean lakes and rivers attract many visitors to the state and contribute to our quality of life in many ways.

Unfortunately, chloride from road salt is entering the environment and threatening the health of Michigan's fresh water ecosystems. Salts, such as those used in winter maintenance activities, dissolve and move downhill with water (snow melt or rain) to the nearest lake, river or pond. Chloride does not settle out or disappear. Chloride stays in our water cycle virtually forever. It only takes about 1 teaspoon of rock salt to contaminate 5 gallons of water to the federal chronic chloride standard of 230mg/l.[1]

There is an overall trend of higher chloride concentrations in water bodies located in the southern region of Michigan. The highest concentrations are around the larger cities and most heavily-traveled roadways.[2] The United States Environmental Protection Agency documented 29 incidences of Michigan groundwater contamination from salt or salt/sand[3] in addition to effects on surface waters.

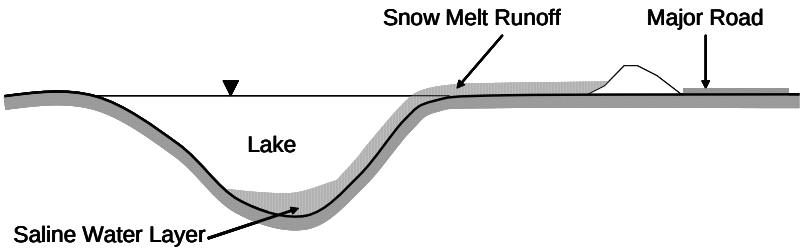


Figure 3: Lake Stratification Due to Saltwater Runoff

In addition to causing aquatic toxicity, salt water is heavier than freshwater and sinks to the bottom of lakes. This can eventually cause stratification of the lake and loss of lake turnover.[4]

A recent study on the negative impacts from road salt runoff concluded that "reduction in usage appears to be the only effective road-salt-runoff management strategy."[5] You, as a winter maintenance professional, are uniquely positioned to safeguard the freshwater resources of Michigan by using less salt. The information in this manual provides many suggestions on how to accomplish this.

Preparing for Winter

All winter maintenance organizations should have a written winter maintenance plan. This plan, if followed, will help protect you legally. It will also help you run a smooth and well-thought-out winter maintenance operation. Each year, in advance of winter, take time to review and update your maintenance procedures. A little planning up-front can help you do an excellent job in keeping the roads safe and decrease the required application of salt throughout the season.

Winter Maintenance Plan

- Develop a winter maintenance plan, and be prepared to follow it.
- Share the plan with all involved staff.
- Define levels of service for all of your snow routes. Your level of service may be based on average daily traffic, environmental concerns, safety, mobility, economics, and other factors.
- Communicate the relevant portions of your winter maintenance plan to your customers so they understand their role and what to expect. See Appendix A for examples of how to reach out to your customers with information on winter maintenance activities.

Route Preparation and Planning

These activities can be done by operators and supervisors, as appropriate, during the fall to lay the groundwork for efficient winter operations.

- Inspect and clear ditches, culverts, and other water channels.
- Remove potential snow traps, such as tall grasses along the road that will catch and deposit snow on the road.
- Assign routes to operators; better performance is achieved when operators have an assigned route throughout the season.
- Drive all routes prior to winter to identify critical or problem areas.
- Understand the target level of service for various areas of a route.
- Inventory all the areas prone to drifting and develop a plan to manage them. Consider installing snow fences.
- Explain the best ways to manage blowing and drifting snow with new operators.

Snow Fences

National research has found that it is 100 times more expensive to plow snow than to trap it with a snow fence.[6] A snow fence can be permanent or seasonal, living or structural. Using vegetation as a snow fence takes long-term vision, as it can take five to ten years before the plantings are of sufficient size to create the desired effect. The economic benefits of using snow fences in winter maintenance operations include savings from: reduced overtime, less need for contract equipment and services, reduced operating expenses, and reduced sand or chemical usage for ice control. See Appendix D for more resources on snow fencing.

Storage and Handling Systems

Proper storage and handling of deicers is a primary way to reduce groundwater contamination from salt. Stored salt needs to be covered, as do sand piles which contains more than 1% of salt. This applies to all piles greater than 5 tons. The DEQ has produced a document to guide the proper storage and handling of road salt. See Appendix D.

The best method to store granular salt and sand/salt mix is in a covered, water-tight building with doors. Having a salt shed with doors greatly improves protection from the elements. The salt and salt/sand mix needs to be stored on an impervious pad such as asphalt. If your impervious pad is constructed out of concrete it should have a sealer applied to it. The surrounding outdoor pad should be sloped and curbed to direct runoff water into a collection area.

Currently, the outdoor storage requirements in Michigan indicate that liquid storage should be in double-walled tanks or that secondary containment should be around single-wall tanks. Secondary containment should be such that if the tank leaks, all of the contents of the tank can be contained and recovered on site. This applies to all liquid deicers over 1000 gallons under the present Part 5 rules. These requirements may change during the Part 5 stakeholder process, so check the DEQ website for the most current information.

The feasibility of outdoor liquid storage is limited based on the eutectic temperature of the liquid product. The eutectic temperature is the freeze point of a liquid at the optimal concentration. Figure 12 lists the eutectic temperature for some of the common liquids.

Key points for salt storage and handling:

- Ensure salt storage is at least 50 feet from the waters of the state (natural wetlands, ponds, lakes, rivers).
- Provide indoor storage for salt and sand that has an impervious floor.
- Use double-wall tanks or secondary containment for liquid deicers.
- Handle salt shipments and loading operations indoors.
- Sweep pad, for outdoor loading, after receiving shipments and after loading.

Storage requirements under Part 5 rules are under review. Check with MDEQ for the most current requirements.

Snow Disposal Sites

Suitable sites for snow disposal should be established prior to the winter season. The optimal sites are those where the debris can be easily recovered in the spring. Snow should not be plowed directly into ponds, rain gardens, lakes, rivers, or wetlands. DEQ draft guidance recommends that snow storage be at least 75 feet from non-community

water supply, 50 feet from private water supply and 200 feet from community water supply wells. This recommendation may change, so keep informed of all local regulations, policies, and guidelines for Michigan water quality protection. See Appendix F for a reference to this draft document.

Calibration

Before the beginning of each snow fighting season, salt trucks must be calibrated to measure the amount of material applied at various settings. The salt discharge should fall within your agency's guidelines. If the automatic controller is not applying the material at the correct application rate per your agency's guidelines, it must be adjusted. The calibration should be rechecked if there are any mechanical adjustments or changes throughout the remainder of the winter season.

By calibrating your equipment, you can be sure your application rates will be accurate and you will know how much product is actually being applied to the roadway. This alone can result in salt cost savings, by avoiding unintentional over-salting. Calibration should be done for all equipment that dispenses liquid or granular material. All granular materials (salt, prewet salt, sand, etc.) flow differently, so calibrate for each material.

With manual-controlled systems, the operator must have a copy of the calibration worksheet in the cab of the truck. This allows the driver to cross-reference the desired material application rate with the speed of travel, and then choose the setting that gives the desired result. A calibration worksheet example is in Appendix C along with other calibration resources.

Key points for calibration

- Calibrate all new equipment prior to use.
- Calibrate all equipment at least once a year or if the truck has had any major service.
- Calibrate for each type or blend of granular material.
- Calibrate liquid application systems, both anti-icing and prewet systems.
- Follow the manufacturer's guidelines for calibration, and contact the manufacturer for training if necessary.
- Put the auger plate in place during calibration for dump trucks. Calibration won't be accurate if the material is gravity-flowing during the calibration process.
- Place a calibration worksheet in each truck and a copy in the shop for those with manual-control spreaders.

Calibration saves you salt and money.

Investment in Equipment

Investing in equipment that can make your organization's winter maintenance more efficient is money that is repaid quickly. Investment in controllers, liquids and blades are areas that that often give a good return on investment. Top performing organizations integrate new practices and equipment to increase their efficiency. The

Clear Roads online cost benefit analysis toolkit can help provide insight into new practices, equipment and operations. See Appendix D for this resource.

Plow early and often to reduce hard pack.

- Mechanical Removal

  Mechanical removal (blading or plowing) is the most effective strategy to remove snow, from a cost and efficiency standpoint. The Clear Roads Pooled Funds Study has an evaluation of plow prototypes. You can find this in Appendix D, under blades and plows.

  - One trend in the industry is towards segmented blades. These offer more flexibility for blading on uneven surfaces, less vibration for the operator, and will wear more evenly and scrape better. Clear Roads has produced some research on cutting edges. This is in Appendix D, under blades and plows.
  - Underbody blades are very common in Michigan; they allow more down pressure and are helpful at removing compaction. The more snow you remove mechanically, the less salt you will need to keep roads safe.
  - The use of wing-plows for winter operations in Michigan has increased over the past few years. Using wing-plows can make a winter operations program more effective by providing a more effective means of mechanical removal. With a wing-plow, operators can clear an entire lane plus a few feet of the shoulder in one pass, a job that usually takes two passes or two trucks working together.
  - In Michigan and other snow-belt states, the tow plow has been tested and proven to be an effective method of snow removal.
  - Brooms can be very efficient at removing light snow. These are common tools at airports and for sidewalks.

Electronic closed loop controls are easier to operate and are a potential money saver!

- Controllers

  The ability to control the application rate of deicers is vital. By improving the accuracy of your controllers, you will be able to achieve a more efficient operation automatic controllers and manual controllers. All agencies should work toward replacing manual controllers with electronic closed-loop controllers.

  Automatic controllers self-adjust the flow of salt to match the target application rate regardless of the truck speed. When the snowplow speeds up or slows down, the controller automatically speeds up or slows down the salt delivery rate so that desired application rate is maintained.

  Manual controllers are not as accurate as automatic controllers. Manual controllers do not self-adjust to meet a target application rate. Application rates are difficult to hold constant with manual controllers because the speed of the truck is often changing. Although accuracy is low, calibration is essential so your organization can attempt to follow application guidelines. Without calibration, you cannot attempt to deliver a specific amount of salt per lane mile.

With manually-controlled systems the operator must have a calibration worksheet in the truck. An example of a calibration worksheet is located in Appendix C along with other calibration resources.

The calibration of the controllers should be completed annually, at a minimum. Calibration should also be completed anytime major truck repairs are done, or if the operator notices that it is not working properly. It is also important to remember that the gate opening must be set and marked during calibration.

Weather Data

Basic, up-to-date weather information is critical for winter maintenance planning and effective response during an event. The means to acquire this information should be in place prior to the start of winter. Information that should be gathered before an event, and tracked throughout, includes:

- Start of precipitation and expected event length
- Type of precipitation expected
- Total precipitation expected/event intensity
- Wind conditions (speed, gusts, directions)
- Temperature trend (rising or falling during the event)
- Pavement temperature trend (rising or falling during the event)
- Dew point

$

Pavement Temperatures should guide your application rates.

Weather information can and should come from a variety of sources, and there are many from which to choose. Many services provide weather forecasts, condition trends but fewer provide pavement temperatures.

The dew point describes the temperature below which water will condense into liquid water at the same rate at which it evaporates. Condensed water is called dew. The dew point is the critical ingredient in predicting the formation of frost on roads. When the pavement temperature falls below the dew point, if that pavement temperature is equal or below freezing, then frost will form. By monitoring the dew point and other weather factors, you can predict frost and be out in front of it. Wind speed and absolute humidity are the other variables which play a role in how quickly the frost forms and how thick the layer will be.

Dew point can be obtained from commercial weather services or the Michigan RWIS system. MDOT's RWIS system started in 2010, and now includes more than 50 stations around the state. The system is made up of a network of sensors, to measure air and road surface temperatures, barometric pressure, wind, salt concentrations on the road surface, frost depth and dew point. You can access MDOT's RWIS system by visiting http://mdotnetpublic.state.mi.us/drive/. Figure 4 is a sample of the information you can get from their RWIS stations.

Pavement Temperatures

Keep in mind that most weather services measure temperature and other conditions in the air, above the ground, which means that the reported conditions can differ substantially from pavement temperatures. It is extremely important to use the pavement temperature, not air temperature, to determine what material(s) to use and the appropriate application rate of your chemicals.

Air Temperature: 61°F
Maximum Daily Temperature: 76°F
Minimum Daily Temperature: 42°F
Relative Humidity: 70.7%
Average Wind Speed: ENE 5 MPH
Maximum Gust Speed: ENE 11 MPH
Barometric Pressure: 29.27"
Precipitation: No Precipitation
Precipitation over the last 24 hours: 0"
Dew Point: 52°F
Visibility: 10 miles

Figure 4: RWIS example (I-75 @ South of M-48 overpass)

Pavement temperature can be measured several different ways. One way is by hand-held temperature sensor guns that can be purchased at any automotive store for under $100. Truck-mounted systems are another alternative. Truck-mounted systems are better than hand-held sensors in that they display in the cab a continuous reading of the air and pavement temperatures. Truck-mounted systems may be incorporated into your spreader controller or can be purchased independently of your controller.

There are many influences on pavement temperature. For example, you will notice changes in pavement temperature first on bridge decks and ramps; pavement temperatures will also be lower in shady areas. The pavement's color and texture, and the type of material in the layer underneath the pavement, all influence its temperature as well. You cannot substitute air temperature for pavement temperature; you must know the pavement temperature before making a decision on application rates. **All of your application rate charts should be based on current and trending pavement temperature.**

Automatic Vehicle Location (AVL) and Maintenance Decision Support Systems (MDSS)

Many organizations are now using computer technology in the form of AVL systems and/or MDSS to further improve the efficiency of their winter maintenance responses.

Use salt carefully! 1 teaspoon of salt pollutes 5 gallons of water.

- Automatic Vehicle Location system

With an AVL system you can see where the snow plow vehicles are deployed in near real time during a winter event. This is typically done through a web portal. Vehicles are depicted on the map via icons indicating the type of actions underway, when and where a vehicle is actively spreading material, or when and where the plow blade is down and pushing snow. Users may hover a cursor over an individual vehicle icon and get a pop-up box describing the vehicle and what it is doing.

Iowa Department of Transportation reported that equipping their trucks with Automatic Vehicle Location (AVL) provided a return on investment of $6.40 for every $1.00 expended.[7]

$

Both AVL and MDSS have shown good results in reducing salt used.

- Maintenance Decision Support Systems (MDSS)

MDSS combines advanced weather prediction service, advanced road condition prediction and your agency's winter maintenance practices for anti-icing and de-icing to generate road treatment recommendations on a route-by-route basis. The goal of MDSS is to suggest more effective use of maintenance resources and increase safety, reliability and mobility on roadways.

The MDSS system allows crews to input real-time conditions, including road and ambient temperature, type of material being used and the application rate. After compiling the information provided by the crews, along with weather reports, the system will then provide suggested treatments based on the information and models. The system may tell the operator to re-treat the road at a later time, apply different products at different rates, or simply to continue current procedures. The suggested treatment can then be followed or the operator can override the system.

MDSS systems have a scenario selector that can be used as a training tool. For more information on MDSS, see Appendix D. There is a report, "Analysis of Maintenance Decision Support System (MDSS) Benefits & Costs," which summarizes the experiences of several states using MDSS.

Anti-icing before the Event

Anti-icing is the process of putting down a liquid deicer before a winter event. It can be a cost-effective strategy that optimizes, and therefore reduces, chemical usage. It is a proactive approach that should be considered first in a series of strategies for managing most winter events. By applying a liquid deicer before an event, you can prevent snow and ice from bonding to the pavement, or even prevent frost from forming on the roadway altogether.

Anti-icing is not always the answer, but when it is, it can buy you time for physical removal that is easier and more cost-effective. To determine when it is appropriate to anti-ice, see an example of an anti-icing decision chart in Appendix B.

Anti-icing procedures look different from other winter maintenance activities and may cause concern with the general public. Educate your customers about anti-icing techniques and their value ahead of its use.

Selection and Storage of Anti-Icing Products

- Liquids are the most effective anti-icing agents.
- At temperatures below 15°F, it may be more cost effective to use a chemical other than sodium chloride brine (see Appendix B for anti-icing cost model).
- Hygroscopic liquids bring the moisture from the air to the pavement surface (similar to dust control on gravel roads). They give added benefit on cold winter pavement because of this property but they can be troublesome at warm (over 28°F pavement temp) or in humid conditions. The most commonly used hygroscopic products are $CaCl_2$ or $MgCl_2$.
- When using hygroscopic products, it is critical to not over-apply.

Guidelines for Anti-icing Product Application

These are only guidelines and not exact recommendations. Generally it is better to under-apply rather than over-apply anti-icing materials. So start low and increase rates, instead of starting high and decreasing rates. Forms such as those shown in Appendix B of this manual are useful to record and track your work and observations, so you can refine your use and understanding of anti-icing products.

Condition	**Gallons per lane mile**		
	$CaCl_2$ or $MgCl_2$	**Brine**	**Brine Blends**
Regularly scheduled application	15-25	20-40	Ask manufacturer
Prior to frost or black ice	15-25	20-40	Ask manufacturer
Prior to light or moderate snow	15-25	20-50	Ask manufacturer

Figure 5: Anti-icing Application Rates

Key points for Anti-icing

- Apply liquids at half the rate (not half the concentration) for the first application of the season, or after a prolonged dry spell. On dry roads, liquids tend to mix with oil from vehicles and cause slippery conditions if over-applied.
- Consider spot-applications on hills, bridge decks, curves and intersections if predicted conditions warrant and you are just beginning an anti-icing program. Continue to expand anti-icing until you treat most of the areas that you de-ice.
- Utilize anti-icing for light freezing drizzle and light frost events; it can be very effective.

- Apply your anti-icing agent during low traffic times and during regular work hours; this saves product and reduces staff costs.
- Avoid anti-icing under blowing conditions, in areas prone to drifting or anywhere else you would not use salt.
- Avoid applying before a predicted heavy rain.
- Apply liquid anti-icers 24-48 hours in advance of an event. The closer to the event start time the better. Tire action and wind wear away material.
- Remember that re-application isn't always necessary. The residual effect of anti-icing applications can remain for up to five days if precipitation or traffic wear-off does not dilute the material.
- Apply liquids with stream nozzles to maintain bare pavement between application areas.
- Use a spray skirt when anti-icing. This helps significantly in directing product to the roadway where it is needed. Adding a simple spray skirt behind the truck's spray bar significantly increases the amount of product reaching the roadway.[8]

Look at anti-icing's costs and benefits and evaluate how it can best serve you. Anti-icing can provide significant cost, safety, and environmental benefits. Appendix B contains anti-icing resources and a link to a Cost Benefit Analysis Tool that can help you understand how anti-icing can provide a return on your investment in equipment.

$

Liquid deicers are faster acting and stay in place better.

During the Event

During a winter precipitation event there is very little extra time. Preparation in advance of an event is the key to success. Integrating best management practices (BMPs) into your operations can help provide safety, appropriate levels of service, and protect Michigan's natural resources. Good documentation is one of the BMP's that helps move your organization ahead. Make sure this is integrated into your winter operations. Appendix E has example charts that you can use for recording your activities.

Effective Use of Plows/Underbody Blades

Plowing or blading is the best approach to snow removal. It can be the most cost-effective approach when all the factors (cost of chemicals, damage to public roadways and infrastructure, etc.) are considered. Physical removal of snow should always be done prior to the application of deicing materials.

Key Points for Plowing/Blading

- Blade prior to an application of chemical in order to minimize product dilution.
- Coordinate blading activities to eliminate windrows at intersections and prevent removal of another operator's deicing material.
- Remove snow from roads as quickly as possible to reduce compaction.
- Avoid pushing snow over the bridge rails and onto roads or water beneath.
- Pay attention to wind conditions. If shoulder blading isn't critical, then delay until wind speeds are lower.
- Reduced speed minimizes the risk of a snow cloud. Lift the blade and wing if a snow cloud forms; do not slow down or brake.

Loading and Hauling Salt

A substantial amount of salt can be spilled, and potentially wasted, during the loading and hauling process. Some easy steps can be taken to ensure that this purchased material ends up only where it is needed, on the roadway.

Key Points for Loading and Hauling

- Load inside the salt shed.
- Sweep outdoor loading areas frequently.
- Fill but do not overfill trucks. One city that uses very little salt inserts a cement base in the truck bed to provide extra weight, thus requiring less material to be loaded.
- Tarp your loads when transporting material.
- Install spill shields to plug up gaps in truck bed.
- Install sander plates to prevent free-fall of salt or sand.

Using Abrasives

Use winter sand and other abrasives when temperatures are too cold for deicing chemicals to be effective, or when immediate traction is needed after a freezing rain event. Be aware that sand does not melt anything. It only provides temporary traction, and only when it is on top of snow or ice. Sand will clog sewers, ditches, and streams. As a result, avoid sand use as much as possible.

Our lakes are turning into wetlands as they fill in and become shallower. Unrecovered winter sand accelerates this process.

A salt/sand mix is generally not recommended as salt reduces the effectiveness of sand, and sand reduces the effectiveness of salt.

Key points for Abrasives

- Sweep up excess sand after each event.
- Apply sand in extreme cold weather, when salt is ineffective.
- Avoid salt/sand mixes. Determine if you need melting or temporary traction and choose the proper tool.
- Employ sand only for short-term traction needs. It has no melting capability.
- Note that, in limited situations such as a freezing rain event, a 25 to 50% sand/salt mix has been documented as effective in increasing friction.[9]

Material Application

Deicing is a reactive operation in which a chemical is applied to the top of snow, ice or frost already on the roadway. Forms such as those shown in the Appendix F of this manual are useful to record and track your deicing work.

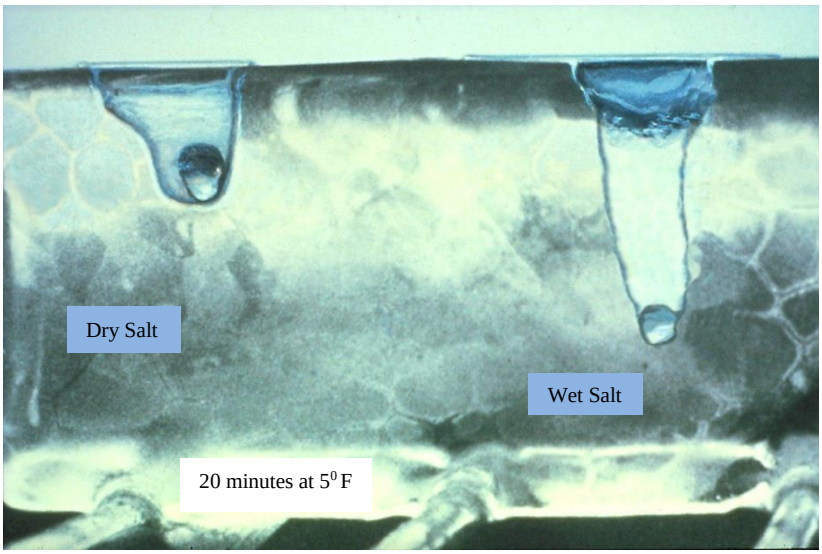
Removing ice that has already bonded to the pavement can be difficult, and removing it mechanically causes wear on equipment and roads. Enough ice must be melted to weaken the bond between the ice and pavement in order to make physical removal

possible. Breaking the bond after it is formed requires more chemical than preventing the bond from forming in the first place.

Integrating science into winter maintenance allows us to use an appropriate amount of product for deicing. Most application rates can be reduced by the best maintenance practices already discussed, such as proper calibration and using closed-loop spreaders. But there are two major handicaps to the effectiveness of a salt application during an event: the precipitation which dilutes it, and the next blade pass which can remove it before it has had a chance to work.

Slower truck speed and prewetting or pretreating salt are best practices for reducing salt waste and lowering the necessary application rates. Applying dry material is a common but ineffective practice. Research and results in the field show that prewetted or pretreated material stays on the road surface better, and is therefore more effective. Another way to reduce salt use is to minimize applications during the storm event. This helps keep blading activities from removing the deicing salt.

Dry salt is slow to dissolve. Adding liquids not only keeps more of the salt on the roadway, it also helps to increase the speed of melting as it jump-starts this process. The greater the liquid to granular ratio, the better control you have over your product during application, and the faster its performance once it is down. The photograph below illustrates the melting speed of prewetted salt versus dry.



Liquids allow you to use less product overall.

Figure 6: Melting Comparison of Dry Salt vs. Prewet Salt
Photo courtesy of the Wisconsin Department of Transportation bulletin #22

How to reduce application rates

1. Speed of application. MDOT recently proved that reducing the speed of application from 35 mph to 25 mph can prevent up to 40% of the salt discharged from being wasted.[10] The speed of trucks during application of granular material should be 25 mph or less, or the lowest safe speed under the conditions.

2. Vary application rates. Use the higher rate listed for the first pass, and reduce on any subsequent passes. Adjust rates as needed if you know you will be able to only make one pass.

$

Salt that is bounced off the roadway or is spread outside the travel lanes is money down the drain.

3. Spread pattern. The most effective spread pattern is a windrow of salt on the centerline or highpoint in the roadway. Set spreaders lower to the ground or use a chute to reduce bounce and scatter. See Appendix D for instructions on how to build a chute or how to set-up a grid to run a test and get your own bounce and scatter data.

4. Pretreated or prewetted salt. Wet salt remains on the road longer (less bounce and scatter) than dry salt and works faster too. With pretreated salt the liquid to granular ratio is about 4 to 6 gallons per ton. In prewetting operations, the ratio of liquid to granular can vary greatly. It starts at about 8 gallons per ton, upwards to over 100 gallon/ton (slurry). Some organizations have nearly abandoned granular products altogether and are applying straight liquids.

5. Application rate. Make sure your organization has an application rate chart that is based on pavement temperatures. Continually work to refine your chart and lower your application rates.

6. Deicers. Not all deicers perform the same under the same conditions. By choosing the combination of liquid and granular deicers that is least toxic and that works the best at your pavement temperature, you can reduce your application rate and costs, as well as your environmental impact. Figure 7 compares four different applications, using different materials (from salt/sand to a higher ratio of salt/liquid), and all would potentially achieve satisfactory results.

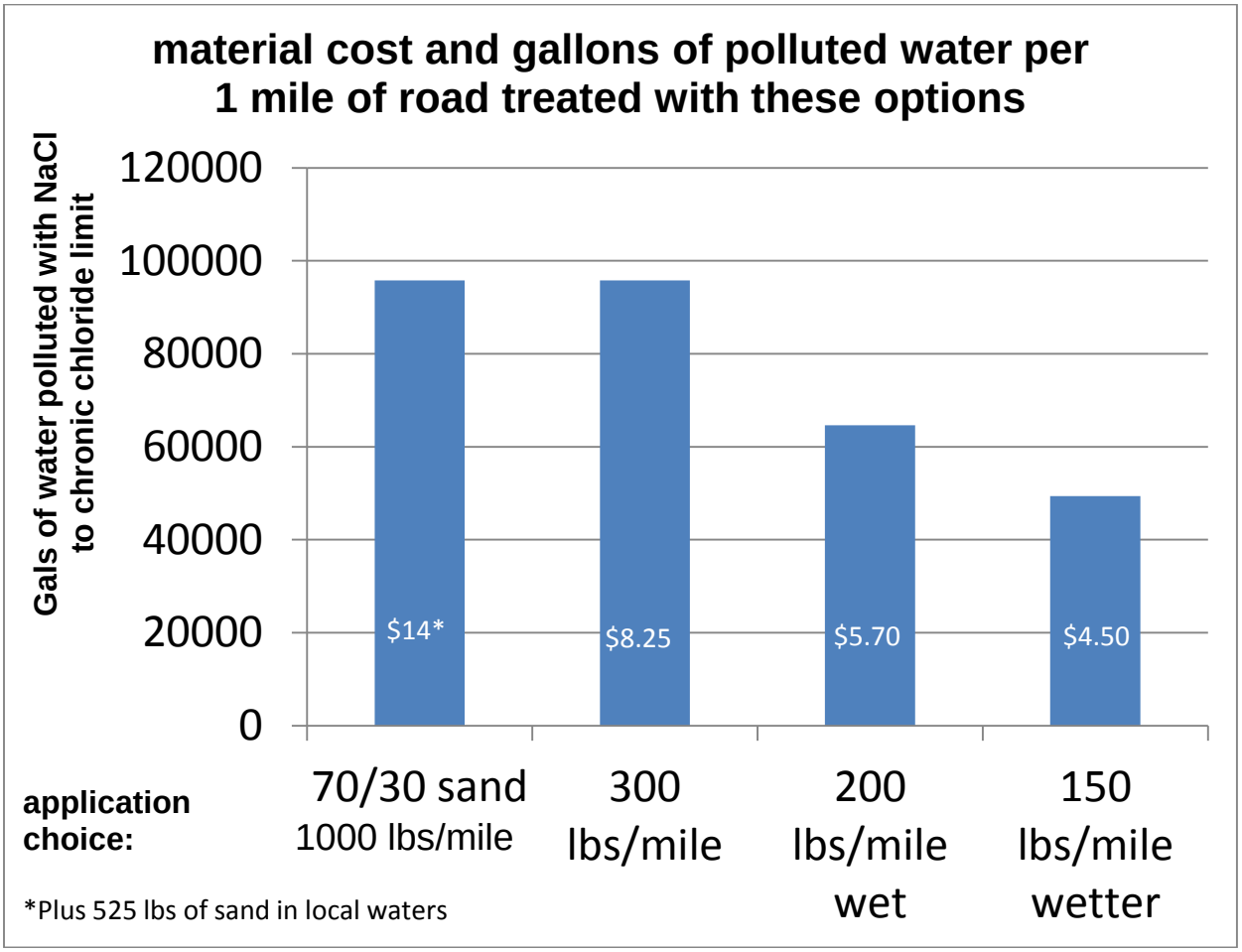


Figure 7: Material Cost and Gallons of Water Polluted

The purchase cost based on $55 ton salt, $16 ton sand and $0.20 gallon brine. Per federal chronic chloride standards of 230 mg/l, 1 pound of salt pollutes 320 gallons of water, 1 gallon of brine pollutes 728 gallons of water. Wet = 10 gal/ton and Wetter = 15 gal/ton

There are many ways to accomplish a safe winter road. We can see from this chart that material selection is a key factor in providing the opportunity to reduce application rates while maintaining effectiveness. By looking at all the factors--performance, cost, and environmental damage--winter maintenance professionals can make the most informed decisions on how to maintain their level of service. See Appendix F for the new Clear Roads Fact Sheet on the Toxicity of Deicers to run your own calculations.

Selecting a Deicer

When selecting a deicer, be careful when looking at the melting temperature on marketing materials. The eutectic temperature is often cited, which is the lowest possible temperature at which a solution remains liquid. At this temperature it would take a very long time for the product or solution to melt ice. Instead, you need to know a product's practical melting temperature range.

Sodium chloride (NaCl, or road salt) is the most widely used of the deicers. It is effective at pavement temperatures above 15◦F. Because it doesn't work well at colder temperatures, it is often over-applied in attempts to get it to work better. See the chart below for the melting capacity of NaCl at various temperatures. Ask your vendor for a similar chart for the products you buy or are considering buying.

By adding liquid to granular salt, you can speed up melting and use less salt.

Avoid using dry rock salt at pavement temperatures below 15° F.

Pounds of Ice Melted Per Pound of Salt

Pavement Temp (F)	One Pound of Salt (NaCl) melts	Melt Times
30	46.3 lbs. of ice	5 min.
25	14.4 lbs. of ice	10 min.
20	8.6 lbs. of ice	20 min.
15	6.3 lbs. of ice	1 hour
10	4.9 lbs. of ice	Dry salt is ineffective and will blow away before it melts any significant amount of ice.
5	4.1 lbs. of ice	
0	3.7 lbs. of ice	
-6	3.2 lbs. of ice	

Figure 8: Ice Melting Capacity of Sodium Chloride at Various Pavement Temperatures

- For a chart showing practical temperature ranges for other deicers, see Figure 12.
- For more information on the toxicity of deicers see "Determining the toxicity of deicing materials," a Clear Roads research project, in Appendix F.
- Melting all the snow or ice on the road is not necessary. This is an overuse of materials. Apply just enough to loosen the bond between the road and the ice/compacted snow so it can be effectively bladed off.
- Use pavement temperatures and trends to help you to apply the right product application rate at the right time. Generally use less chemical when temperatures are warm or rising, and more when they are cold or falling.
- Avoid straight salt when temperatures below 15◦F; use other deicers such as $CaCl_2$ and $MgCl_2$ to obtain better melting at lower temperatures. If you do not have a good alternative available, use sand for traction until pavement temperatures warm.

Spread Patterns

The spread pattern in Figure 9 is a visual representation of the application method on which the application table is based. That is, you blade only (no chemical application) going out, and blade and apply in a windrow to the centerline on the return trip.

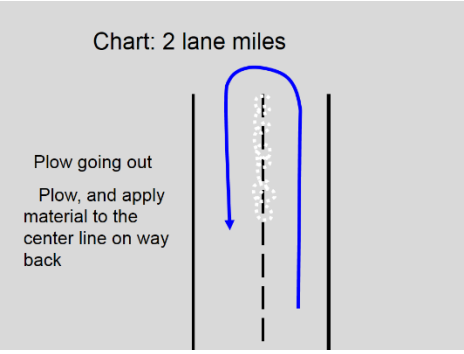


Figure 9: Suggested Plow and Apply Pattern for Deicing

One of the biggest challenges with salt is to keep it on the road long enough for it to work. Narrow your spread pattern to apply salt to the crown of the road. As the salt melts it will migrate across the drive lanes. By driving slowly and applying salt to the center line in a windrow or tight spread pattern you will waste less salt. This applies to all roads, but is essential on high speed roads.

There are various devices and modifications to your spreader that you can make to help you create a tighter spread pattern. Chutes that direct the salt from the spreader to the pavement are one good example. Other examples include skirts below and around the spreader, holes in the spreader, zero velocity spreaders and or simply turning your spreader off.

Strive for an even spread pattern at low application rates. Equipment that was designed to deliver large amounts of sand likely will have trouble delivering a steady spread pattern with a low rate of salt. If this is the case, you will need to retrofit or change your equipment to make it able to deliver an even spread pattern at a low rate. When you purchase new equipment, make sure it can deliver a very low application rate (100 pounds/mile) with an even spread pattern.

Deicing Application Rate Guidelines

Every organization should have an application rate chart that is based on pavement temperatures. This allows you to standardize your operations. The chart below is an example of an application rate chart developed for Minnesota. This chart was developed by a team of city, county and state winter maintenance experts. The rates were chosen with the goal of defining sufficient rates to clear and hold the roads after an event, assuming all of the best practices were done before and during the event.

No chart will be perfect. Make your own chart and keep improving it. See if you can continue to lower the rates as you become more efficient in your winter maintenance practices.

Deicing Application Rate Guidelines

24 feet of pavement (typical two-lane road)

These rates are not fixed values, but rather the low end of a range to be selected and adjusted by an agency, according to its local conditions and experience.

Lbs/two-lane road						
Pavement Temperature (F) and Trend	Weather Conditions	Maintenance Actions	Salt Prewetted/Pretreated with Salt Brine	Salt Prewetted/Pretreated with Other Blends	Dry Salt, least effective*	Winter Sand (Abrasives)
>30 F ↓	Snow	Plow, treat intersections only	**80 (40/lane mile)**	**70**	**100***	Not recommended
	Freezing Rain	Apply product	**80-160**	**70-140**	**100-200***	Not recommended
30 F ↓	Snow	Plow & apply product	**80-160**	**70-140**	**100-200***	Not recommended
	Freezing Rain	Apply product	**150-200**	**130-180**	**180-240***	Not recommended
25-30 F ↑	Snow	Plow & apply product	**120-160**	**100-140**	**150-200***	Not recommended
	Freezing Rain	Apply product	**150-200**	**130-180**	**180-240***	Not recommended
25-30 F ↓	Snow	Plow & apply product	**120-160**	**100-140**	**150-200***	Not recommended
	Freezing rain	Apply product	**160-240**	**140-210**	**200-300***	Not recommended
20-25 F ↑	Snow or freezing rain	Plow & apply product	**160-240**	**140-210**	**200-300***	Not recommended
20-25 F ↓	Snow	Plow & apply product	**200-280**	**175-250**	**250-350***	Not recommended
	Freezing Rain	Apply product	**240-320**	**210-280**	**300-400***	**400**
15-20 F ↑	Snow	Plow & apply product	**200-280**	**175-250**	**250-350***	Not recommended
	Freezing Rain	Apply product	**240-320**	**210-280**	**300-400***	**400**
15-20 F ↓	Snow or freezing rain	Plow & apply product	**240-320**	**210-280**	**300-400***	500 for freezing rain
0-15 F ↓↑	Snow	Plow, treat with blends, sand	Not recommended	**300-400**	Not recommended	500-750 spot treat as needed
<0	Snow	Plow, treat with blends, sand	Not recommended	**300-400**	Not recommended	500-750 spot treat as needed

To calculate for 1 lane, divide application rate numbers in half

Use lower end of application rate range when using super-saturated mixes

Source: Chart: Minnesota Snow and Ice Control Field Handbook for Snowplow Operators (2012).

Figure 10: Application Rate Chart for Deicing

Dilution: the cause of refreeze

An ice control product will work until dilution causes the freeze point of the remaining brine on the roadway to equal the current pavement temperature. At this point, the material will stop melting and you may experience re-freeze if the pavement temperature is dropping. This process is called the dilution of solution.

How long a treatment will last depends on five factors: pavement temperature, application rate, precipitation, beginning concentration, and chemical type. These factors explain why one application rate will not fit all winter events.

Pretreated Stockpiles

Pretreating is mixing a liquid deicer into the stockpile of salt or sand. The liquid used is not brine but a deicer that is hygroscopic and contains a corrosion inhibitor, and may also have stickiness to it. Often a dye is added to help identify the treated pile. You can apply pretreated salt without any equipment changes. Pretreated salt is more effective than dry salt and can allow you to lower your application rate.

- Purchase the pretreated salt from a vendor or mix it on site. If you choose to mix your own be accurate in your measurements.
    - Start out with dry salt. See the salt moisture worksheet in the materials testing section.
    - Treat the stockpile with a liquid deicing chemical (not brine) at 4-6 gallons/ton. Be consistent and check rates.
    - Mix up enough for one storm, not the entire season.
- Store pretreated stockpiles indoors on an impervious pad, consistent with Rule 5 requirements. See Appendix F to locate this information from the DEQ.
- Be aware that pretreated stockpiles have a higher risk of leaching. If you have containment limitations with your storage area, mix up just enough for one event rather than enough for the season. This will limit the leaching risk.

Treated salt piles need proper storage due to a greater risk of leaching

Prewetting Method for Deicing

Prewetting is the addition of a liquid to granular material by means of an on-board truck system. Liquid and granular are combined most often at the spreader, but sometimes in the auger. Wet salt has several advantages; it bounces less and melts ice faster. Prewetting requires some equipment changes, but this practice provides the flexibility to switch chemicals or liquid/granular ratio depending on conditions. Just as with pretreated salt, you can reduce your application rates by using prewetted salt.

- Include salt brine, calcium chloride, magnesium chloride, brine blends, acetates and others among the options you consider for prewetting.
- Check your liquid concentration before using. Figure 12 lists many of the optimal concentrations.
- Start with application ratios of 8-14 gallons/ton; this is the typical starting place for most organizations.[11]
- Super-saturated or slurry mixes activate even more quickly.

- Be sure to properly size the dry volume capacity in the hopper versus liquid holding capacities when purchasing on-board prewetting systems. It is vital that the total truck weight capacity is considered, as liquids add considerable weight to the overall load.

Direct Liquid Application for Deicing

Straight liquids are most commonly used for anti-icing, pretreating salt piles and prewetting on board the truck. However, it is becoming more common, especially in warmer winter conditions, to de-ice with straight liquid product. This is an advanced winter maintenance activity. Called “direct liquid application,” or DLA, this deicing technique is more difficult and should only be attempted by those very familiar with the use of liquid deicers in other areas of winter maintenance. It is possible to create a more slippery surface if straight liquids are used improperly for deicing.

- Attempt liquid-only deicing only after you have mastered the anti-icing and prewetting uses of liquids, and have the proper equipment for the liquid deicing operation.
- Having sufficient pressure on the streamer nozzles, so that the liquid penetrates the snow or ice and spreads out <u>below</u> the snow and ice, is the key to effective deicing with liquids.
- Spraying a liquid deicer on top of compacted snow or ice can increase the slipperiness of the surface.

<u>After the Event</u>

Learn from each storm. Each event provides an opportunity to evaluate what was done, how well it worked and what could be changed to improve operations. Information exchange is the best way to speed up positive changes in winter maintenance. At the end of each event, post or discuss the results of your operation so the entire crew can be informed. When the entire crew is informed and included, change happens faster. Examples of what to track and discuss include: driver statistics such as route length, the type materials used, the amount of material used, and the recovery time. Other things to consider might be the liquid to granular ratio, the type of plow blade, new road surface or other new equipment and/or procedures being tested.

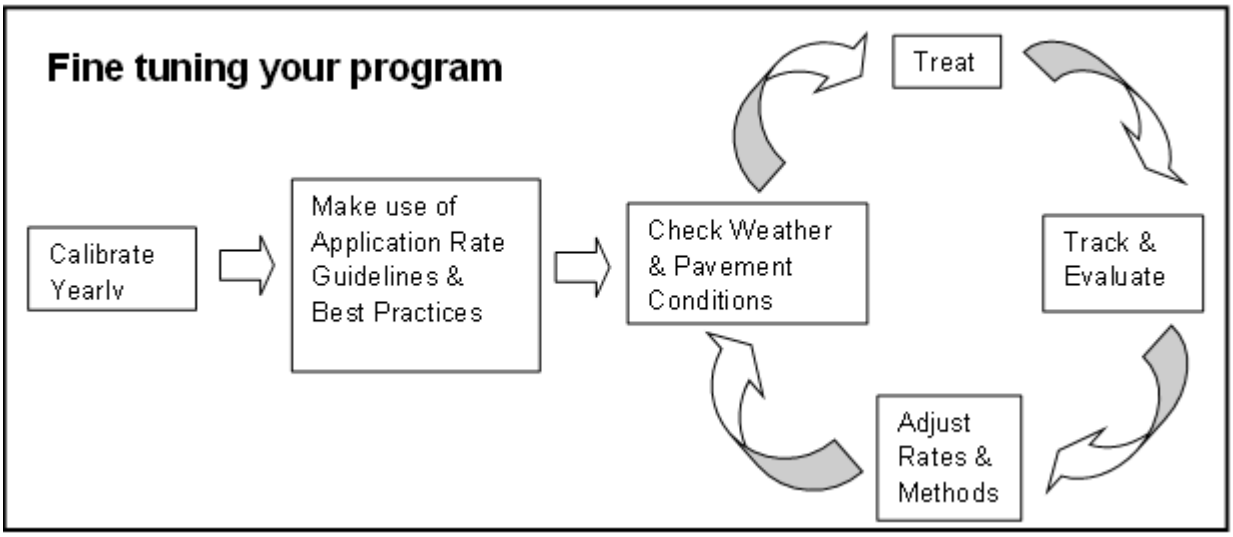


Figure 11: Maintaining a Progressive Winter Maintenance Operation

Key points for after the event

- Use forms such as those shown in the Appendix E of this manual to record and track your material use.
- Report any hazards such as low hanging branches and raised utilities.
- Ensure that all unused granular salt and salt/sand mixtures are stored properly.
- Refine your procedures and material use based on the “end of storm” meeting, and observations from operators.
- Wash vehicles after ensuring they are as empty as possible.
- Direct the wash water to collection/reuse areas or the sanitary sewer system. Do not direct wash water to septic systems or storm drains. Michigan’s DEQ Water Resources Division provides a guidance document on truck washing at municipally owned truck stations. See Appendix D, under salt storage and handling.

Key points for after the season

- Ensure that all unused granular salt and salt/sand mixtures are stored properly and records are kept of the amount of each product remaining.
- Clean and maintain truck tanks, brine making systems and pumps according to manufacturer specifications.

Materials and Quality Control

Practical and Eutectic Temperatures of Deicers

Multiple products can be used in a snow and ice control program. This chart helps you choose the correct product and apply it under the correct conditions. For further guidance on blending chemicals, see the MNDOT Anti-icing Guide, in Appendix B.

Chemical	Lowest Practical Melting Temp.	Eutectic Temp.	Optimal Concen-tration
NaCl (Sodium Chloride) —Delivered as solid rock salt, also can be made into a brine. The basis of most deicing materials. Very corrosive. Inexpensive. Very available. Rarely has a corrosion inhibitor added.	15º F	-6º F	23%
$MgCl_2$ (Magnesium Chloride)—Delivered as a liquid. Often used to wet NaCl crystals to increase adherence to surface and reduce melting points. Corrosive. Higher cost. Often has a corrosion inhibitor added.	-10º F	-28º F	27 to 30%
$CaCl_2$ (Calcium Chloride)—Delivered as flakes, pellets, or liquid. Powerful deicer but extremely corrosive. Sometimes used incorrectly to open storm drains. Higher cost. Often has a corrosion inhibitor added.	-20º F	-60º F	30%
CMA (Calcium Magnesium Acetate)—Delivered as a powder, crystals, pellets, or liquid. Liquid CMA is used mainly on automated bridge deicing systems. Non-corrosive, biodegradable. Sometimes added to sodium chloride as a corrosion inhibiter. Alternative for areas where chloride use must be limited. Often higher cost.	20º F	-18º F	32%
KAC (Potassium Acetate)—Delivered as a liquid. Often used on automated bridge deicing systems and airports. Use for anti-icing, deicing, and prewetting. Non-corrosive, biodegradable. Alternative for areas where chloride use must be limited. Higher cost.	-15º F	-76º F	50%
Blends— Both chlorides and acetates exist in blends. Talk to your supplier and determine the lowest practical melting temperature, the optimal concentration and the basic components in the blend. Most blends are centered on rock salt since it is cheap.			
Winter Sand/Abrasives—Winter sand has salt mixed in it to keep it from freezing. Sand should be used for cold temperatures when deicers are not effective. They provide temporary traction but only work when they are on top of the ice.	Never melts—provides traction only		

Figure 12: Practical and Eutectic Temperatures of Deicers

Material Conversions

The following quick reference table will help you convert between tons and cubic yards. Weight will vary depending on moisture content and density. This chart is based on a density of 80lbs/cubic foot.[12]

Sand		Salt	
Yards	Tons	Yards	Tons
1	1.4	1	1.1
2	2.8	2	2.2
3	4.2	3	3.2
4	5.6	4	4.3
5	7	5	5.4
6	8.4	6	6.5
7	9.8	7	7.6
8	11.2	8	8.6
9	12.6	9	9.7
10	14	10	10.8
11	15.4	11	11.9
12	16.8	12	13
13	18.2	13	14
14	19.6	14	15.1
15	21	15	16.2
16	22.4	16	17.3
17	23.8	17	18.4
18	25.2	18	19.4
19	26.6	19	20.5
20	28	20	21.6

Figure 13: Material Conversions
Minnesota Snow and Ice Control: Field Handbook for Snowplow Operators, Second Revision, published by the Minnesota Local Road Research Board, 2012.

Materials Testing

It is important to understand how deicing chemicals will react on the roadway. Clear Roads developed a guide for testing the effectiveness of chemicals. See Appendix E.

Also test your materials to ensure that they are delivered as ordered and will perform as needed. Refer to your contract or Material Safety Data Sheet (MSDS) for optimal specific gravity and test for that. Michigan's state bid standard for moisture in road salt is 1.5%.

Testing solid salt

Having a standard for the moisture content in your salt prevents having to pay for water weight, and helps reduce the amount of leaching potential should you decide to pretreat the salt. Salt with excessively high moisture content is also more likely to freeze in storage and become difficult to work with.

- Watch the load being dumped and observe if it appears wet.
- Schedule deliveries for days when it is not raining, if delivery will occur outside.
- Test for moisture content. Typically you want a moisture content of less than or equal to 1.5% (check your agency's specification).

How to measure the moisture content of rock salt:

1. Supplies needed:
    - Calibrated scale (triple beam or digital) accurate to 0.1 grams
    - Microwave
    - Sample of the salt (about 1 cup), that is a good representation of the pile
    - Worksheet for recording weight measurements

2. What to do:
    - Place empty container on scale, zero out scale to account for your container.
    - Weigh sample before cooking and record weight on worksheet.
    - Cook sample on low heat (high power may be too hot and make the salt pop, compromising the weight of your sample).
    - Measure cooked/dry weight, record on worksheet.
    - Perform moisture calculations on the worksheet.
    - Save worksheet.

Salt Moisture Worksheet

Date: Company:

P.O. #: Ticket #:

A. Weight of wet salt

B. Weight of dry salt

C. Weight loss (A-B)

Moisture Calculations:

C÷A X 100 = _____ %moisture ***

Tested by:

Remarks:

***Typically you want a moisture content of less than or equal to 1.5% (check your agency's specification).

Testing sand

- Conduct a visual inspection of the material to make sure it is clean.
- Note that each agency has its own specifications based on available materials.

Testing liquids

- Take a 2 cup sample before unloading the tanker truck, use a clean container.
- Make sure you have the correct hydrometer for your material.
- Measure the specific gravity of the liquid using a hydrometer or salimeter.
- Record the results. Salt brine should have a salimeter reading of 85%, or a hydrometer reading of 1.176, which equates to 23.3% salt in the brine.
- Accept the load if the specific gravity is within specifications; if it doesn't meet specifications, don't unload, and notify the responsible supervisor.
- Keep a labeled, dated and sealed sample.

Glossary of Terms

Anti-Icing: The prevention of ice or frost formation upon a surface. Used typically to mean the application of liquid chemicals to prevent the formation of frost or the bonding of snow or ice to pavement.

AVL: Computer-based automatic vehicle location system; a GPS-based system which allows users to view vehicle location and other operational data through a computer portal.

BMPs: best management practices

Black Ice: Popular term for a very thin coating of clear ice which forms on a pavement or bridge deck surface.

Brine: Liquid deicer made of rock salt and water combination, 23% rock salt.

Brine Blends: Any solution for lowering the freezing point of water, with sodium chloride brine as the predominant component.

°C – degrees Celsius

$CaCl_2$: calcium chloride

Calibration: Measurement of the material discharged at each setting of a spreader.

Chloride: The most common ingredient in deicers.

Clear Roads: Clear Roads refers to the pooled funded project for winter maintenance research of which Michigan is a member. www.clearroads.org

De-icing: Defined as removal of existing, snow ice, frost, etc., from a surface. It includes both mechanical (blading or scraping) and chemical (application of salt or other ice melting chemicals) methods. De-icing after snow, ice or frost has already bonded to the pavement surface.

DEQ: Michigan's Department of Environmental Quality. Also referred to as MDEQ.

Dew Point: The atmospheric temperature (varying according to pressure and humidity) below which water droplets begin to condense and dew can form.

DLA: Direct liquid application. The use of straight liquids for deicing purposes.

DOT: Department of Transportation

Eutectic Temperature: Lowest freeze point attainable for a given solution or mixture. At the eutectic temperature, ice and saltwater and solid salt exist in equilibrium. For brine, the eutectic temperature -6°F.

°F – degrees Fahrenheit

Hydrometer: Measures the density of many liquids.

Hygroscopic: Nature of a substance, tending to absorb moisture from the air.

KAC: potassium acetate

DEQ: Michigan Department of Environmental Quality. Tasked with providing guidance and enforcement of the NREPA's Water Resources section, including Part 5 rules. Sometimes referred to as "MDEQ".

Lane mile (LM): An area considered to be 12 foot by 5, 280 feet or an area 63, 360 square feet.

lbs. – pounds

LOS (Level of Service): The LOS describes the desired end-of-storm condition and acceptable interim conditions.

MDSS: Maintenance Decision Support System

Melting capacity: Ice melting capacity is the weight of ice melted per pound of deicer at a given temperature. It can be expressed as the total amount of ice melt that can be achieved or it can be expressed as the amount of ice melt that will occur in a given period of time (e.g. 1 hour, 4 hours, etc.).

mg/l – milligrams per liter

mph – miles per hour

MSDS: Material Safety Data Sheet; content and safety information on chemical products.

$MgCl_2$: magnesium chloride

NaCl: sodium chloride

Non-community Water Supply: A water system that provides water for drinking or potable purposes to 25 or more persons at least 60 days per year or has 15 or more service connections. Michigan is home to nearly 10,000 non community water supply systems, which includes schools, restaurants, motels, campgrounds, and churches.

NREPA: Natural Resources and Environmental Protection Act, 1994 Public Act 451. Regulates facilities of environmental contamination in Michigan. Section 31 deals with Water Resources.

ppm – parts per million

Practical Temperature: Sometimes referred to as the effective temperature; the lowest temperature at which a chemical solution/product is useful for lowering the freezing point of water.

Prewetting: Action by which a solid material is wetted with a liquid via an on-board system either at the spinner or in the auger.

Pretreating: Action by which a solid material is wetted in the stockpile. It can either be delivered already pretreated by the supplier, treated with an overhead showering system, pubmilled, or wetted with a hose and loader, then rolling material to mix.

psi – pounds per square inch

ROI: return on investment

Part 5 Rules: Administrative rules promulgated pursuant to Part 31, Water Resources Portection, of the Natural Resources and Environmental Protection Act, 1994 PA 451, as amended (Act 451) MCL 324.3101 et seq and revised in 2009. The rules address release prevention planning, secondary containment, surveillance and release reporting requirements.

RWIS: Road weather information system; computer-based system of obtaining weather and surface data from remotely-located, permanent sensors.

Salimeter: Instrument that measures the density of salt brine. Also sometimes called a salinometer.

sq. ft. – square feet

Practical Temperature: Range of pavement temperatures within which a chemical will effectively melt ice.

Bibliography

Dean, W., Anderson, R., Bradbury, J.P., and Anderson, D. "A 1500-year record of climatic and environmental change in Elk Lake, Minnesota." Journal of Paleolimnology 2002 (27), pp. 287-299.

Dindorf, Carolyn and Fortin, Connie. "The Real Cost of Road Salt Use for Winter Maintenance in the Twin Cities Metropolitan Area of Minnesota." Draft report created for the Minnesota Pollution Control Agency. January 21, 2013.

Findlay, Stuart E.G. and Kelly, Victoria R. "Emerging Indirect and Long-term Effects of Road Salt on Ecosystems." Annals of the New York Academy of Sciences. March 2011 (Vol. 1223), pp. 58-68.

Gallivan, Frank et al. "Greenhouse Gas Mitigation Measures for Transportation, Construction, Maintenance, and Operations Activities." ICF International. August 2010.

"Global positioning system (GPS) technology can assist in tracking and reducing costs." Inside, (online) p 10. http://www.iowadot.gov/inside/inside_december_2011.pdf.

MDOT Operations Field Services Division. "Salt Bounce and Scatter Study." Final Report, November 2012.

Minnesota Department of Transportation (Mn/DOT), undated. MnDOT 2010-2011 Annual Winter Maintenance Report- At a Glance. http://www.dot.state.mn.us/maintenance/docs/MnDOT%20Winter%20at%20a%20Glance_1.26.12_WEB.pdf . Accessed on 6/21/12.

Minnesota Snow and Ice Control: Field Handbook for Snowplow Operators, Second Revision, published by the Minnesota Local Road Research Board, 2012.

Mullaney, J.R., Lorenz, D.L., Arntson, A.D. "Chloride in groundwater and surface water in areas underlain by the glacial aquifer system, northern United States." U.S. Geological Survey Scientific Investigations Report 2009 (5086) p. 41.

Murray, D M and Brenner, R. "Economic Analysis of the Environmental Impact of Highway Deicing Salts." Transportation Research Board Report. 1977. No. HS-024 782.

"Storm Water Management Fact Sheet: Minimizing Effects from Highway Deicing." US Environmental Protection Agency, Office of Water, Washington, D.C. (EPA 832-F-99-016). September 1999.

US EPA National Water Summary, 1986. Secondary maximum contaminant levels, (subpart B of Part 141, national interim primary drinking water regulations). US Code of Federal Regulations, Title 40, Parts 100-149, revised July 1, 1986.

Vitaliano, Donald F. 1992. “An Economic Assessment of the Social Costs of Highway Salting and the Efficiency of Substituting a New Deicing Material.” Journal of Policy Analysis and Management. 1992 (11-3) pp. 397-418.

Winter Parking Lot and Sidewalk Maintenance Manual: Environmental Impacts of Chloride. 2008 revision. Fortin Consulting Inc. with Minnesota Department of Transportation, Minnesota Pollution Control Agency and CTAP (Circuit Training and Assistance Program).

APPENDIX A: Policy and Education Examples

Level of Service Designations by MDOT.
http://www.michigan.gov/mdot/0,4616,7-151-9620_11057-225137--,00.html

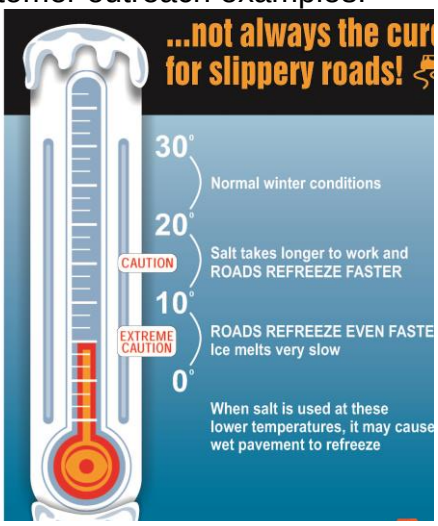
Michigan Winter Maintenance for Michigan Roads Program.
http://miwintermaintenance.weebly.com/

How Salt Works: New Hampshire Best Management Practices.
http://des.nh.gov/organization/divisions/water/wmb/was/salt-reduction-initiative/documents/bmp-salt-works.pdf

Minnesota Winter Maintenance Training and Manuals.
www.pca.state.mn.us/programs/roadsalt.html

Colorado DOT webpage for customer outreach.
http://www.coloradodot.info/travel/winter-driving/faqs.html

MDOT customer outreach examples:



See first link of this Appendix to find this document on-line.

APPENDIX B: Anti-icing Information

Anti-icing cost model
www.dot.state.mn.us/maintenance/training.html

Iowa Department of Transportation. *Anti-icing Equipment Manual* (with drawings for shop-made equipment). 1999.
www.dot.iowa.gov/maintenance/internetpages/chemicals/ManualAntiicingEquipment.pdf

Minnesota DOT *Anti-icing Guide*. 2010.
www.dot.state.mn.us/maintenance/docs/training/antiicingguide8Full.pdf

Anti-icing in winter maintenance operations: examination of research and survey of state practice
www.lrrb.org/media/report/TRS0902.pdf

Manual of Practice for an Effective Anti-icing Program: A Guide for Highway Winter Maintenance Personnel. 1996.
http://www.fhwa.dot.gov/reports/mopeap/mop0296a.htm#I17

Example Documentation Form For Anti-Icing

Anti-icing Route Data Form				
Truck Station: Date:				
Air Temperature	Pavement Temperature	Relative Humidity	Dew Point	Sky

Reason for applying:

Route:

Chemical:

Application Time:

Application Amount:

Observation (1st day):

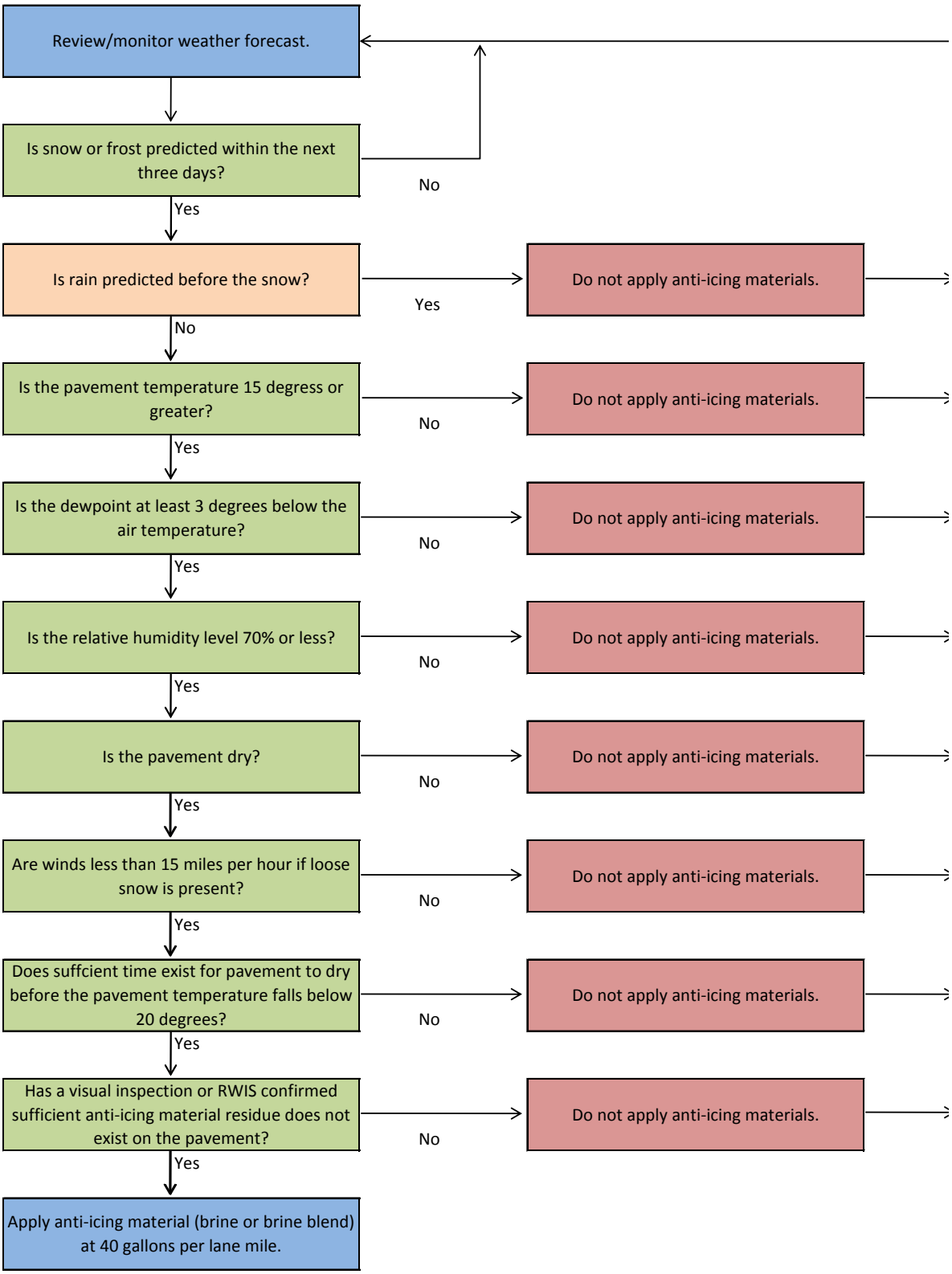
Observation (After event):

Observation (Before next application):

Name:

Source: Minnesota Snow and Ice Control: Field Handbook for Snowplow, Second Revision. Published by the Minnesota Local Road Research Board, 2012.

Anti-Icing Application Decision Flowchart



This is one example of an anti-icing flow chart. You should review this, change as appropriate to fit your organization, and put into place a customized decision tree for your organization.

Source: Anti-icing Decision Flowchart provided by Mark DeVries, McHenry County, Illinois.

APPENDIX C: Calibration information

Calibration Resources

Link to calibration of salt truck
http://michigan.gov/documents/mdot/mdot_ma_2009-02_calibration_of_salt_trucks_349377_7.pdf

MDOT Dickey John ICS 2000 calibration Manual
http://www.dickey-john.com/_media/pw_mac_ICS2000_calibration_and_programming_manual.pdf

MDOT Control Point Calibration Manual
http://www.dickey-john.com/_media/1-1489_1.pdf

Old MDOT Salt Calibration Instructions
http://inside.michigan.gov/sites/mdot/highways/ops/maintenance/mmm/Documents/Salt_Calibration_Instructions.pdf

Clear Roads has links to manufacturers' calibration instructions and a comprehensive calibration guide. Clear Roads: Research for Winter Highway Maintenance.
http://clearroads.org/researchprojects/05-02calibration.html

For liquid calibrations, see page 30 of the Minnesota DOT Anti-icing Guide (2010) at
http://www.dot.state.mn.us/maintenance/docs/Training/Anti%20Icing%20Guide%208%20Full.pdf

Road Salt Education Program, Minnesota Pollution Control Agency. Four types of calibration links, bottom of the page.
http://www.pca.state.mn.us/index.php/about-mpca/mpca-events-and-training/road-salt-education-program.html

Calibration Worksheet

Agency:	
Location:	
Truck No.:	Spreader No.:
Date:	By:
Gate Opening:	Pounds per Revolution:

Control **Setting**	Auger or Chain Sprocket Revolutions per Minute	Discharge Rate per Revolution	Discharge Rate per Minute	15 MPH X 4.00	20 MPH X 3.00	25 MPH X 2.14	30 MPH X 2.00	35 MPH X 1.71
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								
11								
12								

Sample Cab Card: courtesy of Michigan DOT

APPENDIX D: Equipment and Weather Resources

- **Blades and Plows**

The Clear Roads Institute has published a study of plow prototypes. 2011.
http://www.clearroads.org/downloads/Multiple-Blade-Snowplow-Project-Final%20Report_1-6-11.pdf

The Clear Roads Institute has published a study of carbide blade durability with comparisons. 2001.
www.clearroads.org/research-projects/07-01 carbideinsert.html

- **Equipment modification for low application rates**

For those unable to deliver an even spread pattern with a 9-inch auger at low application rates, one suggestion is exchanging the 9 inch diameter auger for either a 6 inch auger or a 9 inch "special" auger with larger core and smaller flighting; these "special" augers deliver about 2/3 less material per revolution.

- **Chute**

How to build a chute:

Minnesota Department of Transportation, Office of Maintenance-Training.
www.dot.state.mn.us/maintenance/training.html and

LLRB: Local Operational Research Assistance Program. Maintenance Decision Support System.
http://www.mnltap.umn.edu/about/programs/opera/fact/documents/washingtoncad.pdf

- **MDSS, AVL**

Pooled Fund Study Maintenance Decision Support System Website.
http://www.meridian-enviro.com/mdss/pfs/

Analysis of Maintenance Decision Support System (MDSS) Benefits & Costs, Study SD2006-10, Final Report. Prepared by Western Transportation Institute and Iteris, Inc., May 2009.
http://www.meridian-enviro.com/mdss/pfs/files/WTI-4W1408_Final_Report.pdf

- **Snow fence resources**

Illinois Department of Transportation. Snow fence information.
www.dot.il.gov/blr/1002.pdf

Minnesota Department of Transportation. Living Snow Fences. Snow fence and road design information to prevent blowing snow.

http://www.dot.state.mn.us/environment/livingsnowfence/index.html

Iowa Department of Transportation. Systems Operation Bureau-Office of Maintenance.
http://www.iowadot.gov/maintenance/snowfence.html

- **General Assessment of New Equipment/Resources**

Clear Roads cost benefit analysis toolkit. This provides instruction on how to do return on investment (ROI) calculations for new equipment and new techniques.
http://clearroads.org/research-projects/08-02costbenefitanalysis.html

Western Transporation Institute. Periodic bulletins with information on new equipment and new techniques.
http://www.westerntransportationinstitute.org/publications

Grid for bounce and scatter evaluation
www.sustainablesaltingsolutions.com/material_application_gr.html

- **Salt Storage and Handling**

Michigan Department of Environmental Quality. Salt is considered to be a polluting material under Part 5 Rules—Spillage of Oil and Polluting Materials, of Part 31 of NREPA—Water Resources Protection.
http://www.michigan.gov/documents/deq/deq-ess-p2tas-commercialsaltguidance_267027_7.pdf

Michigan DEQ Water Resources guidance document on vehicle washing.
http://www.michigan.gov/documents/deq/dnre-oppca-faq-vehiclemaintenance_341557_7.pdf

Indiana DOT Invests in Improved Salt Storage, Salt Institute Newsletter, First Quarter 2010.
http://www.bv.transports.gouv.qc.ca/per/0974374/09_2010/01_vol_47_no_1_2010.pdf

- **Weather Information**

Michigan Department of Transportation. Weather and road camera for specific Michigan highway locations. Provides air temperatures only.
http://mdotnetpublic.state.mi.us/drive/

APPENDIX E: De-icing Information

Example Loader Ticket: Daily Salt/Sand Issued

Operator	Shift	Date
Loader No.	Capacity of Bucket	

Stockpile	Truck #	Yards Sand	Yards Salt	Stockpile	Truck #	Yards Sand	Yards Salt
TOTALS							

Example Daily Salt/Sand Use Ticket

Operator Shift Date

Truck No. Capacity

Weather

Stockpile	Route	Yards Sand	Yards Salt	Yards Used	Yards Returned	Liquid Gallons

TOTALS

Clear Roads: Research for Winter Highway Maintenance. Testing the effectiveness of chemicals.
http://clearroads.org/
Click on research projects, completed projects.

MDEQ FAQ Deicers from Agricultural By-Products. Link to report is on the bottom of this page, under Miscellaneous.
http://www.michigan.gov/deq/0,1607,7-135-3307_36106-167850--,00.html

"Guidelines for the Selection of Snow and Ice Control Materials to Mitigate Environmental Impacts." The National Cooperative Highway Research Program. This is a comprehensive report.
http://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=883

Minnesota Snow and Ice Control: Field Handbook for Snowplow Operators, Second Revision. Minnesota Local Road Research Board. 2012.
http://www.mnltap.umn.edu/publications/handbooks/documents/snowice.pdf

Summary of an evaluation program of de-icing options by the New Hampshire DOT Research Board.
http://www.nh.gov/dot/org/projectdevelopment/materials/research/projects/documents/13733q_poster.pdf

Salt Bounce and Scatter Link
http://michigan.gov/documents/mdot/Final_ReportNov2012_404228_7.pdf

APPENDIX F: Environmental Information

MDEQ. Salt and Brine Storage Guidance for Road Agency Maintenance and Other Facilities.
http://www.michigan.gov/documents/deq/deq-ess-p2tas-bulksaltbrineguidance_267024_7.pdf

MDEQ, Rule 5 Guidance Documents.
http://www.michigan.gov/deq/0,4561,7-135-3313_23420-109985--,00.html

MDEQ guidance on how to develop a Pollution Incident Protection Plan (PIPP).
http://www.michigan.gov/documents/deq/deq-ess-p2tas-Part5PIPPchecklist_267025_7.pdf

Michigan's Storm Water Pollution Prevention Initiative (SWPPI). The SWPPI is a subset of the Watershed Management Plan and is typically due 2.5 years after the certificate of coverage is issued to the applicant. The following link details the SWPPI requirements as stated in the permit.
http://rougeriver.com/stormwater/permit.html

Proof's in: salt management protects the environment. Richard L. Hanneman. Salt Institute Newsletter. Third Quarter 2010
http://www.saltinstitute.org/content/download/12660/79607

Determining the toxicity of deicing materials. Research project funded by Clear Roads. (2012-ongoing).
http://www.clearroads.org/research-projects/11-02toxicity-of-deicing-materials.html

To learn more about Part 31 of NREPA, refer to the guidance document found line at
www.michigan.gov/deq
Select the "Get Involved Programs for Citizens" browser button on the left side of the webpage.

Environmental Fact Sheet, New Hampshire Department of Environmental Services, 2011. Includes information on best management practices.
http://des.nh.gov/organization/commissioner/pip/factsheets/wmb/documents/wmb-4.pdf

Information on the water quality of Michigan's inland lakes. Fuller, L.M., and Taricska, C.K., 2012, Water-quality characteristics of Michigan's inland lakes, 2001–10: U.S. Geological Survey Scientific Investigations Report 2011–5233.
http://pubs.usgs.gov/sir/2011/5233/

Water Quality and Pollution Control in Michigan. 2012
2012 Sections 303(d), 305(b), AND 314. MI/DEQ/WRD-12/001
http://www.michigan.gov/documents/deq/wrd-swas-draft-2012IR_370366_7.pdf

End Notes

[1] *Winter Parking Lot and Sidewalk Maintenance Manual: Environmental Impacts of Chloride*. 2008 revision. Fortin Consulting Inc. with Minnesota Department of Transportation, Minnesota Pollution Control Agency and CTAP (Circuit Training and Assistance Program).
[2] Mullaney, J.R., Lorenz, D.L., Arntson, A.D., 2009, Chloride in groundwater and surface water in areas underlain by the glacial aquifer system, northern United States: U.S. Geological Survey Scientific Investigations Report 2009–5086, 41 p.
[3] US EPA National Water Summary, 1986. Secondary maximum contaminant levels, (subpart B of Part 141, national interim primary drinking water regulations). US Code of Federal Regulations, Title 40, Parts 100-149, revised July 1, 1986, pp. 587-590.
[4] Dean, W., Anderson, R., Bradbury, J.P., and Anderson, D., 2002, A 1500-year record of climatic and environmental change in Elk Lake, Minnesota: Journal of Paleolimnology 27, 287-299.
[5] Findlay, Stuart E.G. and Kelly, Victoria R. Emerging Indirect and Long-term Effects of Road Salt on Ecosystems. Annals of the New York Academy of Sciences, Vol. 1223, pp. 58-68, March 2011.
[6] *Snow Fence Guide*. Strategic Highway Research Program (SHRP), 1991. SHRP - National Research Council, Washington, D.C., SHRP-W/FR-91-106.
[7] "Global positioning system (GPS) technology can assist in tracking and reducing costs." Inside, p 10. http://www.iowadot.gov/inside/inside_december_2011.pdf.
[8] Bruce Erickson, Oregon DOT Fleet Services Manager (Nov. 17, 2009) citied in *Greenhouse Gas Mitigation Measures for Transportation, Construction, Maintenance, and Operations Activities*, requested by Gallivan, Frank et al. ICF International. August 2010.
[9] *Minnesota Snow and Ice Control: Field Handbook for Snowplow Operators, Second Revision,* published by the Minnesota Local Road Research Board, 2012. http://www.mnltap.umn.edu/publications/handbooks/documents/snowice.pdf
[10] Salt Bounce and Scatter Study. Final Report, November 2012. MDOT Operations Field Services Division. http://www.michigan.gov/documents/mdot/Final_ReportNov2012_404228_7.pdf
[11] *Minnesota Snow and Ice Control: Field Handbook for Snowplow Operators, Second Revision.*
[12] Salt Institute. The Salt Institute references a dry density of 72 lbs./ft3 for the ASTM D632 Specification; however, there is a variability of density from mid 70s to 84 lbs./ft^3 for natural halite/salt. http://www.saltinstitute.org/About-salt/Physical-properties

(this page is blank for your notes)