EXHIBIT 18

11.0 – SUCCESSES IN ROAD SALT MANAGEMENT: CASE STUDIES

This is one in a series of Syntheses of Best Practices related to the effective management of road salt in winter maintenance operations. This Synthesis is provided as advice for preparing Salt Management Plans. The Synthesis is not intended to be used prescriptively but is to be used in concert with the legislation, manuals, directives and procedures of relevant jurisdictions and individual organizations. Syntheses of Best Practices have been produced on:

1. Salt Management Plans
2. Training
3. Road, Bridge and Facility Design
4. Drainage
5. Pavements and Salt Management
6. Vegetation Management
7. Design and Operation of Maintenance Yards
8. Snow Storage and Disposal
9. Winter Maintenance Equipment and Technologies
10. Salt Use on Private Roads, Parking Lots and Walkways
11. Successes in Road Salt Management: Case Studies

For more detailed information, please refer to TAC's Salt Management Guide - 2013.

ACKNOWLEDGEMENTS

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Environment Canada
Environnement Canada

CONTENTS

EXECUTIVE SUMMARY

Since its publication, Environment Canada's Code of Practice for Environmental Management of Road Salt has created awareness and prompted a number of road authorities to begin implementing better salt management practices. This SOBP presents a synthesis of case studies and research from across Canada to highlight these successes. A total of 16 case studies are detailed along with seven areas of research. The case studies include examples from six provinces, including Manitoba, New Brunswick, Nova Scotia, Northwest Territories, Ontario and Quebec. The case studies are summarized below.

A study by Stone (2011) found that the Code has been widely adopted by Ontario municipalities, where 89% of survey respondents, which are predominantly larger municipalities, have Salt Management Plans. Stone also found that since the Code was developed, the greatest improvement has been in the areas of salt storage and handling.

There has also been positive development with regard to training. Stone (2010) found that most municipalities train a high percentage of permanent staff – for example, Ottawa's improvements in operator compliance rate accounts for savings of more than half a million dollars. The focus is also shifting to seasonal workers and private contractors (see TAC *SOBP 10: Salt Use on Private Roads, Parking Lots and Walkways*). For example, the Smart About Salt™ program has been launched in Ontario which trains and certifies companies applying salt to parking lots and sidewalks.

Another area of significant adoption has been the use of Global Positioning Systems (GPS) controls and Road Weather Information Systems (RWIS). Many provincial and municipal road organizations, including Windsor, Ottawa and London, have successfully adopted new technologies to optimize their operations with an added benefit of transparency. The driving force comes down to using the right material, in the right amount, in the right place, at the right time.

Many of the case studies presented here describe best practices that reinforce another noticeable trend: a reduction in road salt application rates. A study by Kilgour, Gharabaghi and Perera in 2012 found that the Code appears to have contributed to a reduction in the "normalized" road salt application by about 26% in the City of Toronto, and that this has positive impacts on freshwater taxa. He states that the Code can be expected to have benefited up to 14% of potential freshwater taxa in City of Toronto streams over the long term. In the same study he also found that the City of Waterloo was able to reduce total road salt application by 10% in the broader urban road network, and by 25% in the vicinity of well fields. Similarly, the Ontario Ministry of Transportation (2005) predicted about a 20% reduction in chloride loads and chloride concentrations.

The observable bottom line impact resulting from the implementation of the best practices presented in this SOBP is significant annual savings and positive payback periods. Thus, improving road salt management tends to yield cost savings and environmental benefits.

INTRODUCTION

Purpose

The purpose of this SOBP is to promote and illustrate the benefits and effectiveness of best management practices and new technologies used to reduce the impacts of road salt on the environment. It has been prepared as a result of a recommendation from Environment Canada's report *Five-year Review of Progress under the Code of Practice* and is intended to highlight the successful implementation of the Code. Since its publication a decade ago, the Code has created awareness and prompted a number of road authorities to begin implementing better salt management practices. The case studies presented here outline the benefits found in introducing best management practices and are just a few examples of road maintenance organizations who have taken the lead in responsible road salt management in the last decade.

Layout

Part 1 of this SOBP presents a synthesis of anecdotal case studies that have been provided from agencies across Canada. They will provide brief summaries of BMPs that have been implemented within the last ten years and have achieved successful results. The details highlighted will vary between case studies, but in general they will discuss what was undertaken and the results achieved. For consistency and ease of use, these case studies have been organized using categories from the *TAC Synthesis of Best Practices – Road Salt Management* as a framework. In addition, where consent was given, the contact information from the agency is provided to facilitate future knowledge transfer.

Part 2 of this SOBP presents a synthesis of research analyzing the benefit the Code and the TAC SOBPs have had during the past ten years. The examples discuss successful outcomes observed and relate them to the SOBPs that were applied.

PART 1: ANECDOTAL CASE STUDIES

Salt Management Plans

SALT MANAGEMENT PLANS – REGION OF WATERLOO, ON

About three quarters of Waterloo Region's drinking water comes from groundwater and the remaining comes from the Grand River. In 1997 the Region became aware of elevated chloride levels in some supply wells. In 2002 the Region took the first steps to curb these elevated chloride levels by completing Phase I of its Road Salt Management Study. The same year the Road Salt Advisory Committee (RSAC) was formed, which includes members from the Water Services department, consultants, four Townships and three Cities in the Region and the Regional road departments, to manage road salt application. Phase II of the salt study looked at specific options for managing salt. The reports from Phases I and II totaled more than 500 pages and formed the Region's first Salt Management Plan (SMP). In 2004 the SMP was revamped to a 7 page table containing about three dozen key salt management activities to make it easier to update on an annual basis. In this plan, the Region committed to a 25% target reduction based on long term average salt usage that was recommended in the Phase II salt study.

Currently, about a dozen main areas of the SMP have been active and are briefly described below. These include:

1. Tracking winter material usage and comparing usage to winter severity indicators
2. Constructing a new salt facility to improve salt handling practices
3. Updating the winter maintenance policies and procedures
4. Automatic vehicle location system (AVL) program
5. Use of other ice control materials such as organic based performance enhancer (a.k.a. Beet juice/ brine mixture)
6. Roadside weather station information program
7. Snow removal and disposal study including a salt vulnerable area study
8. Groundwater monitoring program and the Mass Balance Model

1. Tracking Winter Material Usage and Use of Winter Severity Index

Salt, sand and liquid materials are tracked and recorded in the SMP after each winter. The salt loading, measured in tonnes per two lane kilometre, for the season is also recorded based on the total tonnes of salt spread and the length of winter maintained roadway. The loading is then compared to the target loading that reflects the 25% salt reduction (currently 25 tonnes per two lane kilometre annually) to see if the target was met or not. Studies show that the Region's groundwater should be protected provided the long term salt loading average meets this annual salt loading target of 25 tonnes/2 ln km.

Currently the Region uses some basic indicators to determine the severity of the winter including the total salt spread compared to: snowfall, drifting days (any day that snow is accumulated and wind is over 15 km/ hr) and operating days (any day 20 tonnes of salt or more is spread). The Region is currently undertaking a Winter Severity Index review as part of the Winter Deicing Salt Assessment for Higher Priority Well Fields study.

2. Salt Facility

A new salt facility was constructed in 2007 to help improve the way the Region loads and stockpiles road salt and winter maintenance liquids. Salt is delivered to the facility and unloaded indoors by a delivery truck or a fixed conveyor belt. Salt spreading trucks are calibrated, unloaded and loaded indoors in a drive-through. The salt storage area contains high push walls and is capable of holding 3,000 to 4,000 tonnes of salt, which is more than half of the winter salt usage for the Central Yard. Two liquid storage tanks are used to hold about 75,000 L of winter liquids (currently 70% brine/ 30% beet juice mixture). Two liquid fill stations are available in the truck salt loading drive-through and two are located in two adjoining drive-through wash bays. A lab that stores samples and other equipment is located inside the salt facility.

3. Winter Maintenance Policy and Procedures

A number of Winter Maintenance Policies have been developed. Ten of these policies have been approved by the Councils of each municipality in the Waterloo Region. Some of these ten policies include Winter Maintenance Committee and Innovation, Material Storage and Loading, Selection and Application of Materials, Snow Plowing and Winter Maintenance Training are updated every five years.

4. Automatic Vehicle Location System (AVL) program

The Region is in a pilot project with two competing vendors for a 10 year co-operative contract with the City of Brantford, Brant County, City of Kitchener and City of Waterloo. The primary focus of the RFP is to be able to track how much salt is spread, based on spreader controller data, at the street segment level to help monitor how much salt is released into drinking water intake areas.

5. Organic Based Performance Enhancer

The Region uses a premixed salt brine/beet juice solution for both liquid anti-icing (direct liquid application) and onboard pre-wetting applications. The organic requirement in the supply contract is intended to help reduce chloride loadings into the environment.

6. Roadside Weather Station Information program

The Region currently has two road weather information system (RWIS) sites with plans to expand to four sites by 2015 to adequately cover the nine distinct weather zones identified in a weather study completed in the early 2000s. Features of the RWIS sites include the ability to stream live video and an active road sensor that determines the freezing point of any solution on the road.

7. Snow Removal and Disposal Study and Salt Vulnerable Area Study

Phase I of a Snow Disposal Study was completed in June 2011. Various geographic areas for locating potential snow disposal sites were identified. The study used salt vulnerability and snow haul distances to help narrow down the potential geographic areas. Salt Vulnerable Area mapping was completed as part of this study. Discussions regarding the next phase are underway.

8. Groundwater Monitoring Program and Mass Balance Model

Chloride and sodium levels are monitored biannually at various monitoring wells. The plume of migrating salt underneath the Region's roads is entered into a Road Salt Mass Balance Model to predict salt levels in drinking water wells. The Region has several high priority well fields; defined by one or more wells within the well field exceeding the Ontario Drinking Water Standard for Chloride of 250mg/L. The Winter Deicing Salt Assessment for Higher Priority Well Fields study will help to determine if our salt loading target of 25 tonnes/2 lane km will be enough to protect our drinking water.

Contact: David Lukezich
Region of Waterloo
dlukezich@regionofwaterloo.ca
Phone 519-575-4757 ext. 8302

Training

THE SMART ABOUT SALT® COUNCIL – ON

The Smart About Salt® program is a training and certification program run by an Ontario-based not-for-profit Corporation called **The Smart About Salt Council**. The founding members of the Council are: the Region of Waterloo; Landscape Ontario (many snow and ice contractors are their members); and the Building Owners and Managers Association (BOMA) of Ottawa. The Ontario Good Roads Association also sits on the Board of Directors recognizing the strong link to the municipal sector.

Both snow and ice removal contractors and facilities can become Smart About Salt® Certified. The program also provides training on a wide range of salt management practices leading to individual accreditation either as a Smart About Salt® Accredited Operator, or a Smart About Salt® Accredited Site Manager. The training program was awarded the Transportation Association of Canada's Educational Achievement Award in 2010. As of April 1st, 2012, over 300 people have attended the training course.

The Region of Waterloo is a leader in salt management and was the first to include the Smart About Salt® program as part of a comprehensive salt management strategy designed to protect the Region's drinking water supply. The Region's overall program incorporates a multi-faceted approach designed to reduce the application of salt on roads, parking lots and sidewalks by:

1. working collaboratively with transportation operations staff from the municipality
2. developing guidelines and site plan design recommendations to minimize the need for deicing at new developments
3. building public awareness through education programs, and
4. the Smart About Salt® program.

A number of municipalities have followed the lead of the Region of Waterloo by requiring that only Smart About Salt® Certified Contractors are permitted to bid on contracts to clear municipal facilities (city halls, arenas, water treatment facilities etc.). The City of Ottawa has gone further by holding a Smart About Salt® Summit, opened by the Mayor and chaired by the Deputy Mayor, to encourage public and private organizations in the Ottawa area to become Smart About Salt®. Ottawa has certified 5 of its facilities under the program and had approximately 30 internal parks and transit personnel attend the training course. The local colleges and universities are hosting training sessions with many of their operation's staff attending.

GO Transit / Metrolinx in Toronto is also requiring their contractors to become Smart About Salt® certified and has had approximately 50 of its internal operation's staff trained. They are also looking at improving salt management practices at its sites.

To become certified under the Smart About Salt® program contractors and facilities need to implement improved practices including: better record keeping, equipment calibration, tracking and reporting salt use; knowing and using variable application rates geared to site and storm conditions; improving salt storage and handling practices; more effective plowing; and staff training in best management practices. In addition the use of liquid ice control materials and low chloride products is promoted. The program is phased in over 3 years with contractors having to achieve a minimum entry level standard to get into the program and demonstrate increased improvement up to the target standard to remain in the program. Certified contractors and facilities are required to renew their membership each year and pay an annual fee. The renewal process involves reporting on their current status with respect to the certification standards and reporting on their average salt use per unit area serviced per event. As funding levels improve, an audit program, which has been designed, will be implemented.

The focus with facilities is on risk management and proper salt management. Facility managers are encouraged to review site drainage issues that lead to icing problems and to take corrective action to eliminate these problems. By doing, so they reduce their risk of lawsuits while reducing their salt demand. They are also required to hire a Smart About Salt® Certified Contractor to service their sites. This focus on risk management has led to Marsh Canada – the insurance broker for many of the snow and ice contractors in Ontario – to offer a premium reduction to any contractor that is Smart About Salt® Certified. The Smart About Salt® Council, Landscape Ontario's snow and ice commodity group and the insurer have designed standardized forms for recording winter operations that have improved record keeping.

Since the launch of the Smart About Salt® program, winter maintenance and salt management practices are being improved amongst businesses that deliver these services. The annual reporting has already shown a reduction in the amount of salt being used by certified contractors - in some cased by as much as a 50%. Participants in the program have improved their knowledge and understanding of:

- Liability and risk management practices
- Salt science
- Snow and ice control tactics
- Equipment calibration and how to change the application rate to suit weather conditions

- Weather information's role in delivery of winter maintenance services
- Better record keeping

Significant changes in winter maintenance practices have already been realized. Certified contractors in partnership with their customers have:

- Introduced new technologies including the use of liquids and pre-treated salt
- Improved material storage practices
- Improved training for employees
- Reduced the amount of salt used without compromising safety
- Improved site drainage to reduce the potential for icing and the need for salt
- Instituted better record-keeping practices

The benefits of the program to the protection of sources of drinking water are also being recognized in some Source Protection Policies being developed under Ontario's Clean Water Act by Conservation Authorities. Given the increasing need to develop programs that further reduce the transmission of chloride to the environment, the Smart About Salt® program is an example of a management model that can be easily implemented by stakeholders to reduce the use of deicing chemicals at facilities while achieving safe levels of service on parking lots and sidewalks.

This dedication to protection of the environment was recently recognized by the Ontario Parks Association who awarded the Region of Waterloo and the Smart About Salt® Council their *Protecting Tomorrow Today Award*. The award was given "*in recognition of your significant contribution to the betterment of our parks and the overall environment, through your leadership in protecting underground waste systems and water courses in the Province of Ontario*".

In addition to the environmental protection that this program offers there are the following benefits:

- Lower winter maintenance and insurance costs
- Enhanced site safety through proactive strategies
- Reduce infrastructure damage from excessive salting
- Less tracking of salt into buildings
- Better public image

At the present time there is no government funding of the Smart About Salt® program. Operating revenue comes from membership fees and training fees. Organizational support is also provided by the founding organizations.

Learn more about the Smart About Salt® program at www.smartaboutsalt.com.

Contact: Bob Hodgins
Executive Director
Smart About Salt Council
smartaboutsalt@bell.net
Phone: 647-722-5699

Road and Bridge Design

LIVE SNOW FENCE PILOT PROJECT – REGION OF WATERLOO, ON

BMP QUICK FACTS	
Location	Waterloo Region
Average Winter Temperature	- 4.5° C
Average Annual Snow Fall	133 cm
Total Length of Road Serviced	487 two lane km
Level of Service Standard	MMS 239/02, Regional policies and procedures

The Region currently utilizes a temporary snow fence to help reduce the amount of snow that blows onto a 500 metre section of a Class 1 road. It is expensive to purchase, install and remove sections of snow fence on an annual basis. In collaboration with Community Planning, Legal Services, the Township of Woolwich Environmental Enhancement Committee (TWEEC) and a private landowner, the Region proposes (going to council for approval in March 2012; aiming to plant spring 2012) to replace the 500m temporary snow fence with a mixture of native trees, shrubs and grasses to form a 15m wide naturalized wind break on a permanent easement purchased by the Region from the neighbouring farmer. Some larger trees and shrubs will be planted mitigating the need to install temporary snow fence during the establishment period of the naturalized area. (Note: Subject to Council approval).

It is expected that over the next five decades the naturalized live snow barrier will result in a net saving of thousands of dollars a year from eliminating the need to install and remove temporary snow fence section. Reducing drifting snow in rural areas results in a lower salt application, which in turn provides a measure of source water protection. Costs/savings are based on a 50 year life expectancy of the naturalized area. This proposed project aligns with Focus Area 1 (Environmental Sustainability) of the Region's Strategic Plan. Specifically, Strategic Objective 1.1 (Integrate environmental considerations into the Region's decision-making) applies to this project as the Region plans to provide funding to support this community based initiative. Strategic Objective 1.2, which is to improve air quality in Waterloo Region, is accomplished by planting native carbon sink plants, such as native rye grass, by decreasing fuel usage and by reducing the need to plow. Strategic Objective 1.4 refers to the Region's goal to protect the quality and quantity of its water sources and applies to this project in terms of protecting its water quality by reducing the salt required to treat snow covered roads, as indicated in the Region's Salt Management Plan.

This pilot project meets specific objectives of the Regional Official Plan:

- 7.1: Maintain, enhance or wherever feasible restore environmental features and the ecological and hydrological functions of the Greenlands Network including the Grand River and its tributaries and the landscape level linkages among environmental features.
- 7.4: Develop partnerships, programs and policies to maintain, enhance and restore the ecological functions of the Greenlands Network, including the Grand River and its tributaries.
- 7.5: Increase forest cover in appropriate locations to achieve an overall target of 30 per cent or more of the region's total land area.
- 7.6: Promote informed stewardship of the Greenlands Network.
- 7.I.8: The Region encourages landowners to maintain, enhance or, wherever feasible, restore environmental features on their property through measures including conservation easements, buffers and wherever appropriate, fencing.
- 7.I.14: Wherever feasible and appropriate, species native to the region will be used in plantings along Regional Roads and on the grounds of Regional facilities. Area Municipalities are similarly encouraged to use native species in roadside plantings, stormwater management facilities and park naturalization projects.

Costs:

- Purchase of permanent easement and initial plantings - over $1,000 per year.

Savings:

- Eliminating Installation, removal, and replacement of temporary snow fence – several thousands of dollars per year

Contact: David Lukezich
Region of Waterloo
dlukezich@regionofwaterloo.ca
Phone: 519-575-4757 ext. 8302

Pavement and Management

IMPLEMENTATION OF ANTI-ICING, ROAD SENSORS AND PRE-WETTING TECHNIQUES WITHIN THE CITY OF MONCTON – MONCTON, NB

BMP QUICK FACTS	
Location	Moncton, New Brunswick
Average Winter Temperature	- 5.7° C
Average Annual Snow Fall	349 cm
Total Length of Road Serviced	1075 ln km

Moncton has been proactive in implementing ways to optimize salt use with technology such as pre-wetting, road sensors, Road Weather Information Systems (RWIS), Automated Vehicle Location (AVL) and Direct liquid Application (DLA).

Pre-Wetting, the process of spraying salt brine onto solid salt as it is being spread on the roadway, has provided two main benefits. First, it makes the salt sticky and stays on the road better by reducing the effects of bouncing, blowing and sliding of the salt. Second, because the salt is already wet, it reacts faster to snow and ice. Both of these benefits, combined with the use of road sensor, have helped Moncton reduce the amount of salt needed by up to 15%, depending on road surface temperatures.

The City is also equipped to make its own salt brine thereby reducing acquisition costs. During the past few winters, the Operations Center has proceeded with its own evaluation of DLA technology. A DLA tank was purchased and installed on the chassis of an existing City truck. The tank purchased has a capacity of close to 10,000 liters. At an application rate of 115 liters / lane km, it covers a range of about 80 lane kms. The last few winter seasons produced mixed results with less than ideal conditions for this type of trial. For instance, streets were snow packed due to back-to-back storms preventing the timing of plowing to bare pavement, and brine works best when applied to bare pavement. Depending on the type of snow, it did help peel off the snow in certain cases. The City continually monitors this activity to maximize benefits.

MULTIPLE APPLICATION RATES FOR SAND/SALT, CITY OF WINNIPEG PUBLIC WORKS – WINNIPEG, MB

BMP QUICK FACTS	
Location	Winnipeg, Manitoba
Average Winter Temperature	- 4.3° C
Average Annual Snow Fall	110 cm
Total Length of Road Serviced	930 km
Level of Service Standard	City of Winnipeg Snow Policy

The City of Winnipeg went from a single application rate of 120kg per lane kilometer to three application rates of 80kg, 120kg, 160kg based on an assessment of snow/ice conditions. The anticipation is that the City will realize a significant reduction on routine application quantities and the 'best bang for the buck'.

Costs:

- Total cost of the undertaking was $3.5 million

Savings:

- $500,000 on average winter

Contact: Jim Berezowsky
City of Winnipeg, Public Works
jberezowsky@winnipeg.ca
Phone: 204-986-5067

LIQUID DEICER FOR WINTER OPERATIONS – COUNTY OF WELLINGTON, ON

BMP QUICK FACTS	
Location	Wellington County, Ontario
Average Winter Temperature	- 3.5° C
Average Annual Snow Fall	120 - 285 cm
Total Length of Road Serviced	700 km (rural highway)
Level of Service Standard	MMS 239/02; Bare pavement; centre bare; track bare

The County of Wellington staff has extensive experience in the use of liquid deicer and pre-wetting equipment. The Roads Division has gone to great lengths to ensure staff receives thorough training on how the deicer equipment operates, including working directly with the equipment manufacturer. Roads Division staff, in conjunction with the Ontario Road Salt Management Group and the Ontario Good Roads Association helped to develop Equipment Operator and Supervisor training packages for winter operations. (For more information, visit www.ogra.org).

The County of Wellington has been using liquids to enhance winter operations since the mid-1970s. In the mid-1990s they switched from Calcium Chloride ($CaCl2$) to a mixture of Magnesium Chloride ($MgCl2$) and an agricultural product mix. The deicer used is a combination of two products, liquid Magnesium Chloride and a refined 100% corn product. When mixed together, this product is non-toxic, environmentally friendly and has a eutectic freezing point of –65° C. It will also not rust vehicles as it is about 1/10th as corrosive as salt and is easily removed with soap and water. In the future, the County will be adding this deicer to sand and salt, by pre-wetting. The goal is to have all of their snowplows equipped with the ability to pre-wet.

The County will be anti-icing using this product on several Wellington County roads. The liquid will be sprayed directly onto the road surface ahead of a storm to prevent the ice from bonding to the road surface. It may also be applied after a storm to cut thru the ice or hard pack for quicker removal from the roadway and applied in areas prone to black ice, frost, or on bridge decks in place of using rock salt.

The County currently has 27 combination sander/plows all with computerized spreader controls, of which 25 have pre-wetting capability and 2 have anti-icing capability. As well, twenty-five units are 3 in 1 which allow for dry product, pre-wet product or direct liquid applications. The County has already seen benefits in using this product in reducing the need for road salt as a deicer.

Results:

- Reduced salt by up to 25% (if same level of service is maintained)
- Increase level of service (could increase salt use)
- Improves road safety
- Reduced sand use by more than 40%
- Decreased corrosion of equipment
- Quicker cleanup after storm
- Greater residual

Contact: Paul Johnson
County of Wellington
paulj@county.wellington.on.ca
Phone: 519-837-2601 ext. 2230

Design and Operation of Road Maintenance Yards

WINTER SAND STORAGE BUILDING (WSSB) CONSTRUCTION PROGRAM - HAY RIVER, NT

BMP QUICK FACTS	
Location	NWT Highway System
Average Winter Temperature	- 25° C
Average Annual Snow Fall	150 cm
Total Length of Road Serviced	881 km
Level of Service Standard	Centre bared to clean with winging

The Northwest Territories Department of Transportation has always pursued a "best practices process through lessons learned." The Division provides leadership and technical evaluation for the Regions to raise the level of their game for effectiveness (biggest bang for our buck) and quality (best bang for our buck). Improving Salt Management Practices is part of this process because any waste in loading, mixing or hauling salt is a cost that we should not be paying for when considering that it has to be hauled in from approximately 800 km away. Therefore, any improvements per best practices are both a cost saving and an environmental benefit.

One step was the completion of a testing program of a direct liquid application (DLA) system for key bridges including the new Deh Cho Bridge. The DLA program was a test trial with acceptable results. A spray bar apparatus was mounted onto a heavy half ton truck complete with tanks. Several spray cycles were completed in key areas on Highway 3 between Fort Providence and Yellowknife. Highway performance was monitored with patrols by the operations supervisor. The test product: Ice Ban or CF-7 worked well in typical conditions, even surviving small storms and being active for up to six days. CF-7 was sprayed on bridge decks at several crossings in order to judge its effectiveness in terms similar to the results expected at the Deh Cho Bridge. This also allowed for crews to become familiar with DLA tactics and product handling.

Another measure was the completion of a Winter Sand Storage Building (WSSB) in Bechoko (Rae/Edzo) area on Highway 3 at kilometre 298. The sheltered areas within the WSSB reduces unplanned losses in winter sand that occurred in the past when the mixed product was subjected to rain or snow melt during warming trends. Guidance on cleanup was also provided. In the past, during the spring, crews would clean up the area where they thought the winter sand was stockpiled only to find they left out some that became visible much later in summer. With the WSSB, the cleanup effort is directly within the building perimeter. These buildings are also installed over an impermeable liner constructed beneath the building to prevent the migration of road salt into the environment. The NWT environment is of pristine quality and citizens and staff have great respect for the land. It makes sense to establish the cleanest working method possible and that includes WSSB.

Another practice is the use of a clean sand layer to act as a buffer between the regular working area and the mixed winter sand product. This buffer sand is scooped in spring thus removing any potential for Road Salt to enter the environment. A thorough clean up in spring is undertaken by removing any unused winter sand and other material then storing it in the road salt sheds until the next season. Our sheds all have containment features including closing doors and concrete floor slabs to minimize environmental exposure. Some salt sheds will also have weather guard type curtains depending on the orientation of the prevailing winds.

Lastly, sanding trucks are calibrated with a timed measurement of volume during a discharge burst. The truck mounted units will be discharged into a measured box for timed intervals. The measured volumes in the box will be used to adjust the discharge chute controls to match the rated computer settings. This is planned as part of the preparation for winter cycle. Typically we would calibrate each unit once per year however we now will complete added calibrations if the winter sand source changes and after a repair cycle.

Contact: John Suwala
Northwest Territories Transportation
John_Suwala@gov.nt.ca
Phone: 867-874-5028

SALT STORAGE YARDS IN CAPE BRETON HIGHLANDS NATIONAL PARK – CAPE BRETON, NS

Three salt storage yards are located in the Cape Breton Highlands National Park. These locations, generally located in areas with disturbed surfaces (paved, cemented or gravel), often include vehicle washing. The primary concern at these sites was the migration of road salt (chloride) into surface waters through drainage ditches and drains.

At one site, the Chéticamp Compound, the construction of a new vehicle wash building resulted in the cleanup of high chloride soils around the former salt storage facility. The storage of salt was then moved out of the Chéticamp Compound in 2008. Salt trucks are now washed inside and any resultant brine is re-used in the pre-wetting process.

Since the implementation of these measures the Chéticamp Compound has shown a 65% per year decrease of chloride in groundwater when compared to the previous conditions. This is a substantial improvement likely due to changes in the infrastructure.

An additional spring data point is required to evaluate the storm drain water quality levels in the Chéticamp Compound. Preliminary sampling results, however, are encouraging and show a dramatic reduction in chloride levels as a result of changes in infrastructure at the Chéticamp compound area.

IMPLEMENTATION OF CONTROL PROCESSES FOR SALT MANAGEMENT AT THE CITY OF BRAMPTON WORKS AND TRANSPORTATION DEPARTMENT – BRAMPTON, ON

BMP QUICK FACTS	
Location	Brampton, Ontario
Average Winter Temperature	- 3.8° C
Average Annual Snow Fall	116 cm
Total Length of Road Serviced	3, 220 km
Level of Service Standard	Bare road; arterial and collectors; centre bare; locals

A change in road treatments, approved by Council in July 2011, resulted in local roads receiving an application of salt only to achieve centre bare pavement instead of the 75% sand/25% salt mixture that was applied in the past, to achieve the same results. In September 2011, the first of 2 state-of-the-art works yards was completed, with fully indoor material storage and loading and truck under carriage wash with wash water recycled for use in brine making. In the Fall of 2011, the Operations Division of the Works & Transportation Department at the City of Brampton, was challenged by senior management to reduce it's salt usage, as much as possible, while maintaining the level of service mandated by City Council. Staff scrutinized the existing salt handling and application procedures, made recommendations and ultimately implemented the following best practices:

- All combination plow/spreader units were calibrated and controllers set-up with only the required application rates, for the 2011/2012 Winter Season.
- The salt application rate for Arterial and Collector roads was reduced from 140 kg/lane km to 130 kg/lane km.
- The salt application rate for local roads, 65 kg/lane km remained unchanged from previous years as this was the equivalent amount of salt that was being mixed into the sand/salt mix.
- Per route salt requirements were calculated based upon the required application rates and the number of lane kilometres.
- Material Loading Sheets were created tabling the specific amounts of salt required for each truck per route for all typical operation scenarios.
- A new vehicle loading procedure was implemented whereby loader operators were instructed to load only the amount of salt listed on the Material Loading Sheets. Any additional material required to be loaded must be justified and approved by the Foreperson prior to loading.
- In prolonged Winter events, initial application rates for salt are reduced by 50% to allow for multiple applications, if necessary. This reduces the amount of salt plowed off on subsequent passes.
- Effectiveness of salt application rates is being monitored closely in an effort to determine optimal rates, application methods and number of applications required for specific event types.
- Salt usage is scrutinized by yard supervisors following each event. Issues are identified and resolved between events.
- Loader Scales have been requested by Operations staff to allow them to more accurately account for salt usage.

The City of Brampton, Works & Transportation Department, Operations Division achieved a 20% reduction in salt usage and chlorides released into the environment, in December 2011 and January 2012, when compared to the salt usage for the same number and type of events in December 2010 and January 2011, by implementing control processes for salt management. Monitoring of the effectiveness of the current application rates and practices is on-going, but early estimates indicate that there could be up to an additional 10% reduction in salt usage possible if the current practices perform as expected. In addition, the City hopes to realize savings in spring sweeping costs in 2012.

Costs:

- Not yet known

Savings:

- Salt Reduction (Dec. 2011 & Jan 2012) - $137,000
- Sand Reduction (Dec. 2011 & Jan. 2012) - $48,200
- Spring Clean-Up Costs - Not yet known

Contact: Andrew Masiak
City of Brampton
andrew.masiak@brampton.ca
Phone: 905-458-4888 ext. 63157

Snow Storage and Disposal

NEW SNOW DISPOSAL FACILITY – CITY OF TORONTO, ON

BMP QUICK FACTS	
Location	New Toronto Street, Etobicoke, Ontario
Size	6 hectares
Capacity	116 cm
Features	Paved Storage Pad – 26,000 m^2 Paved Containment Pond- 2,000m^2 Berms – 1.5 to 4.5 m high Planting – 5,000 trees and plants
Construction Cost	$1.75 Million

In December 2010, the City of Toronto opened a new snow disposal facility, increasing its storage capacity by about 20 percent. Featuring a paved storage pad, a paved containment pond for run-off and more than 5,000 trees and plants, the facility was completed at a cost of less than $2 million. Faced with a never-ending stream of traffic, narrow streets, sidewalks and a network of streetcar tracks, simply pushing the snow aside is not always an option. Snow banks may be a picturesque part of the winter landscape in the country. In the city, they are an inconvenience at best and a hazard at worst.

According to a 2002 study, Toronto needs about 150,000 loads of snow storage capacity. In fact, its seven disposal sites can only store about 108,000 loads, something that became painfully apparent in the year of the big snow. The disposal areas were soon filled to capacity. With its snow disposal site on Bloor Street slated for development, the city had already started work on a new facility in south Etobicoke and by May 2008 it had acquired six hectares of disused industrial land free of environmentally contaminated soil.

There were two key challenges to meet to ensure that this facility met environmental standards. The City had to contain the runoff from the snow disposal site to stop it getting into the groundwater and it had to meet some stringent requirements to manage stormwater discharges. Ministry of the Environment and City of Toronto standards limited the annual run-off from the new snow disposal site to the same amount of runoff that the site experienced prior to development. All runoff had to be held on site for at least four hours and the runoff from a 25-millimetre storm had to be detained for at least 24 hours. Finally, eighty percent of all suspended solids had to be removed before any snowmelt was discharged into the storm water system. In order to comply with environmental standards, the city's engineering staff added two features to the site: a 26,000 square metre asphalt pad large enough to hold 22,000 loads of snow and a 2,000 square metre, two-metre deep paved containment pond, where many of the contaminants will settle out before the runoff goes into the existing storm sewer system. The pond has two containment areas: the first where most of the settlement occurs and the second for secondary settlement. The entire site is surrounded by high berms that shield the site from view and help contain the noise. Gabion rocks are used on the inside of the berms to prevent scour as the snow melts.

Confident that the Ministry of the Environment would approve the plans, the City started site preparation work throughout 2009. The site was leveled and then more than 40,000 tonnes of millings (old asphalt recovered from road rehabilitation projects) were compacted as the sub-base. A temporary pond was excavated so that the site could be used as a temporary snow dump site and berms were built using, for the most part, recycled material from other city land development operations.

In April 2010, the Ministry of Environment issued a certificate of approval and final construction started almost immediately. Building the pond was the biggest challenge. It took four months to install the sub-drains and finish dewatering the pond site. In August, the pond was completed with an impervious layer of asphalt, 100 millimetres thick. As well, the snow storage pad was paved with 140 millimetres of asphalt, an extra thick layer of pavement to take the heavy truck traffic.

As a finishing touch, the City's Forestry Department planted more than 5,000 trees and plants on the site which not only vastly improves the overall look of the facility but will also, in years to come, help muffle the snow disposal operations.

The new storage site was completed in December 2010 and ready for operation. As it turned out, Toronto lucked out. It was a relatively snow-free winter and the city only stored about 500 loads of snow at the new facility, well below capacity. That is certain to change in the future. The City is, in fact, already planning for the future. Using a 350 tonne per hour snow melter at the site will increase its capacity by an additional 17,000 loads. As part of the requirements of its Certificate of Approval, the City has started monitoring the groundwater and effluent, checking for suspended solids, phosphorous and ammonia nitrogen on a monthly basis at various locations.

Contact: Bill Mason
City of Toronto
bmason@toronto.ca
Phone: 416-394-8349

Winter Maintenance Equipment and Technologies

Road Weather Information – the Ministère des Transports du Quebec

The ministère des Transports du Québec is equipping operational staff with tools to plan winter road network operations. Decision-making tools include weather information systems: in 2012, a fleet of 49 fixed road weather information systems and more than 170 mobile systems housed in vehicles of the Ministère were deployed across the road network.

The fixed road weather information systems developed by the ministère des Transports are based on an open–architecture design that allows flexibility regarding the various sensors of which they are composed. The stations precisely measure the principal road and weather parameters affecting road conditions. In order to facilitate the management and interpretation of the data collected, a computer system was developed and implemented for the operational staff. The system also includes a forecasting component for certain parameters: air, road surface and dew point temperatures.

The mobile weather information systems were designed by the ministère des Transports to complement the data collected by the fixed road weather information systems. They provide a clear picture of how the pavement throughout a whole patrol route is behaving. The various parameters measured allow vehicle operators to anticipate ice forming on the road and to adjust deicing operations when necessary.

To better use the road weather information systems, training sessions were offered to operations managers. Additional training will be offered in the coming years. Furthermore, in collaboration with the Association québécoise du transport et des routes (AQTR), the Ministère set in motion a winter service training action plan, which includes a section specifically covering road weather. These technical training sessions are accessible to everyone working in the field of winter maintenance in Québec.

In 2011, the Ministère conducted a survey regarding the road weather information systems. The survey showed that nearly 90% of operational staff found the data provided by the systems useful for their work, particularly for adjusting snow removal and deicing operations and for tracking road weather phenomena. These tools enable better operations planning, which is directly in line with the sound and responsible management of road salts.

SALT BRINE PRODUCTION FACILITY AT ELLESMERE YARD, CITY OF TORONTO – TORONTO, ON

BMP QUICK FACTS	
Location	Toronto, Ontario
Average Winter Temperature	- 1.3° C
Average Annual Snow Fall	130 cm
Total Length of Road Serviced	5,617 km
Level of Service Standard	Safe and passable pavement to bare pavement

The City of Toronto began using salt brine as its material of choice in 2002 as part of a direct liquid application and pre-wetting program. Currently, approximately 165 of 213 salters (77%) and 21 dedicated direct liquid application trucks have the ability to carry liquids. Toronto uses approximately 2,000,000 litres of salt brine annually. In 2010, to support its winter liquid program, the City of Toronto converted an unused warehouse loading dock into a state of the art salt brine production facility, based around an automated brine maker.

Some highlights of the facility include:

- Ability to accurately manufacture salt brine to precise concentration (23%) using computerized controls
- Storage for 113,500 litres of salt brine in 6 x 5000 litre double walled tanks
- Ability to blend salt brine with alternative materials to produce a 'hot' product for use at lower temperatures where salt brine is no longer effective
- Inside loading of the brine machine
- Secondary liquid containment in the event that any tank should rupture
- Use of recycled wash water from attached wash bay for salt brine production

Results Achieved

- 10% reduction in salt usage for those trucks equipped with liquid capability
- Lowered the eutectic temperature of salt through the introduction of alternative liquids
- Improved winter driving conditions for road users in Toronto
- Introduction of a winter maintenance best practice

Costs:

- Brine making unit & 6 tanks: $100,000
- Construction costs for renovation of warehouse area: $300,000

Savings:

- 10% reduction in salt usage. Total savings would be relative to the size of the fleet using the facility. For example, based on annual salt usage of 50,000 tonnes, a 10% reduction would be 5000 tonnes or approximately $425,000 assuming $85/tonne for salt.

Contact: Dominic Guthrie
City of Toronto
dguthrie@toronto.ca
Phone: 416-396-4802

GPS SYSTEMS – WINDSOR, ON

BMP QUICK FACTS	
Location	Windsor, Ontario
Average Winter Temperature	- 5.5° C
Average Annual Snow Fall	126 cm
Total Length of Road Serviced	1,067 km (deicing coverage)
Level of Service Standard	Arterial roads – cleared after every event. Residential roads – cleared after 10 cm of snow

The City of Windsor installed its first GPS unit in 2005 on a trial basis and, sufficiently impressed with the results, decided to continue to add GPS controls as funds became available. By 2010 about a quarter of the winter maintenance fleet was equipped with the GPS systems. The upgrades consisted of two GPS systems. One GPS provides automatic vehicle locating (AVL); the other is for route guidance and spreader control. The result is better efficiency and better control over salt usage without compromising traffic safety. The first GPS unit and the automatic vehicle locating (AVL) equipment, provides Windsor's operations control with a live picture of where every winter maintenance vehicle is, the speed at which it is travelling, how the salt is being applied to the roads and whether the plow is up or down. As it is a web-based application, the AVL system can be accessed from any computer so supervisors and managers can keep tabs on the work even if they are not in the office.

The value of the AVL system is not just in its ability to monitor events but to record events as well. One of the unwanted side effects of winter maintenance that all municipalities have to deal with is damage claims. Some are warranted but many are not. With the AVL system, a municipality's defense is transparent and the operators, who bare the brunt of any unwarranted accusations, really appreciate that they can prove that they are doing their job properly.

For the second GPS system, the winter maintenance GPS units are pre-programmed for the specific requirements of the route based on traffic and winter conditions and cannot be altered by the operators (although the operators remain in full control of their units and can shut down the GPS if a safety issue arises). The GPS controls the salt spreader, dispensing the right amount of salt over a predetermined width to match the vehicle's location and speed. It also turns off the spreader on specific units where routes coincide to avoid an unnecessary double application of salt. With the added control, the spreaders can now be adjusted to dispense salt across four lanes rather than simply in the lane directly behind the vehicle and that has likely led to some significant savings in time. In addition, with the salt spreaders controlled by the GPS unit, the operators can concentrate on driving, helped by the occasional gentle reminder from the GPS of upcoming intersections and route changes.

It will probably be another three or four years before the city has enough historical data to definitely show how much the new GPS system is saving but the public works department is already convinced that these units are a good investment.

GPS CONTROLS FOR SALT SPREADERS – OTTAWA, ON

BMP QUICK FACTS	
Location	Ottawa, Ontario
Average Winter Temperature	- 7° C
Average Annual Snow Fall	242 cm
Total Length of Road Serviced	12,000 km

It takes about 185,000 tonnes a year of salt to keep the city's streets from turning into skating rinks. In the fall of 2008, in an effort to control the amount of salt it was using, the city installed a GPS system on all its salt spreaders. The Global Positioning System has reduced salt consumption by about 10 percent and paid for itself in less than a year.

The GPS units had to have the flexibility to work with all different salt controllers that the city owns. The system also collects the data via wireless connections, and provides access to the live information through a web link.

The system is not fully automated as supervisors still make the call on salt application rates based on the route that the operators are driving and the specific weather conditions, and the operators still control the amount of salt that their rigs are spreading. What this system does provide is real time information that can be invaluable. The City can monitor where operators are and what they are doing so that if they have to they can make adjustments to the spreaders on the move. All of the data from the GPS units is tracked and stored for future reference and analysis so that the City can review its winter maintenance efficiency and confirm that it is adhering to winter maintenance standards and policies. Using the data to answer complaints that they have missed a street is an added beneficial function of the system.

So far, the City of Ottawa has spent approximately $600,000 on this project. Installation costs for the hardware were about $800 a unit. The remainder went to the collection and storage of the data. It's a substantial sum of money but considerably less than the estimated $840,000 that the city saved in the first year it used the system.

They found that they were able to save costs in a number of different ways. For example, by increasing the salt prewetting rate from 23 percent to 62 percent and using salt more efficiently; they saved about $170,000. Supervisors were able to refine their call on application rates (using 140 kilograms of salt per kilometre instead of 180, for example) and that saved about $165,000. But the biggest improvement of all was in their operator compliance rate – the amount of salt spread compared to the specified application rate. Their compliance rate improved by 15 percent, which accounts for the remaining savings of more than half a million dollars.

The next phase will be the installation of GPS units on the city's road and sidewalk plows so that they can be tracked through an interactive website.

Contact: Dan O'Keefe
City of Ottawa
Dan.Okeefe@ottawa.ca
Phone: 613-580-2400 ext. 16041

EVOLUTION OF WINTER MAINTENANCE EQUIPMENT – CITY OF LONDON, ON

BMP QUICK FACTS	
Location	London, Ontario
Average Winter Temperature	- 3.7° C
Average Annual Snow Fall	220 cm
Total Length of Road Serviced	3,500 km

In anticipation of much tighter regulations over the use of deicing chemicals, the City of London developed a Salt Management Plan in 2001, one of the first municipalities in the province to do so. Their plan, which laid out the guiding principles for better salt management practices, storage, training and applications, was overwhelmingly endorsed by city council.

In 2002, London started to move beyond sodium chloride as its only deicing salt, using its contractors to spread magnesium chloride and corn based anti-icing liquid on bridges. These materials worked better than they had anticipated. Applying the anti-icing liquid before the storm hit stopped the snow and ice from bonding to the pavement and reduced the amount of deicing salt needed by almost 90 percent. The next year, the city built its own liquid anti-icing unit, a relatively simple piece of equipment with nothing more than a tank and a spray bar. Today, London uses about 2 million litres of deicing liquid a year.

In 2003, London installed GPS systems on its contractors' spreader trucks, so that they could check, monitor and verify salt application rates while the fleet is on the streets. Two years later, they installed three Road Weather Information System (RWIS) stations. Using sensors embedded in and below the pavement, the RWIS stations automatically send pavement condition information to the operations control centre so that they could predict icing conditions before they occur and take whatever appropriate action is needed. RWIS is the key to a successful liquid anti-icing and chemical treatment program and London has enthusiastically embraced the technology. It now has five RWIS stations, three with cameras and snow depth gauges, which along with MTO's RWIS stations on Highway 401, provide citywide coverage.

London has also been making some major investments in new equipment, although in this case, bigger is not always better. In 2005, they included farm type tractors and wheel loaders in their tender call for road plows. While these tractors are slower than their other plows and not suited for expressways or major arterial roads, they are ideal for local roads and have proved especially adept at clearing London's almost seven hundred cul-de-sacs and courts. The fact that these smaller units cost less to rent is an added bonus.

There is, of course, still a place for large sophisticated winter maintenance equipment and in 2006, London bought nine combination unit spreaders at a cost of about $1.8 million. An extremely versatile piece of equipment, each unit can be used for both summer and winter maintenance. Unlike other truck combination units, these trucks can be converted from summer to winter use in a matter of hours rather than weeks, simply by sliding one box off and another box on. Once ready for the winter season, each unit can be used to spread anti-icing liquids, sand and salt and come equipped with their own plows. The spreaders have groundspeed oriented electronic controls, infrared pavement thermometers and GPS so that the operations centre can monitor their progress and are considerably more efficient than their older units. Using the trucks' pre-wetting capabilities, their operators have been able to reduce deicing salt application rates by 15 to 20 percent.

In 2009, the City made another major investment in environmental stewardship, opening a new salt storage building. Built at a cost of about $1.3 million, the building is fully enclosed with an impermeable asphalt pad, concrete walls and a drainage system to contain any runoff. Loading and unloading operations are handled inside the building so that the trucks are not exposed to the elements. London is planning to build two more storage buildings within the next three years, by which time it will have enough capacity to store three-quarters of its annual deicing requirements.

PART 2: RESEARCH CASE STUDIES

Ecological Benefits of The Road Salt Code of Practice in Toronto Streams

Kilgour B.W., B. Gharabaghi, and N. Perera. 2012. Ecological Benefit of the Road Salt Code of Practice. Water Quality Research Journal of Canada, Under Review.

This project studied reductions in chloride loads to streams, and associated concentrations in surface waters using road salt application rates for the City of Toronto before and after implementation of the Road Salt Code of Practice. The species sensitivity distribution (SSD), which describes the tolerances of aquatic organisms to chloride, as developed by the Canadian Council of Ministers of the Environment was used as the basis for estimating the benefit of anticipated reductions in chloride concentrations in surface waters. Despite an overall increase in total road salt used over the past 10 years, the Code of Practice appears to have contributed to a reduction in the "normalized" road salt application by about 26%. Species sensitivity distributions in contrast predicted between 1 and 14% of taxa would be positively affected by a 26% decrease in chlorides in surface waters. Thus, the road salt Code of Practice can be expected to have benefited up to 14% of potential freshwater taxa in the City of Toronto streams over the long term.

The estimated reduction in chloride concentrations in Toronto-area streams seems to be a reasonable observation based on other published works. In a review of the anticipated benefits of best practices for road salt applications, Ontario Ministry of Transportation. (2005) predicted about a 20% reduction in chloride loads and chloride concentrations. The City of Waterloo was able to reduce total road salt application of 10% in the broader urban road network, and by 25% in the vicinity of well fields (Stone et al. 2010). However, the net ecological benefit of implementing the Code may be undermined in rapidly urbanizing watersheds where road networks continue to expand at a rate of 3 to 5% per year and chloride loads to urban streams are steadily increasing.

Innovative Highway Ditch Designs for the Identified Salt Vulnerable Areas

Betts A., W. Trenouth, B. Gharabaghi, and B. Kilgour. 2012. Chloride Vulnerability Identification and Mitigation Project. Presentation at the Annual Ontario Ministry of Transportation Maintenance Technology Symposium.

This study focuses on the development of novel and practical methods to minimize potential negative environmental effects of road salt application in urban watersheds. Specifically, this research will focus on improvement of the scientific methods of identification of the "salt vulnerable areas" and more accurate calculation of the contribution of the key sources to the sensitive receptors; this study will also develop innovative design of underground, filter media systems embedded within the lined roadside vegetated ditch, for capture, treatment and controlled release of highway runoff to protect the salt vulnerable areas. This research will develop new methods that further reduce the risk of transmission of chloride to the environment, including the design of suitable lining material for the roadside ditches in the identified salt vulnerable areas to achieve groundwater protection and to design suitable underground filter media systems embedded within the lined roadside ditches, for capture, treatment and controlled release of highway runoff to better protect the receiving surface water receptors.

Adoption of Best Practices for the Environmental Management of Road Salt in Ontario

Marsalek, J., Stone, M. 2011. Water Quality Research Journal of Canada, 46:174-182

There are increasing concerns regarding the adverse environmental impacts of chloride from road salts. A web-based survey was conducted to determine how the Code of Practice for the environmental management of road salts has influenced the adoption of best practices in Ontario, Canada. The majority of large Ontario municipalities have salt management plans that adequately address safety and the environment. Most municipalities train a high percentage of permanent staff but only half of seasonal workers and 21% of private contractors are trained. Most training programs cover key learning goals defined by the Code of Practice. There is little improvement in the management of salt-vulnerable areas. Many existing snow disposal sites are poorly designed and do not manage snowmelt quality. The Code has strongly contributed to the adoption and improvement of salt management practices in Ontario by helping to standardize practices and advance the rate of implementation of best practices. Barriers to further implementation of the Code include understanding the Code, institutional will, liability, limited technical/financial resources and public expectation of high service levels. Further benefits can be achieved by aggressively promoting the Code and improving education and training programs for the public, private contractors and staff of road authorities.

The Code of Practice for Environmental Management of Road Salts has had a major impact on winter road maintenance procedures related to road salting and snow removal/disposal in Ontario. It has been widely adopted by Ontario municipalities and 89% of the respondents, which are predominantly larger municipalities, have SMPs. Salt Management Plans include the principles of safety, environmental protection and accountability but often do not include provisions for continual improvement nor measurement of progress and communication. Salt Management Plans, once in place, are often not reviewed. The level of communication and training for private contractors and seasonal staff regarding SMPs is relatively poor. The Code has improved salt management training of road authority employees responsible for winter road maintenance. In particular, the efforts of the Ontario Good Roads Association and the Ontario Road Salt Management Group in this regard are notable. Although record-keeping has improved since the introduction of the Code and its requirement for annual reporting, many road authorities do not keep records. The Code has increased awareness of Salt Vulnerable Areas (SVAs). Policies for winter maintenance practices in proximity to these areas are slowly being developed but increased technical capacity is required to delineate these areas. Since the Code was developed, the greatest improvement has been in the areas of salt storage and handling. The least improved areas are management of salt-impacted water and environmental monitoring. There is a lack of awareness of TAC's Syntheses of Best Practices (SOBP) and more promotion is warranted. Approximately 61% of municipalities have snow disposal sites but most are not designed in accordance with the Code or the SOBP. Concerns and challenges regarding implementation of the Code arise from a lack of understanding or acceptance of the need for salt management. Changes in personnel at the staff, management and political levels may negatively impact the level of commitment to salt management. Environment Canada is currently completing a five-year review of the progress achieved under the Code of Practice for the Environmental Management of Road Salts as described under the 1999 *Canadian Environmental Protection Act*. The objective of the review is to determine the extent to which the Code has prevented and reduced the environmental impacts of road salts in Canada. The report will provide guidance to identify and implement future actions, if any, that will be needed to achieve environmental protection objectives.

Assessing the Efficacy of Current Road Salt Management Programs

Stone, M., M. B. Emelko, J. Masalek, J.S. Price, D.L. Rudolph, H. Saini, and S.L. Tighe. 2010. Report by the University of Waterloo and the National Water Research Institute to the Ontario Ministry of the Environment and the Salt Institute.

An 18 month study was conducted by a University of Waterloo research team to assess whether adoption of the Code of Practice has effectively reduced chloride inputs to the environment in response to best management practices related to salt application and snow disposal. The study is intended to 1) provide data to support the Environment Canada 2010 review of the Code of Practice 2) evaluate the degree of implementation and effectiveness of selected best management practices to mitigate chloride transfer to the environment 3) identify barriers to implementation and 4) make recommendations to improve winter maintenance practices of roadways and parking lots. The report is divided into sections corresponding to research that was designed and conducted (surveys (see above article) as well as field and laboratory studies) to evaluate the effectiveness of the Transportation Association of Canada's (TAC) Syntheses of Best Management Practices (SOBPs) to reduce chloride transfer to the environment. The SOBPs evaluated in this study include TAC 1 Salt Management Plans; TAC 2 Training; TAC 4 Drainage and Stormwater; TAC 5 Pavements and Salt Management; TAC 7 Design of Road Maintenance Yards; TAC 8 Snow Storage and Disposal and TAC 9 Winter Maintenance Technologies. The results and conclusions of each study component are summarized below in relation to specific TAC SOPBs evaluated.

Drainage and Stormwater (TAC 4)

Three monitoring studies were conducted to evaluate the effectiveness of BMPs to manage chloride loss from drainage and stormwater. They include studies 1) to assess chloride in the shallow vadose zone and groundwater in response to reduced road salt applications in salt vulnerable areas 2) to measure the chloride concentration and loading in roadside snow pack of salt vulnerable areas and 3) to quantify chloride transfer in two Waterloo stormwater ponds.

Chloride in the shallow vadose zone and groundwater in response to reduced road salt applications in salt vulnerable areas. In response to progressively elevated concentrations of chloride (Cl-) in some municipal well fields within the Regional Municipality of Waterloo (RMOW), several Best Management Practices (BMPs) were initiated in 2003-2004 in the vicinity of the impacted well fields in an attempt to reduce road salt leaching the water table which included a reduction in total road salt application of 25% in urban road network. The influence of salt reduction on groundwater quality in the Greenbrook Well Field, Kitchener was assessed by conducting a series of field monitoring activities designed to compare the quantity and mobility of chloride in the vadose zone for pre (2003) and post-BMP conditions (2009).

The groundwater monitoring data show that post-BMP chloride levels in the vadose zone at most of the field locations were ~50% lower than for pre-BMP conditions. However, chloride concentrations in groundwater remained fairly constant or increased slightly at two locations where specific safety concerns (sidewalks adjacent to public schools) resulted in the application of elevated levels of sidewalk deicing salts. The data indicate that substantial improvement in shallow groundwater quality (specifically Cl- concentrations), resulted from the implementation of road salt BMPs. A detailed comparison of the soil core data collected from the unsaturated zone as measured in 2001 and 2008 indicates a significant reduction in average soil Cl- concentration occurred following the implementation of the BMP activities. When these data are combined with estimates of groundwater recharge rates at each of the field monitoring stations, an average reduction of 60% in road salt mass loading to the water table was observed between the initial study (2003) and the 2008 study. The data support the overall conclusion that significant reductions in road salt loads to the subsurface resulted from the implementation of the BMP strategies in 2003. The study shows that a considerably lower percentage of the total applied road salt mass is entering the subsurface under the new salt management practices as compared to historical practices. The trends observed in the groundwater Cl- data collected from the monitoring network correlates well with the observations made from a detailed assessment of chloride occurrence and distribution in the unsaturated zone. Accordingly, monitoring of changes in groundwater quality in shallow monitoring wells provide useful quantitative assessment of the performance of different BMPs in the urban environment. The actual time lag associated with the implementation of the BMPs and an observable influence at the water table, however, will depend on the thickness of the unsaturated zone and the vertical soil water velocity. The groundwater quality data clearly illustrate that the reduction in Cl- concentration at the water table is a transient process that will take years to be fully realized.

Distribution and mass loading of chloride in snowpack of salt vulnerable zones. A field monitoring program was designed to quantify the spatial distribution and mass loading of chloride in roadside snowpack of salt vulnerable areas. The factorial design included measuring chloride concentrations and mass loading (kg m-2) in

3 well field capture zones (2, 5 and 10 year travel times) for 3 road classes (2, 3 and 4) within each capture zone, for 3 cities (Waterloo, Kitchener, and Cambridge). The data show that average chloride concentrations declined with distance from the road way. Variability in the data is related to several factors that influence both the redistribution of snow in urban environments and salt demand. Chloride concentrations in snow varied considerably as a function of road class, well field and sensitivity area (capture zone travel time).

Chloride transfer in two Waterloo stormwater ponds. A field study was conducted to examine the effect of land use and road density/type on chloride concentrations in Laurel Creek and to evaluate the role of stormwater management ponds as a chloride source to receiving waters. Ten sampling stations in Laurel Creek (from its headwaters to the central part of Waterloo) as well as both the inflow and outflow of two stormwater management (SWM) ponds (conventional design– Pond 45 and hybrid extended detention design – Pond 33) were monitored in Waterloo, Ontario during the fall 2008 and winter/spring 2009. Chloride concentrations in Laurel Creek as well as the inflow and outflow of two stormwater ponds often exceeded the CCME chronic toxicity level (250 mg L-1) and occasionally exceeded the CCME acute toxicity level (750 mg L-1). Mean monthly chloride concentrations increased throughout the winter and spring at most sites but were typically lower in the less urbanized headwater sites than in areas with increasing impervious cover and road density/traffic volume. Mean monthly chloride levels at two monitoring sites (Keats and 5B) were often 10 to 20 times higher than background levels in Beaver Creek (site 17). The study found that inflow concentrations of chloride were similar for the two stormwater ponds of varying design but their outflow concentrations varied considerably over the study period. In the hybrid design (Pond 33), mean monthly outflow chloride levels peaked in December (~700 mg L-1) but remained at < 100 mg L-1 for the remainder of the winter. In contrast, chloride levels in the conventional design (Pond 45) were more variable and average monthly chloride concentrations increased steadily at the outflow from ~50 mg L-1 in October-08 to ~400 mg L-1 in April-09. The study suggests that the hybrid design pond (which consists of two settling ponds separated by a berm and a final vegetated area) was more effective at reducing chloride discharge at the outflow.

Pavement and Salt Management (TAC 5)

Performance of Pervious Concrete Pavement in an Accelerated Freeze-Thaw Climate: Transport and retention of water and salt within pervious concrete subjected to freezing and typical winter sanding. Pervious concrete has been shown to reduce stormwater volume and the concentration of many contaminants (with the exception of chloride) in urban runoff. In freeze/thaw environments, where the application of road salt is necessary, it is necessary to understand the impact of pervious concrete structures on the movement of water and hence, the transport of the Cl-within the water. To accomplish this, a study was conducted to characterize the hydrologic performance of pervious concrete under frozen and thawed conditions, with varying additions of sand using both brine (23% salt solution) and fresh water. The overall impact of sand application to the surface of pervious concrete is a reduction in the speed of the movement of water through the pores, causing a delay in the peak flow received at the base of the concrete. In all experiments, the salt was transported through the pervious concrete very quickly. Salt underwent some dispersion with the application of sand and under frozen conditions, due to the more tortuous flow paths. Contrasting this is the impact of freezing water within the pores of the concrete. Although the overall impact of frozen water is similar to sand (i.e. slows water movement), the water is able to have this effect throughout the entire depth of the concrete, as water is able to freeze within the pores near to the base as well as at the surface of the concrete. This would also have consequences on the timing of salt transport, as it is a dissolved constituent within the water, and would also remain in the matrix of the concrete. However, these represent extreme conditions. Observations indicate that the infiltration capacity of the pervious concrete structures, as tested, exceeds the probable maximum water loading rate that will be encountered in Southern Ontario, with or without sand; frozen or unfrozen.

The focus of the *Ontario Clean Water Act* is to reduce significant risks to drinking water by identifying vulnerable areas (wellhead protection areas, intake protection areas and other highly vulnerable areas) and developing plans to reduce significant risks to acceptable levels and prevent future significant risks. Chloride is listed as a potential threat to drinking water as indicated in Section 1.1 of Ontario Regulation 287/07.

Implications of the *Ontario Clean Water Act* for road salt management include 1) Improved design and delivery of parking lot winter maintenance programs 2) Increased adoption of new technology 3) Improved delineation of salt vulnerable areas and refined winter maintenance procedures in intake protection zones (IPZs) 4) Increased level of training (certification) for road authorities and private contractors 5) Integration of salt management plans with source water protection committees (SPCs) objectives to delineate source waters, identify threats and develop and implement SWP Plan and 6) Improved stormwater management practices. While pervious pavement technologies can effectively reduce runoff, they can negatively impact groundwater quality when improperly located and poorly designed. To meet the future requirements of the *Clean Water Act*, better design guidance is required for the use of this material for parking lots located in salt vulnerable areas.

Snow Storage and Disposal (TAC 8)

Snow Storage Disposal Facilities (SSDFs) and Their Role in Urban Snow and Road Salt Management: Guidance for Design, Operation and Maintenance. When snow is transported from urban areas to snow storage disposal facilities (SSDFs), it contains a range of particulate and dissolved constituents that can potentially be released into the environment during snowmelt. Snow removal, transport, storage and snowmelt and potential impacts of these processes on the environment are of concern in both urban and natural environments with transportation corridors. A review of recent literature on SSDFs found that well-planned, designed and operated SSDFs provide cost savings, improve traffic flow and safety in the urban area and reduce overall environmental impacts. However, there are also challenges in implementing such facilities with respect to environmental issues, social impacts and costs. Successful planning and implementation requires long-term strategic planning, including a scoping analysis, comparison of various snow removal and disposal technologies, assessment of snow storage needs and associated costs, selection of the best alternative and securing funding; all done with public involvement and advice through structured consultations. Such information is necessary to improve guidance documents for the design of snow storage and disposal sites.

Characterization of Urban Runoff and Chloride Mass Balance

Perera, N., B. Gharabaghi, P. Noehammer, and B. Kilgour. 2010. Road Salt Application in Highland Creek Watershed, Toronto, Ontario – Chloride Mass Balance. Water Quality Research Journal of Canada, Vol. 45, No.4:451-461

This study focuses on chloride mass balance in the fully urbanized Highland Creek watershed in Toronto, Ontario. The Highland Creek watershed is approximately 100 km^2 in area and situated almost entirely within the City of Toronto boundary. The area is highly urbanized and has a dense road network. Approximately 14.5 % of the study area is covered by road pavements while open areas account for 21.5% of the total area. Parking lot areas for commercial and institutional land use is approximately 2.5% of the total area and multifamily residential and industrial area parking lots cover 4.5% of the study area.

The City of Toronto and the Ontario Ministry of Transportation (MTO) keep daily records of salt application rates. Both agencies have salt spreaders equipped with calibrated electronic spreader controls. Uncertainty in the road salt application data from the City of Toronto and MTO is low because spreader controller calibration is conducted regularly.

Daily road salt application quantities by the City of Toronto and MTO for the study area were determined considering the assigned routes (beats) for each salting truck using Geographical Information Systems (GIS). For each truck route, the proportion of road lane lengths located within the study area was multiplied by the total daily salt application for that truck to determine the actual salt quantity applied within the study area. Road salts applied on sidewalks by the City were also estimated using GIS.

Contribution of chloride mass due to private winter maintenance practices reported in literature varies from 14% to 40% (Howard and Haynes, 1993; City of Madison, 2006; Sassen and Kahl, 2007). Landscape Ontario, which is an umbrella organization for landscape contractors in Ontario (landscape contractors are involved with winter maintenance of parking lots), indicated that road salt application rate estimates of its members range from 1 to 10 times compared to the MTO application rate (Robert Rozzell, 2010 personal communication). Following limited survey data, commercial properties such as shopping complexes and institutional properties were assumed a rate two times higher compared to salt application rate on road pavements on a unit area basis. Industrial and multi-family residential areas were assumed to use the same amount used on roads.

The extent of paved areas under different land use was determined from ortho-photos taken in 2005 and City of Toronto land use maps with the use of GIS. The private contractor application of road salts in the study area was estimated to be approximately 38% of the total salt application. According to the data from the Salt Institute (Novotny et al., 2009), USA national average of the proportion of deicing salts bought by private entities is 24% of the total deicing salts sold by rock salt producers. This proportion should is higher for urban areas considering the length of deiced highway pavement area in non-urban areas where deiced parking lot areas are not significant.

The chloride mass (load) in the stream was computed as the product of stream flow and chloride concentration. Concentration data from stream chloride monitoring program and flow data from the Water Survey Canada flow gauge was used to calculate chloride load in stream water. Stream chloride concentrations were monitored on an hourly basis. Chloride concentration was measured using specific conductance as a surrogate (Granato and Smith, 1999) and then converting specific conductance values to chloride concentration using the correlation developed based on laboratory analysis of frequent grab samples from the creek. Based on the results of this research the following conclusions can be made:

1) Total amount of road salts applied on paved areas has a high variability and is dependent on several climatic factors (total snowfall, type and rate of precipitation, mean winter temperature). However, the variability of the road salt application rate decreases significantly (about 50%) when the rate is "normalized" based on total snowfall and mean winter temperature.
2) Amount of road salt applied by private contractors on parking lots and driveways is estimated to be approximately 38% of the total road salts applied within the Highland Creek watershed. Therefore, impact of private deicing operations on watershed chloride mass balance is significant and any attempts to reduce the amount of road salts being applied on urban areas should also target this chloride source. It is important to note that in some private properties, the salt application rate could be several times higher than the rate applied on road pavements.
3) Approximately 60% of the chlorides from applied road salt is removed from the watershed as short-term chloride output prior to the next winter season. Effect of short-term chloride output on aquatic ecosystems is more significant during the November to March season.
4) Annual chloride mass balance undertaken for the study area indicated approximately 40% of the chloride applied as road salts enter the shallow aquifer and a portion of it accumulates within the aquifer. This net accumulation causes the groundwater chloride concentration to increase gradually.

Winter Sanding with Pre-Wetting

Perchanok, M., et. al. 2010. Presentation at the Annual Conference of the Transportation Association of Canada

Low volume highways in northern Ontario are maintained to winter standards that result in either a centre bare pavement followed by complete clearing within a day after a winter storm, or in a drivable but snow packed surface through most of the winter that is sanded frequently to improve traction. The resulting use of road salt, winter sand and equipment operation add to the environmental effects and the cost of highway operations. A study was undertaken to evaluate whether these impacts can be reduced through a new spreading technology that helps to hold winter sand to a snow packed road surface by pre-wetting it with hot water during application. Operational experience with the technology was gained at three highway locations over 80 days of winter service. The potential for reduction of environmental impacts and direct costs, and of improving winter safety and mobility, were assessed with maintenance records from conventional operations being compared to predictions for a highway maintained with a Hot Water Sander. This study predicts significant economic, safety-mobility and environmental benefits resulting from the revision of Class IV and V winter standards using the Hot Water

Sanding concept. The predicted Road Safety Index for the HWS is intermediate between that of a conventional Class IV and V highway and higher than the average of those classes. This suggests that road safety can be improved on a road network basis by replacing Winter Class IV and V with a new class having a traction performance standard that can be achieved using the Hot Water Sander concept. The HWS concept also demonstrates the possibility of environmental benefits from the predicted large reductions in road salt and winter sand as well as a reduction in GHG emissions, compared with conventional methods on Class IV and V highways. Furthermore, both operating and material costs on Class IV and V highways can be reduced. Several operational and safety related issues were encountered during field trials in Ontario, and these must be overcome to achieve the predicted, network-level economic, environmental and safety benefits. In addition, the predictions use assumptions based on intensively monitored field trials in Scandinavia. Validation of the results under Ontario operating conditions would increase certainty in the predictions.

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