

## 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<sub>2</sub>:** 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](http://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<sub>2</sub>:** 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 Protection, 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](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](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](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](http://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:



## Winter Level of Service Definitions



**Priority #1- Orange Route**  
Provide maintenance service as appropriate under prevailing weather conditions, with a goal of providing a pavement surface over its entire width "generally bare of ice and snow." This work may be accomplished using overtime as necessary.

Clearing the pavement bare of ice and snow over its entire width will be a continuous process during and after the snow event using overtime as necessary.

**Priority #2- Blue Route**  
Provide maintenance service as appropriate under prevailing weather conditions, with a goal of providing a pavement surface "generally bare of ice and snow" wide enough for one-wheel track in each direction. This work may be accomplished using overtime as necessary during a winter storm event.



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

working overtime.

A "generally bare of ice and snow" pavement is defined as a travel lane surface that is free from drifts, snow ridges, and as much ice and snow pack as practical.

Division of Operations – Roadway Operations Support Unit

## **APPENDIX B: Anti-icing Information**

Anti-icing cost model

[www.dot.state.mn.us/maintenance/training.html](http://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](http://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](http://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](http://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#l17>

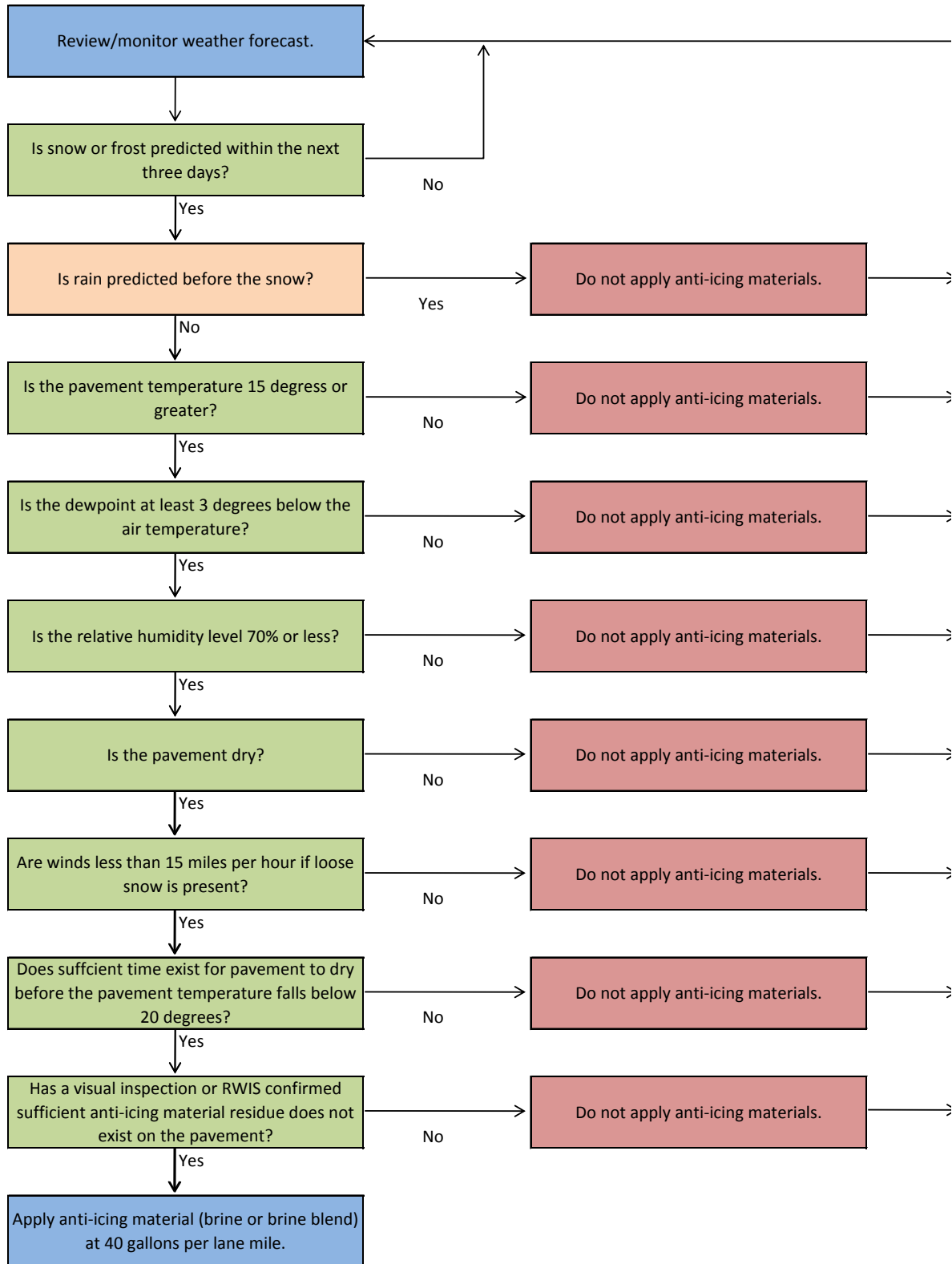
## Example Documentation Form For Anti-Icing

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 (1 <sup>st</sup> 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](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](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](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](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
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**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](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](http://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](http://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](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](http://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 Transportation 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](http://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-commercialssaltguidance\\_267027\\_7.pdf](http://www.michigan.gov/documents/deq/deq-ess-p2tas-commercialssaltguidance_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](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](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
<b>TOTALS</b>							

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
<b>TOTALS</b>						

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](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](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](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](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](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](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](http://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](http://www.michigan.gov/documents/deq/wrd-swas-draft-2012IR_370366_7.pdf)

## End Notes

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- <sup>1</sup> *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).
- <sup>2</sup> 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.
- <sup>3</sup> 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.
- <sup>4</sup> 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.
- <sup>5</sup> 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.
- <sup>6</sup> *Snow Fence Guide*. Strategic Highway Research Program (SHRP), 1991. SHRP - National Research Council, Washington, D.C., SHRP-W/FR-91-106.
- <sup>7</sup> “Global positioning system (GPS) technology can assist in tracking and reducing costs.” *Inside*, p 10. [http://www.iowadot.gov/inside/inside\\_december\\_2011.pdf](http://www.iowadot.gov/inside/inside_december_2011.pdf).
- <sup>8</sup> Bruce Erickson, Oregon DOT Fleet Services Manager (Nov. 17, 2009) cited in *Greenhouse Gas Mitigation Measures for Transportation, Construction, Maintenance, and Operations Activities*, requested by Gallivan, Frank et al. ICF International. August 2010.
- <sup>9</sup> *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>
- <sup>10</sup> 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](http://www.michigan.gov/documents/mdot/Final_ReportNov2012_404228_7.pdf)
- <sup>11</sup> *Minnesota Snow and Ice Control: Field Handbook for Snowplow Operators, Second Revision*.
- <sup>12</sup> Salt Institute. The Salt Institute references a dry density of 72 lbs./ft<sup>3</sup> for the ASTM D632 Specification; however, there is a variability of density from mid 70s to 84 lbs./ft<sup>3</sup> for natural halite/salt. <http://www.saltinstitute.org/About-salt/Physical-properties>