Executive Summary

Stantec Consulting Ltd. has been commissioned by Communities of Tomorrow to develop a set of guidelines or best practices of winter road maintenance practices, materials, and equipment that Saskatchewan municipalities can readily adopt and implement. The report analysis examines current sanding practices in Saskatchewan and other jurisdictions in Canada and the United States. The report also looks at alternative materials, technology, methods, and guidelines for best practices according to Transportation Association of Canada (TAC), and reviews recommendations for next steps. Questionnaires were sent out to jurisdictions within and outside Saskatchewan. In addition, significant research was conducted in accordance to the questionnaires.

The results of the questionnaires and research indicate that municipalities have their own level of service to achieve and one set of guidelines is not suitable for all municipalities. Many municipalities within Saskatchewan are focusing on traction control and de-icing for winter road maintenance operations. During low temperatures, sand is used to provide traction. Salt is the main chemical used because of availability and low cost. The use of abrasives can be effective, but is costly to clean up and may be more detrimental to the environment than salt. Both anti-icing and pre-wetting can be cost-beneficial winter operations. Anti-icing is more successful with accurate weather forecasting/pavement temperature technology, as well as warmer temperatures. Pre-wetting of materials can result in higher efficiency and effectiveness without the use of accurate weather forecasting/pavement temperature technology. Since the level of service provided and the size of Municipalities vary, a single set of recommendations may be less than desirable. The following are a number of suggestions for Municipalities to consider:

- Municipalities should establish a defined and achievable level of service, based on public consultation and on approved budget, then
- Develop procedures to provide the defined level of service.
- Creating a Salt Management Plan in accordance to TAC’s Syntheses of Best Practices is highly recommended. The Syntheses considers efficiency, effectiveness, and environmental concerns. A Plan would organize current practices, with consideration for future goals.
- Anti-icing has been found to be a cost-beneficial operation. However, it is suggested that anti-icing not be implemented until more accurate weather forecasts and pavement temperatures can be acquired through Road Weather Information Systems (RWIS) or any like technology. Once this is fully implemented, agencies may start looking towards adding anti-icing to their winter operations. Since many of the Municipalities within Saskatchewan are small in nature and RWIS is quite costly, the municipalities would require the support of the Province to install and implement RWIS. (Anti-icing is the application of a chemical to a roadway prior to or at the start of a weather event to prevent ice from forming. Preventing ice from forming makes it safer for road users, decreases the amount of abrasives used for traction control.)
• Municipalities may want to carry out pre-wetting trials as an additional operation to their winter road maintenance program. Many other agencies outside of Saskatchewan are using pre-wetting and have had great success with it. Pre-wetting of granular materials would aid in de-icing and provide a higher level of service to the public. However, pre-wetting cannot be recommended for all municipalities as it requires additional equipment, such as on-board spray systems, storage tanks, pumps, as well as additional maintenance. (Pre-wetting is a process of coating or treating the dry chloride de-icers and/or abrasives with a liquid prior to spreading on the road. Pre-wetting salt, sand/salt will better adhere to the pavement becoming less prone to blowing off from traffic before it can begin to activate.)

• Municipalities may wish to determine the merits of obtaining material with or from other communities for economic efficiency as it may be more cost beneficial to purchase and deliver larger quantities from a supplier.

• Several alternative materials were researched. Calcium chloride currently seems common when it comes to pre-wetting or anti-icing. It also has the lowest working temperature of the common snow and ice control chemicals, making it suitable for Saskatchewan’s climate. Calcium chloride can be supplied within Saskatchewan.

• Fusion, a sugar beet extract, may also be a product that is worthwhile conducting trials on. Its organic content makes it more eco-friendly, but has the risk for fermentation if not agitated regularly. It also has a low working temperature that would work well with Saskatchewan’s climate. Fusion is supplied out of Manitoba.

• In regards to equipment/technology, it is suggested that the larger municipalities obtain AVL/GPS for their fleet. It would be beneficial for tracking, monitoring, and record-keeping purposes.

• Salt and sand runoff is an environmental concern. If indoor storage is not possible, impermeable pads and covers are advised, as well as specialized wash bays with oil/grit separators for washing equipment.

Appendix A provides information on the responses to the questionnaire by Saskatchewan communities. For response to the questionnaire by communities from other provinces refer to Appendix B.
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1.0 Introduction

Communities of Tomorrow commissioned Stantec Consulting Ltd. to research and analyze winter sanding practices to provide the most effective results for participating Saskatchewan municipalities. The research and analysis consists of municipalities within Saskatchewan, other jurisdictions, and other possible options to generate a set of winter sanding guidelines, including suggested specifications for materials and application processes.

1.1 BACKGROUND

Environment Canada developed the Code of Practice for the Environmental Management of Road Salts to ensure environmental protection while maintaining roadway safety. The Code of Practice recommends the development of salt management plans and the implementation of best management practices for salt application, storage, and disposal.

The goal of Communities of Tomorrow’s project is twofold: to provide the municipalities in Saskatchewan with a set of cost beneficial and effective winter road maintenance guidelines that they can readily adopt and apply; and to provide these municipalities with potential alternatives that they can consider for future use.

To achieve these goals, existing municipal sanding practices in Saskatchewan, other provinces, and U.S. states were researched. A universal set of winter sanding guidelines for Saskatchewan municipalities will be analyzed and if applicable identified. Potential alternative materials, mixes, methods, scheduling, equipment, and technologies will be researched and analyzed, as well as options to broker relationship between municipalities and material suppliers. Based on these findings and evaluations, Stantec will provide suggestions on subsequent steps.
WINTER SANDING GUIDELINES

2.0 Existing Practices

2.1 SASKATCHEWAN SANDING PRACTICES

A Salt and Sand for Winter Road Maintenance questionnaire was sent out to 17 Saskatchewan municipalities early in 2012. Twelve responses were completed and received. Communities that responded include Humboldt, Lloydminster, Martensville, Meadow Lake, Melfort, Moose Jaw, North Battleford, Prince Albert, Regina, Saskatoon, Swift Current, and Yorkton. The objective of the questionnaire was to examine the current winter road maintenance practices within these municipalities and determine the level of need to adopt and implement alternative or more appropriate guidelines, practices, or specifications. Knowledge of other municipalities’ practices provides the opportunity for a municipality to improve their winter road maintenance operations by adopting practices of other communities. Appendix A contains the table summary of questionnaires sent to Saskatchewan communities.

2.1.1 Approach

The approaches to addressing snow and ice on roadways can be reactive and/or proactive. All municipalities stated that their only approach is reactive. The reactive approach has two goals: traction and/or de-icing. Eight of 12 municipalities stated their goals were both traction and de-icing. The remaining four municipalities focus on only traction.

2.1.2 Pre-wetting

Pre-wetting is a process of coating or treating the dry chloride de-icers and/or abrasives with a liquid prior to spreading on the road. Pre-wetted salt, sand/salt will better adhere to the pavement becoming less prone to blowing off from traffic before it can begin to activate. Most of the municipalities do not use pre-wetting as part of their snow and ice control operations. Lloydminster and Prince Albert were the exception. Lloydminster applies 32% calcium chloride to abrasives and/or solid chemicals as a pre-wetting agent. Prince Albert applies Ice Ban to abrasives and/or solid chemicals. The pre-wetting materials are applied by using on-board systems that spray the material as it falls down the chute onto the spinner. Saskatoon has equipment set up to pre-wet, but the method is not normally used. When used, Ice Ban is sprayed from on-board systems onto abrasives and/or solid chemicals as it falls onto the spinner. Regina has also conducted a trial pre-wetting with the product Caliber. Application rates are unknown or were not provided.

2.1.3 Material

The majority of municipalities use a blend of salt and sand. Some use solid salt, sand, or different mixes of sand and salt depending on the pavement temperature or weather event. Sand and salt is mainly used during and after the weather event, as opposed to before the event. Three municipalities specified that the material is used predominantly at intersections. As mentioned previously, Regina is conducting trial with Caliber as a pre-wetting agent. Saskatoon uses solid salt and liquid magnesium chloride for all weather events.
2.1.4 Cycle times/Frequency
Less than half of the municipalities that responded have cycle times/frequency for snow and ice control operations. Generally the cycle times of larger centers are more frequent than those of the smaller communities.

2.1.5 Material Supply/Volume/Cost
All municipalities use salt and sand. The quantity used per season ranges from 54 to 30,000 tonnes of sand and 5 to 3,000 tonnes of salt. Each municipality has a different supplier for sand. Four of the municipalities acquire their salt from NSC Minerals, two from Kayway Industries, two from Ministry of Highways and Infrastructure, and the remaining from various suppliers. Lloydminster also uses 40,000 L of calcium chloride supplied by Tiger Calcium at $0.285/L, including transportation to the City yard. Prince Albert uses 2,000 L of calcium chloride that they purchase from the Ministry of Highways and Infrastructure (MHI). In addition to sand and salt, Saskatoon uses 400 tonnes of solid magnesium chloride at $270/tonne supplied by Pounder Emulsions.

2.1.6 Material Specification
Half of the municipalities, mostly the larger ones, have a specification for sand. The gradations that were provided vary by municipality. The smaller sieve sizes, 160 µm and 80 µm, mostly have little to no material passing through (0-5%), as those smaller particles can create loss of traction.

The majority of the municipalities uses a 3-7% sand and salt blend. Depending on conditions, some jurisdictions use a 50/50 mix, 100% sand, or 100% salt. A few municipalities indicated they use a blend, however the ratio was not provided.

2.1.7 Monitoring/Record-keeping
Five of the municipalities have monitoring and record-keeping as part of their winter road maintenance program. These municipalities are the larger communities and focus on type/priority of material placed, and cycle times/frequency. Without monitoring or record-keeping it is difficult to assess progress and identify areas for further improvement. Progress can only be confirmed by tracking specific indicators and comparing these to the baseline that were benchmarked.

2.1.8 Equipment
Equipment capabilities include infrared thermometers, pre-wetting, anti-icing, AVL (Automatic Vehicle Location) or GPS (Global Positioning System), and ground-speed oriented electronic controllers with data collectors and variable spreading settings. Many municipalities are lacking equipment with such capabilities. Lloydminster has largest percentage of equipment with the largest percentage of equipment with the above capability. Regina and Saskatoon are the other centres with a large percentage of the equipment having the above capability. Regina has pre-
wetting capability and equipment equipped with infrared thermometers. However, percentages of equipment equipped with pre-wetting capability and surfaced thermometer weren’t provided.

2.1.9 Material Storage/Loading
For material storage, those who have solid or liquid chemicals store it indoors. Most sand/salt piles are stored outside with no cover and no runoff control. Only two municipalities have a tarp for covering their sand/salt piles. Most material is loaded outdoors. A few municipalities unload their salt indoors.

2.1.10 Salt-Vulnerable Areas
All municipalities, except for Moose Jaw, stated they have no salt vulnerable areas. There are eight considerations according to Environment Canada’s Code of Practice for Road Salts (2004) when determining salt vulnerable areas that some municipalities may not have considered. Areas draining into bodies of water (lakes, ponds, watercourses, significant wetlands adjacent to roadways) where road salts could potentially have serious adverse effects:

- Areas draining into small, moderately deep lakes where road salts could potentially create layers of water of different salinity to prevent vertical mixing
- Areas where road salts could harm local fish or fish habitat
- Areas adjacent to salt-sensitive native or agricultural vegetation
- Areas where road salts could potentially harm the integrity of a life cycle
- Areas where road salts could potentially harm a wildlife species on the List of Wildlife Species at Risk
- Areas draining into sources of drinking water
- Areas draining into groundwater recharge zones or that have an exposed or shallow water table

2.1.11 Snow Disposal Sites
Of the Municipalities that responded to the questionnaire, none have engineered snow dump sites. Three municipalities monitor non-engineered snow dump sites. Six municipalities do not mix and store their salt on impermeable surfaces, while five do. None have engineered snow dump sites, and only three monitor non-engineered snow dump sites. Also, three municipalities have specialized wash bays to wash winter road maintenance equipment.

2.1.12 Wash Bays
Three of the respondents indicated they utilize specialized wash boys to wash winter road maintenance equipment.

2.1.13 Weather Monitoring
The majority of the municipalities use both Environment Canada and the Weather Network services to monitor incoming weather events. Melfort does not use any monitoring system, while Martensville and Meadow Lake use the Weather Network only.
2.1.14 Operator Training
Ten of the 12 municipalities that responded to the questionnaire have incorporated operator training as part of their winter road maintenance program. The main topics of the training program include route familiarization, pre-season driver training, circle check procedures, spreader control operation, minor equipment repair, good housekeeping practices, record-keeping, and agency policies. Training demonstrates the value of new procedures and ensures personnel have the necessary skills and knowledge and are competent in delivering the program.

2.1.15 Existence and Use of Internal Guidelines
Four of the larger municipalities have sanding guidelines, practices, and specifications while three have a salt management plan in place.
3.0 Sanding Practices in Other Provinces

3.1 OUT OF PROVINCE QUESTIONNAIRES

In order to determine the overall most effective winter sanding guidelines, other jurisdictions were analyzed in terms of their municipal sanding practices. The Salt and Sand for Winter Road Maintenance questionnaire was sent out to seven municipalities outside of Saskatchewan. Responses were received from Airdrie, Edmonton, Red Deer, and Brandon. A table summary of the questionnaire responses can be found in Appendix B.

3.1.1 Approach
Half of the municipalities’ surveyed outside of Saskatchewan take a proactive and a reactive approach to addressing ice and snow buildup on roadways. The remainder only uses a reactive approach. The goal of the reactive approach by all municipalities is both traction and de-icing.

3.1.2 Pre-wetting
Three of the municipalities use pre-wetting as part of their normal winter road maintenance operations. Red Deer has done some pre-wetting, but feels they need further information and education before implementing pre-wetting as a standard practice. Pre-wetting is generally carried out on abrasives and solid de-icing chemicals. Airdrie and Edmonton use a pre-wetting solution of 20% and 30% calcium chloride, respectively. Brandon uses salt brine and Red Deer has used a 23% solution of salt brine in the past. Edmonton reported an application rate of 15-20 L/tonne. Most municipalities use on-board systems that spray the material as it falls down the chute and onto the spinner. Airdrie uses Epoke Spreaders which pre-wet the material at the spinner. This method includes a dosing system that pre-wets when the material has left the spinner and is in the air before the material lands on the roadway.

3.1.3 Material
All out of province municipalities use a blend of salt and abrasives (sand or chips). A higher concentration of salt is used as the temperature increases. Pavement temperatures indicating use of certain material vary by municipalities. Pre-wetting is typically applied at colder temperatures, when salt becomes less effective. One municipality that uses anti-icing uses liquid calcium chloride at pavement temperatures just below zero and at application rates of 70, 140 L/km, while another municipality uses liquid magnesium chloride at a rate of 1.21 L/m² at an unknown pavement temperature.

3.1.4 Cycle Times/Frequency
Cycle times/sanding frequency of ice control and sanding operations are part of all the municipalities’ winter road maintenance program. These times vary for each municipality and are more frequent in the larger centers.
3.1.5 Material Supply/Volume/Cost
Sand use ranges from 3,200 to 130,000 tonnes. Airdrie uses 0.481 tonnes of chips. Edmonton is using manufactured chips as well. Salt use ranges from 0.61 to 5,200 tonnes. Liquid calcium chloride ranges from 216,007 to 250,000 L. Brandon uses 4,000 L of liquid magnesium chloride. The only cost for sand that was given is $41.68/tonne. The cost of salt ranges from $93.53/tonne to $104/tonne. Airdrie gets their chips for $15.60/tonne. The cost of liquid calcium chloride and magnesium chloride are approximately the same at $0.26/L.

Abrasives are purchased from different suppliers. All salt is purchased from NSC Minerals, while calcium chloride is purchased from Tiger Calcium. Brandon purchases their magnesium chloride from Fort Distributors.

3.1.6 Material Specification
Most municipalities have a specification for sand, however they are all different. Brandon uses sand particles that are finer than specifications of other municipalities. Red Deer uses 5 mm washed sand. Since Airdrie does not use sand, their specification for fragmented washed chips is 10 mm or less.

The municipalities mostly use a 3-7% salt blend mixed with sand and/or chips. Airdrie also uses straight salt during and after the weather event when pavement temperature is -10°C or warmer.

3.1.7 Monitoring/Record-keeping
Monitoring and record-keeping items include type and priority of materials placed, percentage of equipment equipped with ground-speed controllers, percentage of equipment with pre-wetting capability, percentage of equipment with anti-icing capability, percentage of equipment with direct liquid application capability, percentage of fleet calibrated annually, application rates, and cycle times/sanding frequency. All out of province municipalities include monitoring and record-keeping as part of the winter road maintenance program. Airdrie and Brandon include almost all of the topics that were listed. Edmonton only focuses on a few, while Red Deer did not specify which topics they include.

3.1.8 Equipment Capability
Equipment capability includes features such as infrared thermometers, pre-wetting, anti-icing, automatic vehicle location (AVL/GPS), and ground-speed electronic controllers with data collection and variable spreader settings. All municipalities have equipment that has pre-wetting capability. Airdrie and Red Deer have equipment that has all the capabilities that were listed. Two of the municipalities use hand-held infrared thermometers for measuring the pavement temperature, and Airdrie relies on RWIS.

3.1.9 Material Storage/Loading
Brandon stores all material indoors. The remaining municipalities store all solid and liquid chemicals indoors or on an outdoor covered facility. Anything stored outside has an impermeable pad. Edmonton stores abrasives and sand/salt piles outside uncovered but includes impermeable pads with 100% runoff control.
WINTER SANDING GUIDELINES
Sanding Practices in Other Provinces
June 15, 2012

3.1.10 Salt-Vulnerable Areas
Two of the out of province municipalities stated that they do have salt vulnerable areas. All municipalities stated they mix and store sand and salt on impermeable surfaces.

3.1.11 Snow Disposal Sites
Most jurisdictions have engineered snow dump sites. Edmonton is the only jurisdiction that stated they monitor non-engineered snow dump sites. However it is believed that Regina monitors non-snow dumping sites.

3.1.12 Sidewalks
Most municipalities are responsible for a portion of the communities’ sidewalks and have sand available for residents to access.

3.1.13 Wash Bays
Many of the municipalities utilize specialized wash bays to wash winter road maintenance equipment.

3.1.14 Weather Monitoring
Environment Canada and the Weather Network are used by all municipalities. Airdrie, Winnipeg and Edmonton also use Road Weather Information Systems (RWIS) data.

3.1.15 Operator Training
Operator training includes route familiarization, pre-season driver training, “circle check” procedures, spreader controller operation, brine equipment operation, equipment washing procedures, minor equipment repair, good housekeeping practices, record-keeping, use and interpretation of pavement sensor data and forecasts, infrared thermometer use, and agency policies. All out of province municipalities include operator training as part of the winter road maintenance program. Three of the municipalities train employees in almost all of the topics that were listed. Red Deer’s operator training is not fully implemented. However, Red Deer plans to have their operator training program fully implemented in the future.

3.1.16 Existence and Use of Internal Guidelines
The length of roadway that the municipalities are responsible for ranges from 147 to 3751 km. All the municipalities have sanding guidelines, practices, & specifications and a salt management plan in place.

3.2 RESEARCH FROM OTHER PROVINCES
Municipalities in other provinces were researched, including Calgary, Cochrane, Ottawa, Richmond Hill, Toronto, Vaughan, and Winnipeg. Salt management plans for some of these municipalities were found. These jurisdictions may have information that may be useful to Saskatchewan communities.

3.2.1 Calgary
All information for Calgary was obtained in their Snow and Ice Control Policy (2011, AB). Plowing operations begin after at least 5 cm of snow has accumulated or when drifting snow significantly hinders traffic flow. On residential streets, plowing operations begin after at least 12
cm of snow has accumulated or when drifting snow significantly hinders traffic flow and it is too cold for truck mounted plows to be effective. Salt or a mixture of sand chips, and salt are generally applied if the snowfall amount is less than 5 cm. Salt is used as a de-icer when pavement temperatures are between 0 and -5°C. A sand chip mixture of 4% salt and 96% gravel is used when pavement temperatures are below -5°C.

Priority 1 Routes are plowed and sanded within 24 hours of the end of the snowfall, while Priority 2 Routes is 48 hours.

3.2.2 Cochrane

Information for the town of Cochrane was obtained from their council policy *Snow and Ice Removal* (2004, AB).

Sanding and salting of roadways is designated by eight priority classifications. Designated roadways, hills, and curves are spot sanded. Straight 7.0 mm sanding chips are applied when pavement temperatures are -12°C and lower and the temperatures are falling. A mixture of 15% salt and 85% sand is applied when pavement temperatures range from -5 to -12°C and temperatures are expected to be constant. When pavement temperatures range from 0 to -5°C and the temperature will be rising within five hours, straight salt is applied.

The Road Transport Division manages the melt water through their snow storage facility to abide by Alberta Environment Water Quality Regulations to protect surface and ground water resources. Melt water is not discharged to salt vulnerable areas and/or into groundwater recharge areas and areas over shallow aquifers. Six different salt vulnerable areas have been identified, ranging from surface water and groundwater bodies to vegetation along roadways. Reducing the runoff to these areas is part of their mitigation measures. They also ensure that stockpiling of sand and salt, sander loading, deliveries, and off-loading of materials can be done within the facility that is provided. Annual facility inspections are conducted to warrant that no salt has infiltrated the soil.

The Best Management Practices included in Cochrane’s Salt Management Plan are training, equipment and technologies, road salt usage, sand and salt storage, stormwater management, snow disposal, operations maintenance yard, vehicle washing, identifying and monitoring environmentally sensitive areas, and record-keeping.

A comprehensive training program is included in their Salt Management Plan. The following are learning goals and topics of the training program: Salt Management Plan, principles of ice formation, science of freeze point depressants, road salt usage, brine production and use, pre-wetting, anti-icing, plowing techniques, environmental protection, maintenance yards, spreader controls and calibrations, drift control, weather forecasts and decision-making, pavement temperatures, record-keeping, snow removal equipment, snow disposal, and the 4 R’s of Salt Management (right material, right amount, right time, right place).

Cochrane recognizes that equipment and technology is an important part of effective winter road maintenance. In recent years, they have purchased a motor grader, a front mount snowplow for a three-quarter ton truck, and two handheld infrared temperature thermometers. They planned to purchase loader mount electronic material scale, snow wing for motor grader, ARWIS, front mounted plows for tandem axle trucks, and pre-wetting and anti-icing equipment.
Spreader are calibrated every fall, checked regularly, and recalibrated as needed. Using electronic spreader controls, salt application is spread at a rate of 131 kg/km (gate setting 4.6 cm) and sand application is spread at a rate of 100-350 (average 345) kg/km (gate setting 9.4 cm). The salt is placed on the crown or high side of the roadway to allow distribution over the road surface.

Cochrane did not have specialized wash bays for washing equipment in 2004, but planned to implement this by 2006. To minimize corrosion, spreaders are often washed following a storm. The waste water is likely contaminated and is handled carefully and directed through an oil-grit separator before being discharged.

Monitoring and record-keeping is included in Cochrane’s program. Along with weather data reports from Environment Canada, areas maintained, material used (sand and/or salt), quantities of material used, specified operator, shift hours, and pavement and air temperature are documented. In 2004, they were using approximately 252 tonnes of salt per year. This is the latest information from Cochrane found. There is no information available that verifies if the initiatives stated in their policy have been implemented.

3.2.3 Ottawa

The City of Ottawa (2012) applies various materials such as dry salt, wet salt, 50/50 sand/salt mix, salt brine, calcium chloride brine, and abrasives to their roadways. Abrasives, sand and crushed rock, are used when temperatures are too cold for salt to be effective or when there is snow pack on the roads (Ottawa, 2012). Abrasives are used only to create traction.

Rock salt is pre-wetted with a liquid de-icer at the time of application to help the rock salt adhere to the roads and accelerate the melting process. The City has stated that pre-wetting decreases the use of salt by 20% (Ottawa, 2012).

Anti-icing is used only on the Transitway (bus rapid transit) and Highway 174 by applying a pre-wetted salt or a liquid solution. This prevents ice from forming and bonding to the pavement (Ottawa, 2012).

3.2.4 Richmond Hill

Richmond Hill (2005) has implemented a Salt Management Plan. As part of the plan, they have a Quality Control Plan that includes monitoring salt use, application rates, and training of operators.

Richmond Hill has two domes for sand and salt storage, limiting the amount of salt exposure to the environment caused by wind and storm water runoff. The town has an engineered snow disposal site that has the following design features: an impervious deck to protect ground water from contaminated melt water, stormseptor to separate grit from the melt water, water quality pond that provides a second grit separation, as well as diluting and cooling melt water, and a storm system that provides secondary cooling of melt water prior to entering a larger body of water (Richmond Hill, 2005).

Richmond Hill uses anti-icing for their primary road network, which comprises 375 out of the 1200 lane kilometers of roadway. Anti-icing is used under the following weather conditions: light snow storm, light snow storm with period(s) of moderate or heavy snow, moderate or heavy snow storm, frost or black ice, freezing rain storm, and sleet storm. Salt brine is sprayed on the
road surface (up to two days prior to a storm provided that the storm does not start out with freezing temperatures and rain). Successful anti-icing is dependent on type of precipitation, pavement temperature, and traffic volumes (Richmond Hill, 2005).

Pre-wetting of salt is utilized as it accelerates the de-icing process and reduces the loss of salt from bounce and scatter. Salt brine is made in-house with a 2,000 gallon brine-making unit. A third of the town’s trucks are capable of pre-wetting (with onboard poly tanks) and all contractor trucks have pre-wetting capability (Richmond Hill, 2005).

For salt and sand spreading, electronic spreader controls are utilized for plowing and sander trucks. This improves the accuracy of material application, and also allows for data collection and programmable settings. These are calibrated at the start of the season and midway through, or as needed. On average, a 50/50 salt/sand mix is applied at a rate of 70 kg/lane km, which results in a salt application of 35 kg/lane km (Richmond Hill, 2005).

There is one RWIS system, located in the south end of the town. Patrol vehicles also have mobile road temperature sensors. From data the RWIS station gathers, they are able to obtain the pavement temperature, pavement condition, wind speed and direction, and atmospheric temperature and humidity (Richmond Hill, 2005).

GPS is installed in all winter maintenance vehicles. In spreader/plowing trucks this allows for the recording and analysis of whether the plow is up or down, truck speed, vehicle location, start and finish, and if the spreader is on or off. In patrol vehicles this records and analyzes road conditions, pavement temperature, air temperature, precipitation type, general comments, and vehicle location (Richmond Hill, 2005).

The town is committed to recording when and where their material is used, and also the quantity that is taken out for each trip. This data is used to calculate and keep track of salt usage and distribution over the entire roadway network. Operator training is included in the winter maintenance program and consists of preseason preparation, weather basics, snow and ice control, equipment operations, and salt properties and environmental impacts (Richmond Hill, 2005).

The future initiatives set in 2005 include identifying and protecting salt vulnerable areas, replacement of the salt domes with drive-thru shed, enhanced salt brine storage facilities, have all equipment capable of pre-wetting, installation of another RWIS station, and enhancement on training and data collecting (Richmond Hill, 2005). No current information is readily available to confirm if these initiatives have been implemented.

3.2.5 Toronto
The City of Toronto implemented their Salt Management Plan in 2004. The guideline recommends applying a solid or pre-wetted solid de-icer once snow starts to accumulate on arterial roads or expressways. The salt application guideline is shown in Table 3-1 (Toronto, 2004). There is no updated information readily available since 2004.
### Table 3-1: City of Toronto Salt Application Guideline

<table>
<thead>
<tr>
<th>Road Classification</th>
<th>Winter Service</th>
<th>De-icer</th>
<th>Application Rate (kg/lane km)</th>
<th>Time Frame to Complete De-icer Operations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Expressways</td>
<td>Bare pavement</td>
<td>Rock salt</td>
<td>70/140/180</td>
<td>2-3 cm snow &amp; continuing 1-2 hrs</td>
</tr>
<tr>
<td>Arterials</td>
<td>Bare pavement</td>
<td>Rock salt</td>
<td>70/140/180</td>
<td>5 cm snow 2-3 hrs</td>
</tr>
<tr>
<td>Collectors</td>
<td>Center bare pavement</td>
<td>Rock salt</td>
<td>70/90</td>
<td>8 cm snow &amp; stopped 4-6 hrs</td>
</tr>
<tr>
<td>Locals</td>
<td>Safe &amp; passable pavement</td>
<td>Rock salt</td>
<td>70/90</td>
<td>8 cm of snow &amp; stopped 8-12 hrs</td>
</tr>
<tr>
<td>Laneways</td>
<td>Safe &amp; passable pavement</td>
<td>Rock salt</td>
<td>180</td>
<td>24 hrs</td>
</tr>
</tbody>
</table>

### 3.2.6 Vaughan

The City of Vaughan implemented a Salt Management Plan in 2005, and revised it in 2006 and 2007. The Salt Management Plan includes review and analysis of industry approaches and practices, implementation and documentation of the plan, staff education and training, monitoring and analysis, management review, environmental review, and practices and policy revision (Vaughan, 2007).

The City has a roadway network of approximately 790 center line kilometers (1,518 lane kilometers). The roads are classified into three classes. Straight salt is used in urban areas and a sand/salt mixture is used in rural areas on gravel roads (Vaughan, 2007). All de-icing materials are stored under cover in permanent storage structures; all salt is stored in indoor facilities on impermeable surfaces. The de-icing and plowing guideline is shown in Table 3-2 (Vaughan, 2007).

### Table 3-2: City of Vaughan De-icing and Plowing Guideline

<table>
<thead>
<tr>
<th>Road Classification</th>
<th>Type of Winter Service*</th>
<th>De-icer</th>
<th>Application Rates (kg/lane km)</th>
<th>Duration to Complete the De-icer Operation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary Roads</td>
<td>Bare pavement</td>
<td>100% rock salt</td>
<td>170</td>
<td>5 cm of snow &amp; within 4 hrs after snowfall stops</td>
</tr>
<tr>
<td>Primary Roads</td>
<td>Bare pavement</td>
<td>100% rock salt</td>
<td>130</td>
<td>2-4 cm of snow &amp; within 4 hrs after snowfall stops</td>
</tr>
<tr>
<td>Primary Roads</td>
<td>Bare pavement</td>
<td>100% rock salt</td>
<td>85</td>
<td>&lt;2 cm of snow &amp; within 4 hrs after snowfall stops</td>
</tr>
<tr>
<td>Secondary</td>
<td>Limited bare</td>
<td>100% rock salt</td>
<td>170</td>
<td>5 cm of snow &amp;</td>
</tr>
</tbody>
</table>
WINTER SANDING GUIDELINES
Sanding Practices in Other Provinces
June 15, 2012

<table>
<thead>
<tr>
<th>Road Classification</th>
<th>Type of Winter Service*</th>
<th>De-icer</th>
<th>Application Rates (kg/lane km)</th>
<th>Duration to Complete the De-icer Operation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roads</td>
<td>pavement</td>
<td></td>
<td></td>
<td>stopped 12 hrs after snowfall stops</td>
</tr>
<tr>
<td>Secondary Roads</td>
<td>Limited bare pavement</td>
<td>100% rock salt</td>
<td>130</td>
<td>2-4 cm of snow &amp; stopped 12 hrs after snowfall stops</td>
</tr>
<tr>
<td>Secondary Roads</td>
<td>Limited bare pavement</td>
<td>100% rock salt</td>
<td>85</td>
<td>&lt;2 cm of snow &amp; stopped 12 hrs after snowfall stops</td>
</tr>
<tr>
<td>Rear Laneways</td>
<td>Safe &amp; passable pavement</td>
<td>100% rock salt</td>
<td>130</td>
<td>2+ cm of snow &amp; stopped 24 hrs</td>
</tr>
</tbody>
</table>

*This is the desired condition of the pavement. However, it is necessary to have sufficient traffic volumes to activate and improve the characteristics or the de-icer, the time to achieve this condition will vary with time, duration, and intensity of each storm event.

Table 3-3 summarizes the City of Vaughan’s annual material use (Vaughan, 2007).

Table 3-3: City of Vaughan Annual Material Usage

<table>
<thead>
<tr>
<th>Material</th>
<th>2006/2007</th>
<th>5 Year Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solids</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rock salt (NaCl)</td>
<td>21,014.59 tonnes</td>
<td>21,929 tonnes</td>
</tr>
<tr>
<td>Sand*</td>
<td>465 tonnes</td>
<td>1,525 tonnes</td>
</tr>
<tr>
<td>Other</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ClearLane by Cargill De-Icing</td>
<td>2,048.61 tonnes</td>
<td>13,025</td>
</tr>
<tr>
<td>Technologies</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Sand is applied on sidewalks and on rural (gravel) roads only.

In 2007 their fleet size of 113 units included a variety of equipment, such as ploughs, spreaders, and combined units. Road patrol information is utilized with observations from municipal staff, adjacent municipalities and MTO contractors, and The Weather Network. They also use Environment Canada radar and their on-board infrared thermometers for monitoring/forecasting weather. In 2005, Vaughan partnered with the Weather Network to install Vaughan’s first RWIS station (Vaughan, 2007).

The Salt Management Plan lays out objectives to meet in terms of:
- record-keeping and monitoring;
- training;
- additional equipment and technology;
- finding alternative materials; and
- improving equipment washing (oil/grit separator).
3.2.7 Winnipeg

Winnipeg has one RWIS station and plans to have a second one operating in the fall of 2012. The Province of Manitoba has two RWIS stations and is reviewing and assessing the need for an additional RWIS station. Winnipeg currently has a contract with The Weather Network. Winnipeg uses liquid calcium chloride for pre-wetting and salt brine for anti-icing. Calcium chloride is added to the salt brine when temperatures are lower. The following salt application rates in Table 3-4 were provided by the City of Winnipeg. Sand is applied at 320 kg/lane km.

**Table 3-4: City of Winnipeg Salt Application Guidelines**

<table>
<thead>
<tr>
<th>Current Pavement Temp (°C)</th>
<th>Anticipated Pavement Temp Change</th>
<th>Precipitation Type</th>
<th>Salt Application Rate (kg/lanekm)</th>
<th>Recommended Maintenance Actions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Above 0</td>
<td>Higher</td>
<td>Any</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>0 or lower</td>
<td>Any</td>
<td>80</td>
<td>Apply chemical</td>
<td></td>
</tr>
<tr>
<td>-5 to 0</td>
<td>Higher</td>
<td>Frost/freezing rain</td>
<td>80</td>
<td>Apply chemical. Reapply as needed</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Snow</td>
<td>80</td>
<td>Apply chemical. Plow when snow depth exceeds 3cm. Reapply chemical as needed</td>
</tr>
<tr>
<td>Lower</td>
<td>Frost/freezing rain</td>
<td>80</td>
<td>Apply chemical. Reapply as needed</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Snow</td>
<td>120</td>
<td>Apply chemical. Plow when snow depth exceeds 3cm. Reapply chemical as needed</td>
<td></td>
</tr>
<tr>
<td>-10 to -5</td>
<td>Higher</td>
<td>Freezing rain</td>
<td>80</td>
<td>Apply chemical. Reapply as needed</td>
</tr>
<tr>
<td></td>
<td>Snow</td>
<td>120</td>
<td>Apply chemical. Plow when snow depth exceeds 3cm. Reapply chemical as needed</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Lower</td>
<td>Freezing rain</td>
<td>120</td>
<td>Apply chemical. Reapply as needed</td>
</tr>
<tr>
<td></td>
<td>Snow</td>
<td>160</td>
<td>Apply chemical. Plow when snow depth exceeds</td>
<td></td>
</tr>
<tr>
<td>Current Pavement Temp (°C)</td>
<td>Anticipated Pavement Temp Change</td>
<td>Precipitation Type</td>
<td>Salt Application Rate (kg/lanekm)</td>
<td>Recommended Maintenance Actions</td>
</tr>
<tr>
<td>--------------------------</td>
<td>---------------------------------</td>
<td>--------------------</td>
<td>-----------------------------------</td>
<td>--------------------------------</td>
</tr>
<tr>
<td>Below -10</td>
<td>Steady or falling</td>
<td>Snow</td>
<td>Not recommended</td>
<td>Plow when snow depth exceeds 3cm. Apply abrasives. Reapply as needed.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>3cm. Reapply chemical as needed</td>
<td></td>
</tr>
</tbody>
</table>
4.0 U.S. Sanding Practices

4.1 PRE-TREATING/PRE-WETTING

According to Ketcham, Minsk, Blackburn, & Fleege (1996), material gradations for pre-wetting range from coarse particles to fine particles, depending on the ice control operation. Coarse particles are better for de-icing, as they will move through the ice or snow layer more rapidly and with greater success. Fine particles are more suited for anti-icing as they cover a greater surface area and go into solution much faster. Calcium chloride may be a better pre-wetting agent than salt brine as it is hygroscopic; by absorbing moisture from the air, it will help the material stay on the pavement more effectively than salt brine that will dry up (Ketcham et al., 1996). The application rate will vary depending on particle size distribution, but it has been found that 38-45 L of salt brine will be sufficient for 1 ton of dry chemical of coarse gradation (Blackburn, Bauer, Amsler, Boselly, & McElroy, 2004). Some states have found that pre-wetted sand on a snowpacked road tends to break up the snow pack in a way that makes it more difficult to drive on (CTC & Associates LLC & WisDOT, 2011). When pre-wetting, Wisconsin usually applies 30-45 L of liquid/ton of salt (University of Wisconsin-Madison, 2005).

Pre-wetting can be accomplished by one of three methods (Ketcham et al., 1996):

- a pre-wetting chemical is injected into a material stockpile
- a pre-wetting chemical is sprayed onto a loaded spreader or onto the material as it is being loaded into the spreader
- by an on-board spray system that sprays the material as it is being spread

Pre-wetting the stockpile has many advantages; there is no spray equipment to purchase or maintain, no installation of liquid storage tanks, and there is no need for employee training on application procedures. However, if a stockpile is pre-wetted, it is essential that it is covered and placed on an impermeable surface to reduce the potential of dilution and runoff. Also, the material may not be uniformly pre-wetted. The stockpile may need to be worked frequently to keep it workable, and cannot be readily carried through a warm season without the chemical migrating from the pile (Ketcham et al., 1996). Minnesota’s ice and snow control handbook suggests treating a salt stockpile at 23-38 L/ton and a sand stockpile at 15-23 L/ton (Fortin & Dindorf, 2005). Pre-wetting of a load, or while loading, can have high corrosive effects on the truck equipment. Unused pre-wetted material cannot be left, and must be completely discharged. It is also difficult to get uniform coating of chemical on all particles. An on-board spray system is the most common method. It produces a more uniform spreading than the other two methods, and the material and pre-wetting solution is kept separate. However, this method also uses electric and hydraulic spray systems that need calibration and maintenance (Ketcham et al., 1996). Minnesota suggests an optimal application rate of 30-53 L of salt brine/ton (Fortin & Dindorf, 2005).
4.2 ANTI-ICING

Ketcham et al. (1996) provide an operations guide for anti-icing for six various weather events that can be found in Appendix C. Kline (2009) also surveyed various U.S. jurisdictions. The results were taken from Anti-icing in Winter Maintenance Operations: Examination of Research and Survey of State Practice, and can be found in Appendix D. Dry, solid materials are suitable for anti-icing if there is enough moisture on the pavement. For the initial application, solid chemicals will be effective when enough precipitation has fallen, but needs to be applied before ice or snowpack bonds to the pavement (Ketcham et al., 1996). If liquid chemicals are used, it can be used at temperatures below-5°C by increasing the application rates. If a rapid rise in temperature is forecasted, liquid chemicals can be used as low as -9°C (Ketcham et al., 1996). A 23% solution of sodium chloride applied at 94-141 L/lane km has been proven to be effective for anti-icing from non-precipitation events (Blackburn et al., 2004). Anti-icing with liquid chemicals is also a good strategy for temperatures above -6°C. Treating for anticipated or already occurred frost/black ice/icing with liquid chemicals is noted to be a good method. However, anti-icing is not a good strategy when temperatures are below -6°C, at the onset of a snowfall, at any freezing pavement temperature when the snowfall is preceded by rain, or during freezing rain or sleet events. There have been some occasions where using a liquid chemical has resulted in slippery conditions, even in the absence of precipitation or freezing temperatures. This seems to be caused by a combination of relative humidity, pavement temperature, and type of chemical used (Blackburn et al., 2004). It is important to note that there is the potential for chemical residuals becoming diluted and resulting in refreeze. Venner (2004) recommends that the first application of anti-icing should be completed two hours prior to the anticipated event. Pavement should also be cleared of as much snow, ice, and/or slush as possible before applying a liquid anti-icing chemical. For this reason, it may be beneficial for anti-icing trucks to be equipped with front end plows. Minnesota’s snow and ice control handbook (Fortin & Dindorf, 2005) recommends using stream nozzles for anti-icing application to maintain some bare pavement and reduce slipperiness. Scheduling applications on bridge decks and critical areas if temperature and conditions could produce frost or black ice may be something to consider. Anti-icing is not used under blowing/windy conditions or before predicted rain. Calcium or magnesium chloride is not recommended on warm roads (above -2°C) as they will absorb moisture and become slippery. Fortin & Dindorf (2005) provide a table for general anti-icing application rate guidelines as seen in Table 4-1:

<table>
<thead>
<tr>
<th>Condition</th>
<th>Litres/lane kilometer</th>
<th>Other products</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regularly scheduled applications</td>
<td>35-59</td>
<td>47-94</td>
</tr>
<tr>
<td>Prior to frost or black ice</td>
<td>35-59</td>
<td>47-94</td>
</tr>
<tr>
<td>Prior to light or moderate snow</td>
<td>35-59</td>
<td>47-118</td>
</tr>
</tbody>
</table>

Follow manufacturers’ recommendations.
University of Wisconsin-Madison (2005) states that most state DOT’s have extensive RWIS to rely on for anti-icing. Using liquid chemicals instead of pre-wetted solid chemicals may be more beneficial and cost-effective, but may dilute and cause refreeze. North Dakota DOT (2010) states that they use snow plows, tankers, automated bridge deck sprayers, and other equipment in the anti-icing operations. Direct liquid of applications include salt brine, a liquid sugar beet by-product added to salt brine, and potassium acetate (bridge surfaces). They primarily use anti-icing as their experience has shown that it takes three times the resources to de-ice than anti-ice.

4.3 DE-ICING

In Minnesota’s handbook, plowing to remove snow and loose ice is exercised before applying de-icing chemicals (Fortin & Dindorf, 2005). In regards to direct liquid application, some regions say that MgCl₂ is more effective than CaCl₂ because CaCl₂ burns hotter and faster and is more likely to have refreeze problems (CTC & Associates LLC & WisDOT, 2011). In Wisconsin, salt is the most common chemical used (University of Wisconsin-Madison, 2005). If chemical de-icer is used when the snow is still loose and unpacked, it will start to melt and turn the rest to slush for easier plowing. More de-icing chemical is needed at lower temperatures, during heavy snowfall, or if the snow is wet, and if freezing rain is expected. Salt is used at pavement temperatures above -6°C. Below this, calcium chloride or magnesium chloride are common alternatives.

4.4 ABRASIVES

Minnesota’s handbook suggests that a 25-50% salt/sand mix has been effective in increasing friction. Abrasives are only used in slow-moving traffic areas such as intersections and curves (Fortin & Dindorf, 2005). CTC & Associates LLC & WisDOT (2011) state that many agencies are trying to minimize their sand use because of effectiveness and impacts on the environment. Maine DOT has found that applying sand pre-wetted with a blend of 70/30 salt brine and Ice B’ Gone (a magnesium chloride blend) is the most cost effective approach. Boselly (2008) states that particle size should be limited to 1.3 cm, but particles passing through a #50 mesh sieve (300 µm) should not be used. To maintain workability, abrasives are usually treated with 3-5% of salt. In Wisconsin, abrasive material larger than a #50 sieve and smaller than 3/8” is used only at hazardous locations such as intersections, curves, and hills (University of Wisconsin-Madison, 2005). They have also found that pre-wetting sand with a de-icing chemical is effective.

4.5 ALTERNATIVE MATERIALS

McHenry County (MCDOT) created a blend of 85% salt brine, 10% Geomelt De-ice 55, and 5% calcium chloride (Devries & Hodne, 2006). For anti-icing operations, it was applied at a rate of 94 L/lane km and for pavement temperatures above -9°C. For pre-wetting, it was applied at 38 L/ton of salt, which worked to a pavement temperature of -17°C. The product seems to work well in all conditions and does not experience refreeze.
4.6 CLEAR ROADS: DEVELOPMENT OF A TOOLKIT FOR COST-BENEFIT ANALYSIS OF SPECIFIC WINTER MAINTENANCE PRACTICES, EQUIPMENT AND OPERATIONS

This project by Clear Roads (Veneziano, Fay, Ye, Williams, Shi, & Ballard, 2010) summarizes the results of practitioner surveys on information related to the winter road maintenance costs and benefits observed by agencies in the United States and some in Canada.

Most regions surveyed in the Clear Roads project use RWIS, followed by GPS and AVL. De-icing is generally used with solid chemicals and anti-icing with liquid chemicals. The most common application method is a spinner to apply solid de-icers followed by stream and spray methods for liquid de-icing. Based on their survey responses, the top ten items in relation to cost-benefit are: anti-icing, front and underbody blades, AVL, pavement temperature sensor, RWIS, de-icing, GPS, Maintenance Decision Support Systems (MDSS), carbide blades, and air temperature sensor.


Table 4-2: Salt Institute Stormfighting Guidelines for Various Types of Storms

<table>
<thead>
<tr>
<th>Stormfighting Guidelines</th>
<th>Condition 1</th>
<th>Condition 2</th>
<th>Condition 3</th>
<th>Condition 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature</td>
<td>Near -1°C</td>
<td>Below -1°C</td>
<td>Below -6°C</td>
<td>Below -6°C</td>
</tr>
<tr>
<td>Precipitation</td>
<td>Snow, sleet, or freezing rain</td>
<td>Snow, sleet, or freezing rain</td>
<td>Dry snow</td>
<td>Snow, sleet, or freezing rain</td>
</tr>
<tr>
<td>Road surface</td>
<td>Wet</td>
<td>Wet or sticky</td>
<td>Dry</td>
<td>Wet</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>If snow or sleet, apply salt at 500 lb per two-lane mile. If snow or sleet continues and accumulates, plow and salt simultaneously. If freezing rain, apply salt at 200 lb per two-lane mile repeatedly. If rain continues to freeze, reapply salt at 200 lb per two-lane mile. Consider anti-icing procedures.</td>
<td>Apply salt at 300-800 lb per two-lane mile, depending on accumulation rate. As snowfall continues and accumulates, plow and repeat salt application. If freezing rain, apply salt at 200-400 lb per two-lane mile repeatedly. Consider anti-icing and de-icing procedures as warranted.</td>
<td>Plow as soon as possible. Do not apply salt. Continues to plow and patrol to check for wet, packed or icy spots; treat them with heavy salt applications.</td>
<td>Apply salt at 600-800 lb per two-lane mile as required. If snow or sleet continues and accumulates, plow and salt simultaneously. If temperature starts to rise, apply salt at 500-600 lb per two-lane mile; wait for salt to react before plowing. Continue until safe pavement is obtained.</td>
</tr>
</tbody>
</table>
## Stormfighting Guidelines

<table>
<thead>
<tr>
<th>Condition 5</th>
<th>Temperature</th>
<th>Precipitation</th>
<th>Road surface</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Below -12°C</td>
<td>Snow or freezing rain</td>
<td>Accumulation of packed snow or ice</td>
<td>Apply salt at rate of 800 per two-lane mile or salt-treated abrasives at rate of 1500-2000 lb per two-lane mile. When snow or ice becomes powdery or slushy, plow. Repeat application and plowing as necessary.</td>
</tr>
</tbody>
</table>
5.0 **Alternative Sanding Practices**

The majority of Saskatchewan’s municipalities are currently using similar methods and materials. Traction with some de-icing and pre-wetting and the use of sand and sodium chloride are the more common options. The following alternative sanding practices will be discussed: materials, technology, and anti-icing.

5.1 **MATERIAL**

There are a variety of materials that various jurisdictions use for de-icing, anti-icing, or pre-wetting. Each material has unique characteristics that may be more beneficial to a certain jurisdiction, than another. Choosing a material is mainly dependent on climate, cost and availability, and the intent of use. For each material it is important to know the positives and the negatives, the cost, possible application rates, and the type of equipment and storage needed.

5.1.1 **Pros/Cons**

Table 5-1 contains general information on these materials. Also included in the table are pros and cons of the material listed. Some materials are more readily available, while others are more environmentally friendly or more effective at lower temperatures.

<table>
<thead>
<tr>
<th>Product</th>
<th>General</th>
<th>Pros</th>
<th>Cons</th>
<th>Document/Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>GEOMELT</td>
<td>- made from sugar beets</td>
<td>- freeze temp of -40°C</td>
<td>- cost?</td>
<td>GEOMELT (2012)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- reduces freeze point of salt brine to -34°C</td>
<td>- not for anti-icing</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>- working temp -15°C to -20°C</td>
<td>- requires agitation at least once a month to reduce the potential of fermentation</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>- less corrosive</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>- reduces salt use</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>- may reduce the number of applications</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>- improves melting efficiency</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>- prevents chunking and crusting</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>- no special mixing equipment</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fusion Liquid De-icer</td>
<td>- sugar beet extract</td>
<td>- working temp 37°C</td>
<td>- find source of transport</td>
<td>Eco Solutions (2012)</td>
</tr>
<tr>
<td></td>
<td>- anti-icing, pre-wetting salt/sand - 60/40 Fusion/salt brine blend</td>
<td></td>
<td>- agitate once a month</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Product</td>
<td>General</td>
<td>Pros</td>
<td>Cons</td>
<td>Document/Source</td>
</tr>
<tr>
<td>-------------------------</td>
<td>-------------------------------------------------------------------------</td>
<td>----------------------------------------------------------------------</td>
<td>----------------------------------------------------------------------</td>
<td>-----------------------------------------</td>
</tr>
<tr>
<td>Ice Bite</td>
<td>- sugar beet based anti-icing, de-icing, pre-wetting</td>
<td>- lowers working temp of salt to -20°C</td>
<td>- cost? - supplier? - will not spoil, recycle storage tanks every 2-3 weeks</td>
<td>Road Solutions, Inc (2012)</td>
</tr>
<tr>
<td>Ice Ban</td>
<td>- liquid made from corn milling, alcohol, and MgCl2</td>
<td>- eutectic temp of -55 to -31°C, depending on the blend</td>
<td>- ferments</td>
<td>Meltsnow.com (2012)</td>
</tr>
<tr>
<td>Caliber</td>
<td>- 30% MgCl2 with corn carbohydrate derivative</td>
<td>- working temp of -45°C</td>
<td>- Glacial Technologies - Dust Free Road Maintenance (2012)</td>
<td></td>
</tr>
<tr>
<td>Calcium Magnesium Acetate (CMA)</td>
<td>- works to -3/-6 C° - less toxic to environment - lasts longer, fewer applications - biodegradable - noncorrosive</td>
<td>- 20x more expensive than rock salt - slower acting than road salt - requires more quantity</td>
<td></td>
<td>Green Venture (2012) State of Michigan (2004)</td>
</tr>
<tr>
<td>Potassium Acetate (KAc)</td>
<td>- less toxic to environment - works to -26/-30°C - freezing point 60°C</td>
<td></td>
<td>- 8x more expensive than rock salt</td>
<td>Green Venture (2012)</td>
</tr>
</tbody>
</table>
### Product

<table>
<thead>
<tr>
<th>General</th>
<th>Pros</th>
<th>Cons</th>
<th>Document/Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Magnesium Chloride (MgCl₂)</td>
<td>- works to -15/-29°C - eutectic temp is about -33°C at a concentration of 21.6% - apply when pavement temp is between -23 and -1°C - less corrosive and expensive than calcium chloride - can be combined with a corn by-product to lower the freezing point of water - only apply when certain a storm is coming</td>
<td>- 5x more expensive than rock salt - chloride impact - attracts moisture - residual effect can remain up to 5 days if it doesn't get diluted. refreezing can occur from precipitation or moisture in air - don't apply if road temp is 0°C and above - add water if MgCl₂ gets slick</td>
<td>Green Venture (2012) Facilities Net (2008) Minnesota Department of Transportation (2012) Kline (2009) Ecomag Solutions Ltd. (2008)</td>
</tr>
<tr>
<td>Potassium Chloride (KCl)</td>
<td>- works to -11°C - no cyanide</td>
<td>- 2.5x more than rock salt - chloride impact</td>
<td>Green Venture (2012)</td>
</tr>
</tbody>
</table>

### 5.1.2 Temperatures and Concentrations

The following table, taken from SIRWEC (2011), includes five of the major de-icing chemicals and their practical working temperature, eutectic temperature, and eutectic concentration.

**Table 5-2: Chemical Temperatures and Concentrations**

<table>
<thead>
<tr>
<th>Chemical</th>
<th>Practical working temperature (°C)</th>
<th>Eutectic temperature (°C)</th>
<th>Eutectic concentration (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calcium chloride (CaCl₂)</td>
<td>-31.6</td>
<td>-51</td>
<td>29.9</td>
</tr>
<tr>
<td>Sodium chloride (NaCl)</td>
<td>-9.4</td>
<td>-21</td>
<td>23.3</td>
</tr>
<tr>
<td>Magnesium chloride (MgCl₂)</td>
<td>-15</td>
<td>-33</td>
<td>21.6</td>
</tr>
<tr>
<td>Calcium magnesium acetate (CMA)</td>
<td>-6</td>
<td>-27.5</td>
<td>32.5</td>
</tr>
<tr>
<td>Potassium acetate (KA)</td>
<td>-26</td>
<td>-60</td>
<td>49</td>
</tr>
</tbody>
</table>

### 5.1.3 Cost and Supplier

One Team. Infinite Solutions.
Not all costs and suppliers were readily available for each alternative material. Table 5-3 contains the current findings. Note that these are approximate costs. Transportation costs are excluded as these costs can be significant. Supplier locations are an important consideration.

Table 5-3: Material Cost and Supplier

<table>
<thead>
<tr>
<th>Product</th>
<th>Cost</th>
<th>Suppliers/Users</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>GEOMELT</td>
<td>- approx. $0.40/L</td>
<td>- supply from states</td>
<td>GEOMELT (2012)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- <a href="mailto:larry@futureroadsolutions.com">larry@futureroadsolutions.com</a></td>
<td></td>
</tr>
<tr>
<td>Fusion Liquid De-icer</td>
<td>- supplier: Collet Gravel in Notre Dame De Lourdes, MB Marcelle Robitaille (204) 248-2418 Jeff Gulyas (204) 792-8649 <a href="mailto:jeffg@ecosolutions.net">jeffg@ecosolutions.net</a> - user: Bob Last, district manager (204) 745-7471</td>
<td>Eco Solutions (2012)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ice Bite</td>
<td>- Jay Walerstein (317) 407-9772</td>
<td>- supplier: Collet Gravel in Notre Dame De Lourdes, MB Marcelle Robitaille (204) 248-2418 Jeff Gulyas (204) 792-8649 <a href="mailto:jeffg@ecosolutions.net">jeffg@ecosolutions.net</a> - user: Bob Last, district manager (204) 745-7471</td>
<td>Road Solutions, Inc (2012)</td>
</tr>
<tr>
<td>Ice Ban</td>
<td>- Pounder Emulsions (Saskatoon)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Caliber</td>
<td>- roughly $0.30-0.60/L - the more SK municipalities that use it, the cheaper it will be</td>
<td>- supplier: Dust Free Road Maintenance (Winnipeg) <a href="mailto:JimFreeday@DustFreeRM.com">JimFreeday@DustFreeRM.com</a> <a href="mailto:willy@forddistributors.com">willy@forddistributors.com</a> (204)785-2224 - supplier: meltsnow.com</td>
<td>Dust Free Road Maintenance (2012)</td>
</tr>
<tr>
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<tr>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Potassium Acetate (KAc)</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Calcium Chloride (CaCl)</td>
<td>- $800/tonne dry - $0.25-0.3/L liquid</td>
<td>- supply from Edmonton; Ward Chemical (780) 940-1133 - user: Bob Dunford, city of Edmonton <a href="mailto:Bob.dunford@edmonton.ca">Bob.dunford@edmonton.ca</a> - Tiger Calcium Inc. - NSC Minerals (Rocanville, Vanscoy)</td>
<td>Ward Chemical (2012)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Magnesium Chloride (MgCl)</td>
<td></td>
<td>- NSC Minerals (Rocanville, Vanscoy)</td>
<td>NSC Minerals (2012)</td>
</tr>
<tr>
<td>Potassium Chloride (KCl)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Product</td>
<td>Cost</td>
<td>Suppliers/Users</td>
<td>Source</td>
</tr>
<tr>
<td>------------------</td>
<td>------</td>
<td>-----------------</td>
<td>----------------------</td>
</tr>
</tbody>
</table>

### 5.1.4 Application Rates

Application rates will vary according to temperature, weather event, and the type of treatment that the material will be used for.

**Table 5-4: Material Application Rates**

<table>
<thead>
<tr>
<th>Product</th>
<th>Application Rates</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>GEOMELT</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fusion Liquid De-icer</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ice Bite</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ice Ban</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Caliber</td>
<td>- anti-icing: 70-95 L/km - de-icing: 95-141 L/km - pre-wetting: 15-60 L/tonne - mix sand and Caliber at 40L/tonne</td>
<td>- Glacial Technologies - Dust Free Road Maintenance (2012)</td>
</tr>
<tr>
<td>Calcium Magnesium Acetate (CMA)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Potassium Acetate (KAc)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Calcium Chloride (CaCl)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Magnesium Chloride (MgCl)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Potassium Chloride (KCl)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Salt (NaCl)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### 5.1.5 Type of Equipment and Storage Needed

Each alternative material will require a different type of storage and equipment depending on whether it is solid or liquid. How the supplier transports the material and the minimum quantity of material being transported will also dictate the volume of storage needed. Table 5-5 indicates the type of equipment and storage needed for each product, as well as the types and quantities of product delivery.

**Table 5-5: Material Equipment and Storage Needed**

<table>
<thead>
<tr>
<th>Product</th>
<th>Equipment/Storage</th>
<th>Source</th>
</tr>
</thead>
</table>

One Team. Infinite Solutions.
| GEOMELT | - transported by rail car  
- need min of 100,000 L storage | GEOMELT (2012) |
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Fusion Liquid De-icer</td>
<td>- available in freight size and totes (1000 or 1200L)</td>
<td>Eco Solutions (2012)</td>
</tr>
<tr>
<td>Ice Bite</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ice Ban</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
| Caliber | - comes in totes (1000L)  
- larger quantities available | |
| Calcium Magnesium Acetate (CMA) | | |
| Potassium Acetate (KAc) | | |
| Calcium Chloride (CaCl) | - 1000 L totes, 60,000 L rail  
- 25 kg bags, 1 ton bags, bulk, hopper bins | Ward Chemical (2012) |
| Magnesium Chloride (MgCl) | | |
| Potassium Chloride (KCl) | | |
| Salt (NaCl) | Generally supplied by truck load | NSC Minerals (2012) |

### 5.2 TECHNOLOGY

Weather detection technologies have a significant impact on effective winter road maintenance. Accurate weather is essential in providing the best choice of method, material, timing, and application rate to acquire the level of service that is set forth. Such weather detection technologies can reduce costs while improving snow and ice control programs. Some of these technologies include Fixed Automated Spray Technology (FAST), Global Positioning System (GPS)/Automatic Vehicle Location (AVL), and Road Weather Information Systems (RWIS).

Shi (2009) states in his article, *Winter Road Maintenance: Best Practices, Emerging Challenges, and Research Needs*, that FAST can be a useful and economical tool for specific locations that have more of a potential for dangerous conditions, such as bridge decks, to control these conditions before they arise. FAST can be cost-effective if their locations are chosen carefully and if it is coupled with reliable environmental sensors. RWIS can also provide pavement temperature and condition information through roadside sensing and processing equipment to aid in snow and ice control operations.

According to SIRWEC(2011), a RWIS is the most effective tool for making the most appropriate winter road maintenance decisions, specifically when to apply anti-icing and de-icing chemicals and the timing of snow removal operations. SIRWEC (2011) also mentions the following:

- RWIS are not comprised solely of sensors embedded in the road or mounted on roadside towers. On a broader level, they can include any device that captures and transmits road weather information; such as mobile infrared thermometers which are either handheld or mounted on a vehicle or electronic spreader controls which monitor prescribed chemical application rates and location. Static outstations are not necessarily the best solution for all situations. They are extremely valuable for large road networks, but less useful for monitoring urban road systems [depending on size of community]. In these environments, local conditions can vary considerably due to the presence of...
buildings and heavy traffic, and as such vehicle mounted and hand held sensors can be more effective in tracking localized variations in road surface conditions.

Infrared technology works well for wet, slushy, and damp roads, but not as well for dry pavement on clear nights, heavy snow or ice, or when there is a major variation between air and pavement temperature (Boselly, 2008). Although infrared technology is easier to maintain, they are not as accurate as pavement sensors. The Green Municipal Fund (2004) did a case study, Advance Road Weather Information System Network, in the County of Renfrew, Ontario in 2004. In the case study, two stations were installed and evaluated over a course of two years. The stations would collect and transmit road and atmospheric data to Environment Canada to develop weather forecasts to allow the County to make more accurate decisions for snow and ice control measures. Though the study indicates that the RWIS did not directly make significant improvements, it is arguable that RWIS is only a component of improving salt management and effectiveness, and that other elements need to be implemented in conjunction in order to achieve considerably improved results. From this study, it was learned that for RWIS to be successful, staff requires training and need to support the use of the new technology. Steve Boland, County of Renfrew’s Manager of Maintenance, comments that it may not be necessary for smaller municipalities in Ontario to carry out their own RWIS systems since the Ontario Good Roads Association has developed a way for the smaller municipalities to buy into the Ontario Ministry of Transportation RWIS. This may be something that Saskatchewan may wish to pursue in the future.

These technologies may be extremely useful and beneficial; however the challenge lies within identifying the level of need and the various obstacles that come with implementing new technology. Some of the central obstacles include cost and training. Geographic Information Systems (GIS) and/or AVL/GPS may be more feasible options that can help the municipality track their routes and the positions of their fleet.

5.3 ANTI-ICING

Anti-icing is the application of a chemical to a roadway before or at the start of a weather event to prevent ice from forming. If successful, anti-icing has many advantages. The prevention of ice from forming makes it safer for road users, as well as decreasing the amount of abrasives used for traction control reducing the cost of spring clean-up. This proactive approach to winter road maintenance essentially uses less material than the reactive approach of de-icing and traction, which is in turn more effective in the long run. However, successful anti-icing requires accurate weather forecasts and pavement temperatures in advance to have sufficient time to apply anti-icing as well as to know when to apply since anti-icing is not recommended during certain conditions. Perfect timing of anti-icing results in the least amount of product used for the most effectiveness. This accurate weather information comes from accurate weather forecasts along with RWIS technology that was previously discussed. Saskatchewan municipalities do not currently have RWIS, which is needed for anti-icing. Also, anti-icing with liquid chemicals is generally effective for temperatures above -5°C, and -9°C for solid chemicals; temperatures in Saskatchewan during winter are usually much below that (Kline, 2009). Anti-icing also requires equipment that has the anti-icing capability, increasing capital and maintenance costs. Though anti-icing has its benefits, Saskatchewan does not have the equipment and technology (and possibly the budget) to incorporate this snow and ice control operation at the time. Anti-icing
may be something Saskatchewan municipalities could adopt in the future, however further study and analysis would be needed in terms of obtaining RWIS and the equipment and resources to support it.
6.0 Guidelines for Best Practices

6.1 TRANSPORTATION ASSOCIATION OF CANADA (TAC)

The Transportation Association of Canada (2003) published a Syntheses of Best Practices for Road Salt Management covering nine various topics. The topics discussed will be salt management plans, pavements and salt management, snow storage and disposal, and winter maintenance equipment and technology. The Syntheses of Best Practices was created to help agencies in managing their road salt and to find the most effective winter road maintenance program for each agency. It is suggested that jurisdictions create their own best practices based on level of service, equipment capabilities, and budget in accordance to TAC’s Syntheses of Best Practices.

6.1.1 Salt Management Plans

The objective of a Salt Management Plan is to guide the agency to provide safe, efficient, and cost-effective roadway systems. The framework for a Salt Management Plan should contain the following elements as outlined in Transportation Association of Canada (2003):

1. Salt Management Policy and Objectives
   - The agency should adopt a salt management policy that commits the organization to measurable improvements in its salt management practices.

2. Situational Analysis
   - Current practices must be established to prove a benchmark against which progress can be measured. The following elements may be considered:

   On Road Use
   - type and amount of chloride freeze point depressants used
   - type and amount of non-chloride freeze point depressants used
   - application rates of each material
   - percentage of fleet with pre-wetting
   - percentage of fleet with liquid only applications
   - percentage of fleet with electronic spreader controls
   - number of RWIS installations
   - number of other surface temperature measuring devices (hand-held or vehicle mounted)

Salt Vulnerable Areas
   - location of salt vulnerable areas
   - description of winter maintenance practices in the area
     - groundwater recharge areas
     - exposed or shallow water tables with medium to high permeability soils
     - sources of drinking water
     - salt-sensitive vegetation
- salt-sensitive wetlands
- small ponds and lakes
- rivers with low flows
- salt-sensitive agricultural areas
- salt-sensitive habitats for species at risk

Sand and Salt Storage Sites
- number and capacity of storage sites
- percentage of sand/salt piles covered and type of cover
- percentage of indoor loading
- management of drainage from sand/salt mix
- levels of environmental indicators (chloride levels)
- percentage of salt in sand
- percentage of sites with washwater treatment
- existence of good housekeeping policy and adherence

Training
- percentage and frequency of staff receiving training in best salt management practices broken down into categories of hierarchy (managers, supervisors, operators)

3. Documentation
Each agency should have documented policies, procedures, and guidelines in the following areas:
- level of service for each roadway type
- salt and sand application rates
- sand and salt storage
- good housekeeping practices for maintenance yards
- equipment calibration and recalibration
- training
- snow disposal
- incorporation of salt management consideration into road design and construction
- salt vulnerable areas

4. Proposed Approaches
Clear tasks, schedules with milestones, budget considerations, and assigning responsibilities should be incorporated into salt management plans. The plan should also be focused on the four areas of concern: general road use, salt use in salt vulnerable areas, salt storage, and snow storage and disposal. It should include pre-season, in-season, and post-season actions to be taken to reduce the adverse effects of road salt, and consider equipment, labour, materials, and local climate. The plan should be aimed towards providing results.
6. Training
Salt management plans will require changes in procedures, practices, and equipment. Therefore, a comprehensive training and education program should be included. Training demonstrates the value of new procedures and ensures personnel have the necessary skills and knowledge and are competent in delivering the program.

7. Monitoring, Record-keeping, Reporting & Analysis
Progress can only be confirmed by tracking specific indicators and comparing these to baseline conditions. The monitoring and record-keeping system should document and analyze the indicators identified in the situational analysis. Any changes from the baseline should be sufficiently assessed to account for variances and the degree of progress being made. All results should then be reported to senior management. Without monitoring record-keeping or reporting of analysis, it is difficult to assess progress and identify areas for further improvements.

8. Management Review
The previous year’s salt management actions should be reviewed each year to confirm that the salt management plan has successful outcomes and to adjust next year’s plan to improve on shortcomings and include new opportunities. Policies and procedures should be updated. Budget factors should be taken into consideration at this time for funding needs.

6.1.2 Pavements and Salt Management
Salt management is affected by type of pavement surface, pavement thermal and material properties, and environment and climate (Transportation Association of Canada, 2003). Snow and ice control decisions should be based on pavement temperature rather than air temperature. Continuous monitoring of pavement temperatures is important to good decision-making because pavement temperatures can fluctuate based on time of day, degree of sunlight, sub-surface conditions (frost penetration, moisture presence, thermal retention properties, etc.), and type of pavement. This can be done using hand-held or truck mounted infrared thermometers, or Road Weather Information Systems (RWIS). Pavement temperatures should be recorded, as well as pavement conditions, weather conditions, and snow/ice control treatment strategy.

Road salt is usually placed on the crown or high side of the roadway where a good cross slope and traffic will distribute the brine over the road surface. Wider spread patterns are needed on deteriorated pavements that have undulating or poor cross fall surface, as well as when treating frost or black ice conditions. Liquid chemicals or pre-wetted salt can prevent or clear frost more quickly than dry solid salt. Straight liquid may avoid the endothermic cooling effect that solid salt can have on pavements. Good pavement design and construction can also improve salt performance, minimize usage, and reduce environmental impacts.

6.1.3 Snow Storage and Disposal
Snow storage and disposal sites contain snow with contaminants that are deposited on the ground or carried away in the meltwater. The meltwater and debris should be treated before being discharged into the environment. TAC includes a site selection and development process
that includes these steps: needs assessment, identify candidate sites, environmental inventory, site selection, design & construction, and operation, monitoring, & maintenance (Transportation Association of Canada, 2003).

It is important to understand how much snow you need to handle and the source areas. This comes from determining the snow removal locations and volumes of snow to be removed. Include any future snow removal locations. There may be a need for a variety of sites. A permanent site is used to handle snow disposal for most years. Temporary, contingency, or emergency sites can be used for the unusually bad years. Determine the cost of snow removal, storage, and disposal. Costs include loading, hauling, dumping, melt snow, maintenance, repairs, and upgrades.

The next step is identifying candidate sites. This includes assessing existing sites to determine their acceptability and determining baseline conditions for candidate sites. Candidate sites should have the following features: low permeable soils, natural slopes with a ponding area, and discharge to a high volume surface water receiver or sanitary sewer (Transportation Association of Canada, 2003).

The assessment and evaluation step includes reviewing and evaluating existing snow removal methods and storage and disposal sites. Once candidate sites have been identified, they are also assessed and evaluated. The following criteria should be considered (Transportation Association of Canada, 2003):

- Snow hauling distances
- Snow hauling routes and site access (accommodate heavy truck traffic)
- Past and current site land use (type of land, use of land, electrical transmission lines, underground utilities, etc.)
- Current and future land use (avoid residential, institutional, and recreational land uses)
- Zoning
- Size of the site (sufficient area)
- Sub-surface conditions (underlying soil and rock structures)
- Protection of water quality (proximity to water sources, meltwater discharge)

The design, construction, and implementation stage should address the requirements of (Transportation Association of Canada, 2003):

- efficient site operation (truck routes, vehicle management/snow loading areas, access to electrical power, onsite building, monitoring points and equipment, maintenance access for collection, treatment, and discharge areas)
- proper base construction (solid base, low permeability, sloping)
- drainage and meltwater management (meltwater collection pond)
- site security and environmental controls (fenced-in site, lighting, berms)

Once a site has been approved and commissioned for use, the following operational and maintenance issues should be addressed (Transportation Association of Canada, 2003):

- Site management (site responsibility, security, vehicle management, large debris management, litter control, monitoring and data collection)
- Snow pile and meltwater management (pile management, equipment, proper and efficient pile melting, flow of meltwater)
- Off season (spring, summer, fall) maintenance (collection and disposal of contaminants, evaluating route roads, evaluating site surface and base, cleaning, security)

Site monitoring and record-keeping is also an important aspect of snow storage and disposal. Staff should monitor: what is brought onto the site, what is being discharged from the site, any on-site and downstream contamination and environmental impacts, and the operation of the site. Records should be kept of general site information, volume of snow dumped and when, estimate of melt rate, debris volume and type, contaminants, and maintenance and operation records (Transportation Association of Canada, 2003).

Communities of Tomorrow will provide information with respect to snow storage and disposal.

6.1.4 Winter Maintenance Equipment and Technology

Equipment and technology is evolving in cost-effectiveness and efficiency. In addition to methods and road conditions, equipment is a significant factor in winter maintenance. In order to make the best winter maintenance decision, information is needed to support their judgment.

6.1.4.1 Information and Decision-making Tools

Road Weather Information Systems (RWIS) supports winter road maintenance operations with the following (Transportation Association of Canada, 2003):

- Pavement temperature forecasts and trends can improve the accuracy of decision-making
- Sensors in the pavement or sub-surface can generate data that can be transmitted to develop trends and forecasts
- Pavement sensors can monitor pavement and subsurface temperatures, wet/dry status, freeze point of solution on the road, presence of chemical and concentration
- Tower based sensors can provide real-time information of atmospheric conditions such as precipitation, relative humidity, dew point, air temperature, and wind speed and direction
- Other types of sensors and systems can be added to RWIS for further support (fixed automated spray technology)

Infrared thermometers (IRT's) provide current road surface temperature, with a portable feature. Hand-held and truck mounted versions are available. The data can also be recorded and transmitted as part of the data stream of a GPS/AVL system.

Road surface traction measurement provides information about the current friction level of the road surface. Friction sensors have been used extensively on airport runways, but their high cost restricts the use on roads. There have been some instances of friction sensors being mounted on spreader vehicles and used with on-board pavement temperature measurement equipment to automatically control the application rate of chemicals. Road surface traction measurement can be accurate and reliable, as well as have the potential to eliminate the unnecessary use of salt on roads with adequate traction (Transportation Association of Canada, 2003).
6.1.4.2 Using Mechanical Means to Control Snow and Ice

Anti-icing can result in overall less salt use, and prevents snow and ice from bonding to the pavement surface, and thereby simplifying the mechanical removal process. Accumulated snow and slush can be mechanically removed through the use of plows mounted on trucks, motor graders, or loaders.

There are a variety of snowplowing options to choose from, including the type of vehicle unit and the type of plow. A more detailed description of each can be found in series 9.0 Winter Maintenance Equipment and Technology of TAC's Syntheses of Best Practices. Vehicles can include:

- Trucks
- Motor Graders
- Loaders

Plows must be carefully selected to be mounted properly on the vehicle and best achieve the desired outcome. There are many features that plows should be equipped with, such as shoes, tripping mechanisms, and sufficient weight. TAC also suggests a few different angles to allow for the most efficient snow removal. Plows with an angle of 55° between the blade and the road are efficient at moving large quantities of snow. Angles of 75° between the blade and the road provides effective cutting of heavy packed snow and ice. Plows can include:

- Front mounted one-way plows (move snow to the right)
- Front mounted reversible plows
- Front mounted “V” plows
- Wings or wing plows
- Underbody plows
- Vertical plows
- Cutting edge or blade

Various snow removal and disposal methods and equipment are available. The following are some methods that the agency may use (Transportation Association of Canada, 2003):

- Loading, hauling, dumping
  - Most cost effective and easily mobilized (determined by capacity of loader and truck body)
  - Loader fills dump truck(s), which then hauls the snow to the site
  - Auxiliary equipment may be needed
  - Impacts traffic flow
- Mobile conveyors
  - Used to load snow from shoulders or windrows directly into trucks
  - Operate entirely on shoulder to not impact traffic
- Snow melting
  - Snow that is picked up is placed into a heated box to melt. It is usually then drained in to the storm sewer system
  - May be useful if hauling costs are high (snow disposal site is far)
  - If sand is heavily used, it may cause plugging problems
- Snow moving
Moving the snow accumulations further back beyond the roadway and shoulder

Snow blowers
- Normally used for post-storm removal
- Used to load trucks
- Mounted on dedicated trucks, trucks, or large front-end loaders
- Used to relocate snow
- Must be aware of wind conditions
- Leaves behind some snow

6.1.4.3 Using Road Salts to Control Snow and Ice

Preventing a snow/ice bond to the pavement surface should be the first priority. If that is not possible, then destroying that bond should be done as quickly as possible. By doing so, removal by plowing is made easier. The following are various chemical control strategies, including methods and equipment.

Anti-icing is the proactive approach to snow and ice control by preventing the snow/ice bond to the roadway surface. It can involve the chemical application of liquids, pre-wetted materials, or dry materials. Direct liquid application is most efficient since they provide immediate melting action, and do not depend on various factors to dissolve into brine. The timing of liquid application is not as critical as granular materials. Traffic will help spread the liquid across the roadway. If NaCl brine is applied earlier than the onset of a storm, it will evaporate leaving a salt crystal residual on the pavement, which will re-dissolve and form brine with precipitation. Hygroscopic brines, such as CaCl₂ and MgCl₂, attract moisture and will continually wet the road until dissipated. However, using any liquid will temporarily decrease the friction of the road. This can be minimized by using the appropriate liquid application method. Generally the same weight of salt as liquid is more effective than same weight of dry solid salt. However, the cost may be greater for liquid application. Trucks used for anti-icing can range in size to accommodate frame-mounted or slide-in tanks. Pencil streams at 200 mm to 300 mm spacing are the preferred application. Tube trailers that run from each nozzle to the road surface are also used. Though the tube may wear from friction against the pavement surface, it better targets the liquid onto the road (Transportation Association of Canada, 2003).

Pre-wetting is a common method to improve the retention of snow/ice control materials on the roadway (Transportation Association of Canada, 2003). It uses a liquid chemical such as salt brine, calcium chloride, or magnesium chloride to wet solid salt or abrasives as they are being spread. This method also improves the melt action by accelerating the dissolving of the salt. Spraying stockpiles or truck loads is also a way of pre-wetting or pre-treating. However, it is not as practical since the granules are not uniformly coated. The agency should also consider the gradation of the granule materials, ratio of liquid to solid, application rates, amount of mixing, caking/clumping, corrosion resistant equipment etc. Adjusting the spray nozzles to achieve the maximum coverage is critical. Pre-wetting requires additional equipment, such as storage tanks, brine-making equipment, and pumps to load the spreaders; this also means extra maintenance. Spreaders should also be equipped with ground-speed controllers to ensure correct liquid application rates.

Spreader equipment is a significant factor in winter road maintenance and affects the use of snow and ice control materials. The application rate should always be consistent under all
conditions, whether the tank is nearly empty or full, material variations, or temperature changes. The agency should always request test results when purchasing new equipment. To be more beneficial, a spreader should be multi-functional for other tasks to be used for other operations. Hoppers should be constructed so that sand and salt is easily removed from the body. To ensure that material does not jam the chain or conveyor mechanisms, spreaders should be fitted with screens. Spreaders should be composed of corrosive resistant materials. High strength, low alloy self-coating steel, combined with surface preparation and special primers has been proven to be cost effective and lasting up to fifteen years (Transportation Association of Canada, 2003). Fiberglass is also another material, but is more expensive. Electrical wiring and hydraulic components must be enclosed in vapour proof or sealed systems. Neoprene spinners are commonly used to improve durability and spreading efficiency (Transportation Association of Canada, 2003). There are various types of spreaders. An in-depth description of each of the following can be found in series 9.0 Winter Maintenance Equipment and Technology of the Syntheses of Best Practices.

- Hopper spreaders
- Tailgate spreaders
- Reverse dumping or dual dump spreaders
- Multipurpose spreaders
- Rearward casting spreaders (zero velocity)
- Rear-discharge spreaders

Spread patterns can aid in the efficiency of salt use. Salt use may be reduced when applied in concentrated locations (windrows on the crown), rather than uniformly across the road (Transportation Association of Canada, 2003). Solid or pre-wetted material should usually be applied in a continuous narrow windrow along the centerline. This is achieved by a chute, rather than a spinner. Windrowing along the centerline will not work and is not recommended if the crown is not consistently in the center, if the road surface is badly deteriorated, or if the entire road is slippery. In the latter case, higher chemical application rates across the entire roadway may be needed.

Accurate electronic spreader controls are required for all spreaders to ensure correct application rates. Electronic ground-speed spreader controls provide consistent and accurate rates. The output is adjusted to maintain a steady rate by monitoring the truck’s speedometer. Data may be recorded as well, including amount and type of material applied, gate position, run time, blast information, average speed, spread width/pattern, etc. (Transportation Association of Canada, 2003).

A calibration policy should be established. Calibration checks or recalibration should occur before the season starts, after repairs, discrepancies with distributions, and during spot-checks on units throughout the season.

6.1.4.4 Operational Support Equipment

Operation support equipment helps manage operations by generating data or supporting the service delivery through functions of material usage monitoring and material loading and handling.

Equipment of material usage monitoring includes (Transportation Association of Canada, 2003):
Loader mounted electronic weighing equipment
  - Precisely load the right amount salt

Truck scales
Liquid meters
Automated vehicle location (AVL)

Material loading and handling equipment includes (Transportation Association of Canada, 2003):

- Bulk salt handling by loaders
  - Usually results in spillage and environmental contamination
- Bulk material conveyors
- Sand/salt blend mixers
  - Dual auger pugmill or twin conveyor feed
  - Two supply lines are metered to a given ratio; final conveyor stacks the mixture
- Brine production equipment
  - Batch plants, continuous flow plants
  - Pump into spreader-mounted tanks or holding tanks
  - Corrosion issues with brine production equipment
- Brine delivery equipment
  - No equipment required for brine delivery

Monitoring and record-keeping includes, but is not limited to (Transportation Association of Canada, 2003):

- Type and amount of winter materials placed
- Percentage of fleet equipped with electronic spreader controllers
- Percentage of fleet equipped with pre-wetting
- Percentage of fleet equipped with direct liquid application
- Percentage of fleet calibrated annually
- Percentage of staff trained in equipment use

The agency may want to train their staff in the following equipment related topics, if applicable (Transportation Association of Canada, 2003):

- Route familiarization
- Pre-season driver training
- Spreader calibration
- “circle check” procedures
- Spreader controller operation
- Brine equipment operation
- Equipment washing procedures
- Minor equipment repair
- Good housekeeping practices
- Record-keeping
- Use and interpretation of pavement sensor data and forecasts
- Infrared thermometer use
- Agency policies
7.0 Conclusions

Based on the results of the questionnaires received from Saskatchewan municipalities, the approach to winter road maintenance is mainly de-icing and traction control. Because of colder temperatures, sand is used. Likewise, because of the availability and low cost, salt is used. There are environmental concerns with salt/sand stockpiles being stored outside and uncovered, unstated salt vulnerable areas, no specialized wash bays, un-engineered snow disposal sites, etc. Overall, the results of the questionnaires and research indicate that municipalities have varying levels of service which can be attributed to size of community, equipment availability, budgets and public tolerance, etc. Therefore a single set of guidelines for all Municipalities is less than desirable.

Research indicates snow and ice control decisions should be based on pavement temperatures and air temperature versus only air temperature.

Anti-icing and pre-wetting seems to be the more efficient and cost-effective methods of snow and ice control. Although pre-wetting of material for de-icing can be beneficial and effective without accurate weather forecasts, the same cannot be said for anti-icing. The majority of jurisdictions in the U.S. and Canada that have used anti-icing effectively and efficiently have had road weather information systems in place or other means of obtaining pavement temperature and forecasts, along with equipment having anti-icing capability.

At the time of writing, Saskatchewan jurisdictions have neither the technology to provide more accurate weather information nor the equipment with anti-icing capability in order to incorporate on effective efficient anti-icing program.

A Road Weather Information System (RWIS) is something Saskatchewan Municipalities may wish to adopt in the future. However, further study and analysis would be needed prior to adopting such a system along with the support of the Province.

Using abrasives can have its benefits; however it is costly to clean up and can be more harmful to the environment than salt. More eco-friendly alternative materials are being considered more due to awareness of environmental concerns. There are many products out there, such as Fusion, Geomelt, Ice Ban, etc. that appear to be less detrimental to the environment, and can lower the freezing point of salt and make snow and ice control more efficient. On the other hand, because they are made from organic materials, they need more attention throughout the year to prevent potential fermentation. These products also have a higher cost associated with them.

Using Transportation Association of Canada’s Syntheses of Best Practices for Road Salt Management and creating a Salt Management Plan is a good start towards finding the most effective winter road maintenance program for an agency. A winter road maintenance program is a system of components that work together to improve the system as a whole. What may work for one municipality, may not work for another. This is not an easy task and requires in-depth assessment based on factors such as budget and level of service.
8.0 Suggested Next Steps

- Municipalities should establish a defined and achievable level of service, and then develop procedures to provide the defined level of service.

- Creating a Salt Management Plan in accordance to TAC’s Syntheses of Best Practices is highly recommended. The Syntheses considers efficiency, effectiveness, and environmental concerns. A Plan would organize current practices, with consideration for future goals.

- As concluded, anti-icing has been found to be a cost-beneficial operation. However, it is suggested that anti-icing not be implemented until more accurate weather forecasts and pavement temperatures can be acquired through RWIS or any like technology. Once this is fully implemented, agencies may start looking towards adding anti-icing to their winter operations. Since many of the municipalities within Saskatchewan are small in nature and RWIS is quite costly, the Municipalities would require the support of the province to install and implement RWIS. (Anti-icing is the application of a chemical to a roadway prior to or at the start of a weather event to prevent ice from forming. Preventing ice from forming makes it safer for road users, decreases the amount of abrasives used for traction control reducing the cost of spring clean-up. However, successful anti-icing requires accurate weather forecasts and pavement temperatures.)

- Municipalities may want to carry out pre-wetting trials as an additional operation to their winter road maintenance program. Many other agencies outside of Saskatchewan are using pre-wetting and have had great success with it. Pre-wetting of granular materials would aid in de-icing and provide a higher level of service to the public. However, pre-wetting cannot be recommended for all municipalities because it requires additional equipment, such as on-board spray systems, storage tanks, pumps, as well as additional maintenance. (Pre-wetting is a process of coating or treating the dry chloride de-icers and/or abrasives with a liquid prior to spreading on the road. Pre-wetting salt, sand/salt will better adhere to the pavement becoming less prone to blowing off from traffic before it can begin to activate.)

- Municipalities may wish to determine the merits of obtaining materials with or from other communities for economic efficiency as it may be more cost beneficial to purchase and deliver larger quantities from a supplier.

- Several alternative materials were researched. Calcium chloride currently seems common when it comes to pre-wetting or anti-icing. It also has the lowest working temperature of the common snow and ice control chemicals, making it suitable for Saskatchewan’s climate. Calcium chloride can be supplied within Saskatchewan.

- Fusion may also be a product that is worthwhile conducting trials on. Its organic content makes it more eco-friendly, but has the risk for fermentation if not agitated regularly. It also has a low working temperature that would work well with Saskatchewan’s climate. Fusion is supplied out of Manitoba.
- In regards to equipment/technology, it is suggested that the larger municipalities obtain AVL/GPS for their fleet. It would be beneficial for tracking, monitoring, and record-keeping purposes.

- Salt and sand runoff is an environmental concern. If indoor storage is not possible, impermeable pads and covers are advised, as well as specialized wash bays with oil/grit separators for washing equipment.
9.0 References


One Team. Infinite Solutions.


