EXHIBIT 17

Ecological benefit of the road salt code of practice

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ABSTRACT

Despite an overall increase in total road salt used over the past 14 years (the data record in this manuscript), there has been a 26% reduction in the rate (normalized as tonnes of salt per cm of snow per km of road) of road salt application by the City of Toronto since that city implemented mitigations from the Road Salt Code of Practice. The ecological benefit of the reduced use of road salt was approximated by comparing the estimated 26% salt reduction to the distribution of chloride tolerances that has been recently published by the Canadian Council of Ministers of the Environment (i.e., CCME). Species sensitivity distributions predict that between 1 and 14% of taxa would benefit from a 26% reduction in chloride concentrations in surface waters. Assuming that a typical 'healthy' Canadian watercourse might support between 100 and 200 species of fish, invertebrates and plants, the Code of Practice might provide benefit to between 14 and 28 species. 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 3–5% per year and chloride loads to urban streams are steadily increasing.

Key words | chlorides, ecological benefits, maximum field distribution, road salt, species sensitivity distribution

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INTRODUCTION

Snow and ice conditions on the road system have a significant impact on public safety, roadway capacity, travel time and economic costs (Keummel 1992). In Canada, control of snow and ice on road pavements and sidewalks is generally achieved by a combination of de-icing with road salts and mechanical plowing. Each year, approximately 5 million tonnes of road salts are used as de-icers on roadways in Canada (Environment Canada 2004). The City of Toronto, with about 5,500 km of dense road network (City of Toronto 2005) relies on about 135,000 tonnes per year salt application during the winter to provide safe transportation surfaces for all road and sidewalk users in an efficient and affordable manner.

Both aquatic and terrestrial ecosystems can be adversely affected by exposure to chloride concentrations associated with the typical use of road salts (USEPA (United States Environmental Protection Agency) 1988; Novotny *et al.* 1999; Environment Canada & Health Canada 2001; Rutherford & Kefford 2005). Elevated concentrations of chlorides in surface waters can cause changes in behavior (e.g., increased 'drift' of stream invertebrates; Crowther & Hynes 1970), and increase mortality rates of aquatic organisms (Evans & Frick 2001; Benbow & Merritt 2004). Cladocerans (e.g., *Ceriodaphnia*) are considered particularly sensitive to chlorides with concentrations as low as about 450 mg/L causing harm to individuals during short-term exposures (Dowden & Bennet 1965; Elphick *et al.* 2011). The larvae of some select rare and endangered Canadian freshwater mussels are also highly sensitive to chloride with concentrations as low as 113 mg/L causing harm to individuals in laboratory toxicity tests (Bringolf *et al.* 2007; Gillis *et al.* 2008; Gillis 2011).

Chloride concentrations vary spatially in Canada. Natural background freshwater chloride concentrations are generally in the 10–20 mg/L range, but stream chloride concentrations in highly urbanized areas can be as high as

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10,000 mg/L. Loadings are highest in urban centers including Toronto and Montreal (Mayer *et al.* 1999). Concentrations of chlorides are generally increasing in ground (Kincaid & Findlay 2009; Mullaney *et al.* 2009) and surface waters (Todd *et al.* 2009) in urbanized areas. There may be a relationship between percent imperviousness and chloride concentrations in streams, based on work in the USA (Kaushal *et al.* 2005), and implying that areas with an imperviousness of >30–40% are likely to have chloride concentrations in their surface waters of some 200–300 mg/L.

Environment Canada classified road salt a toxic substance on the basis of extensive review of fate and effects (Evans & Frick 2001). That classification required that Environment Canada consider regulatory instruments for mitigating the risks that were considered to be posed by the product. Environment Canada (EC) & Health Canada (HC) (2001) carried out additional research assessing various mitigation techniques (Marsalek 2003; Stone & Marsalek 2011), and then developed its Code of Practice (EC 2004). The Code of Practice is an assemblage of best practice guidelines for reducing the use of road salts in municipalities that use large amounts of the product. Environment Canada is encouraging municipalities that use more than 500 tonnes of road salt per year to implement the mitigations recommended in the Code. Municipalities that implement the best practices (including reduced application rates and more efficient timing of application) have been able to reduce chloride concentrations in groundwater by 50% over a 3–4 year period (Bester *et al.* 2005; Stone *et al.* 2010).

The ecological benefit of implementing the Code is questionable, considering that our road networks are continuing to expand and chloride loads to watersheds are increasing. Estimating the ecological benefit of the Code of Practice requires an understanding of the relationship between exposure concentration (as well as frequency and duration) and ecological effect. Chloride tolerances determined from laboratory toxicity tests provide one line of evidence of the potential effects that chloride concentrations can have in the environment. USEPA (1998) developed toxicity thresholds for chloride including a longer-term chronic criterion of 230 mg/L which is to be applied to exposure durations of 96 h or more, and a short-term acute criterion of 860 mg/L which is to be applied to exposure durations of 4 h or less. The Canadian Council of Ministers of the Environment (CCME) recently published a national guideline for chloride (CCME 2011). CCME recommended that concentrations of 640 mg/L would protect most species (95%) during short-term acute exposures, while 120 mg/L would protect most species under longer-term chronic exposures. CCME (2011) further recognized that some watersheds in southwestern Ontario contain species of Unionidae (freshwater mussels; northern riffleshell – *Epioblasma torulosa rangiana* and the wavy-rayed lamp mussel – *Lampsilis fasciola*) that are not only highly sensitive to chloride during their larval stages (concentration lethal to 10% of larvae is ~24 mg/L), but are rare and at risk of extirpation (COSEWIC (Committee on the Status of Endangered Wildlife in Canada) 2010a, b), and that these watercourses may require further protection greater than that afforded by the general guidelines.

The objective of this paper is to provide one estimate of the ecological benefit of Environment Canada's implementation of the Road Salt Code of Practice. The estimate here is specific to the City of Toronto's experiences. Reductions in chloride loads to streams, and associated concentrations in surface waters, were modeled using road salt application rates for the City of Toronto before and after implementation of the Code of Practice. The ecological benefit was estimated by comparing the observed salt reduction (pre to post implementation of the Code) to the distribution of chloride tolerances (Posthuma *et al.* 2002) that has been recently published by the Canadian Council of Ministers of the Environment (i.e., CCME).

METHODS

Normalized road salt loadings

Road salt application rates were computed for the Toronto area for the period 1996 to 2007. Salt application rates were provided by the City of Toronto – Transportation Services and by the Ontario Ministry of Transportation. Road salt application rates within watersheds and catchments depend in part on road density and primarily on the weather. Higher road densities generally result in more road salt being applied within a catchment. Greater amounts of snow also generally require a greater amount of road salt application in a given year. Changes in surface water concentrations pre-post the Road Salt Code of Practice (i.e., before versus after 2004) could, therefore, have varied because of changes in road density (i.e., increase) or changes in snowfall. Road salt application rates were thus standardized for road density and snowfall to better understand the impact of the Code of Practice on road salt application rates. Annual snowfall data for the Toronto area were obtained from the nearby Environment Canada weather station in North York. Digital road network data were obtained from the Ontario Ministry of Transportation. The relationship between road salt application rate (tonnes per year) and road density, as well as between road salt application rate and snowfall accumulation (cm per year) were quantified annually for the years 1996 through 2007. Salt application rates were scaled to road density and snowfall accumulation, and ultimately expressed as kg salt/km road/cm snow. Total length of salt-applied roads within the watershed was considered for the normalization as all roads drain to the stream network within a couple of hours due to lower roughness in storm sewer systems. The lag time in getting salty runoff to a stream is, therefore, much smaller than the time frame considered for short-term exposure for aquatic organisms (generally 24–48 h). A simple t-test was used to test for differences in normalized application rates between the period before (1996–2003) and the period after implementation of the Road Salt Code of Practice (2004–2007). The percent change in normalized road salt application rate was computed from before to after implementation of the Code.

Quantifying ecological benefit

CCME (2011) reviewed the existing chloride toxicity literature and developed a species-sensitivity distribution (SSD), which describes the expected distribution of species tolerances when exposed to chloride. CCME developed two curves: (1) the first SSD_a was for acute, or short-term (24–48 h) exposure to chloride; and (2) the second SSD_c was for chronic, or long-term (96 h or longer) exposure to chloride. Both SSDs were based on the set of taxa for which reliable toxicity data are available; data are not available for all of the tens of thousands of aquatic organisms that occur in surface water environments (creeks, streams, rivers, ponds, lakes) in Canada (Morton & Gale 1985). The SSDs, which are approximately normally distributed, however, can generally be used to predict the percentage of species that will be affected when exposed to chlorides for short- or long-term periods. Both short- and long-term SSDs were considered well fit using a log-Weibull model with the following form (as per CCME (2011)):

$$y = 1 - e^{-\left(\frac{x}{\lambda}\right)^k}$$

where, y is the percentage of species affected, x is the logarithm of the chloride concentration, and λ and k are constants that define the shape and form of the relationship. In the case of the short-term SSD, λ was 3.6268 and k was 10.9917; in the case of the long-term SSD, λ was 3.2119 and k was 7.0473. The SSDs are reproduced in Figure 4.

The SSD models were used with the normalized reduction in road salt application rates to quantify a potential ecological benefit to having implemented the Road Salt Code of Practice. Here, the reduction in normalized road salt application rates was taken as an estimate of the reduction in chlorides that could be anticipated, all other factors being considered, after implementation of best practices post the Road Salt Code of Practice. So for example, if the normalized road salt loadings were to have decreased by 10% post implementation of best practices, it was assumed that chloride levels in surface waters in Toronto area streams would be roughly 10% lower than if the Code of Practice had not been implemented. It is recognized that there are various lags when chlorides transport to streams, and that some of the lags are considerable (e.g., decades in some cases). For the purpose of this paper, it was assumed that chloride loadings to watercourses responded immediately to reductions in application of road salt to roadways. The ecological implication of that reduction was estimated considering the magnitude and form of the short-term and long-term SSDs. We computed the percentage of species that would be anticipated to benefit from reductions in chlorides (as per the estimated reduction in normalized road salt application rates), using both the short-term and long-term SSDs.

RESULTS

Reduction in normalized road salt application rates

Road salt application in the City of Toronto varied by an order of 3× from a low of ~57,000 tonnes in the winter of 2001/2002 to ~200,000 tonnes in the winter of 2007/2008 (Table 1). Over 50% of the variation in road salt application was related to cumulative snowfall (Figure 1). A little less than 5% of the variation in salt application rate was related to road density (Figure 2). Salt application rates normalized for both road density and snowfall are illustrated in Figure 3. There was a subtle but distinctive reduction in road salt application rates in the period defined as being after the Road Salt Code of Practice was implemented. The difference (26% reduction in mean normalized salt application rate)

Table 1 | Normalized road salt application rates

Winter period	Total amount of road salt applied (tonnes)	Cumulative snowfall (cm)	Length of roadway lanes (km)	Normalized road salt application (tonnes/cm/km)
1995/06	128,000	150	12,343	0.069
1996/97	157,600	167	12,415	0.076
1997/98	101,900	112	12,493	0.073
1998/99	140,400	124	12,493	0.091
1999/00	142,900	88	13,846	0.117
2000/01	176,600	181	13,800	0.071
2001/02	56,900	77	13,800	0.054
2002/03	208,200	145	13,800	0.104
2003/04	108,200	108	15,052	0.067
2004/05	147,400	166	15,052	0.059
2005/06	94,700	108	15,052	0.058
2006/07	89,100	83	15,052	0.071
2007/08	195,600	233	15,052	0.056
2008/09	147,100	195	15,052	0.050

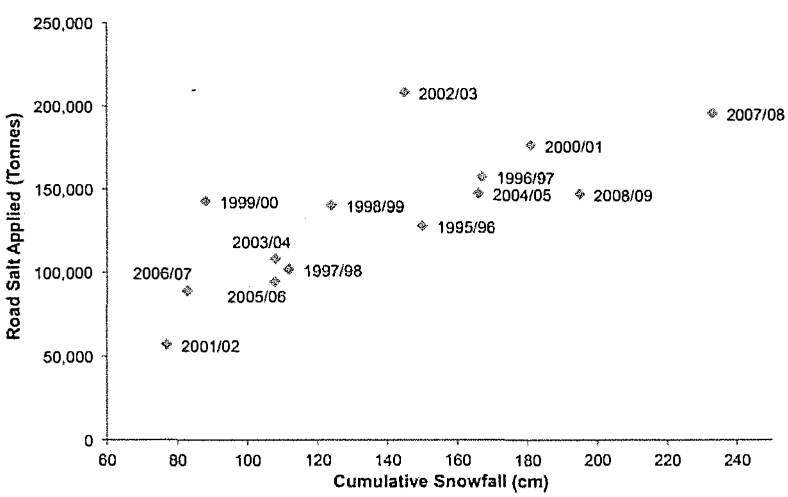

Figure 1 | Relationship between cumulative snowfall and tonnes of road salt applied in the Toronto area between the winters of 1995/1996 and 2008/2009.

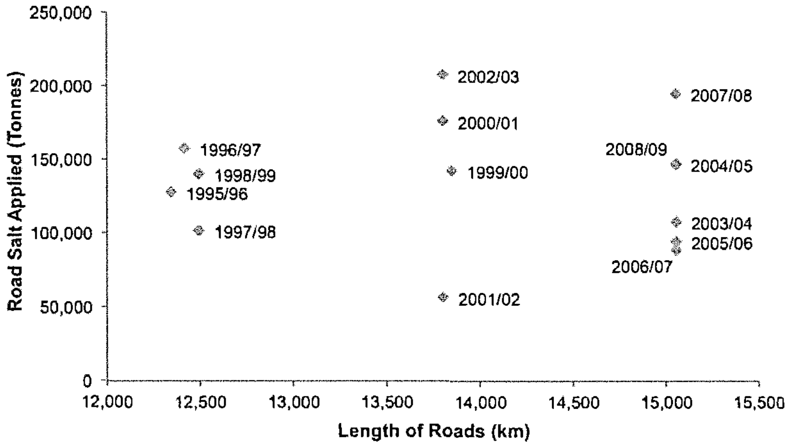

Figure 2 | Relationship between length of roads (km) and tonnes of road salt applied in the Toronto area between the winters of 1995/1996 and 2008/2009.

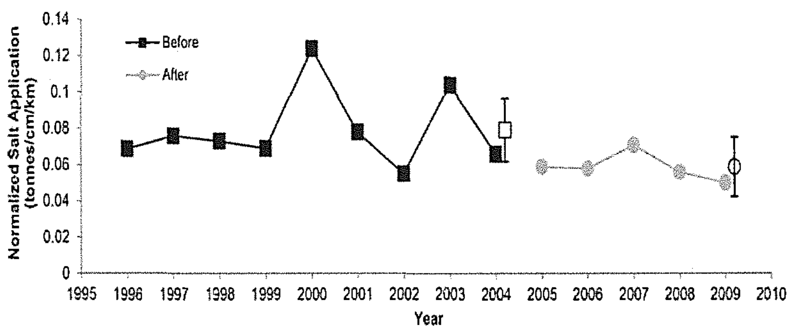

Figure 3 | Variations in normalized road salt applications rates, City of Toronto.

was statistically significant at a probability level of 0.03% (for a one-sided *t*-test).

Ecological benefit

The relationship between percent of taxa affected and chloride concentration was sigmoid in shape (Figure 4). The percentage of species benefiting from a 26% reduction in chloride concentrations, therefore, varies from a negligible fraction when the chloride concentrations are already low (say <200 mg/L), to ~14% when chloride concentrations decrease from ~6,000 to 4,400 mg/L in a short-term acute exposure (Table 2; Figure 4). The percentage of species benefiting also depends on whether the exposure is short- or long-term, with a greater benefit occurring under short-term acute exposure (Figure 4; Table 2). The ecological benefit was greatest within the zone of the SSD in which the slope of the relationship between species affected and concentration was the most extreme, for both the short-term and long-term relationships.

DISCUSSION

This analysis demonstrated a potential 26% reduction in chloride loads to watercourses in the Toronto area after implementation of the Code of Practice. That loading should, in the longer term, result in chloride concentrations being ~26% less than what they otherwise would have been, had the Code of Practice not been implemented. Those reductions in chloride concentrations, further, have the potential to benefit as much as 14% of potential freshwater

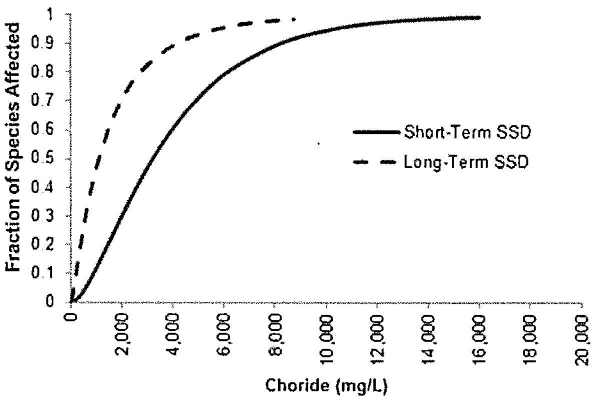

Figure 4 | Models of species sensitivity distributions for short-term and long-term exposures to chloride in surface waters. Models are from CCME (2011). Vertical lines indicate 2,000 and 1,400 mg chloride/L; horizontal lines indicate fraction of species affected by 2,000 and 1,400 mg/L in short-term and long-term exposures.

Table 2 | Percent of taxa benefiting from a 20% reduction in chloride concentrations in surface water

Initial chloride (mg/L)	Final chloride (mg/L) with 26% reduction	% benefiting under short-term exposures	% benefiting under long-term exposures
10,000	7,400	8	2
9,000	6,660	9	2
8,000	5,920	11	3
7,000	5,180	12	3
6,000	4,440	14	4
5,000	3,700	14	6
4,000	2,960	14	7
3,000	2,220	13	9
2,000	1,480	10	10
1,000	740	4	10
800	592	3	9
600	444	2	8
400	296	1	6
200	148	<1	3
100	74	<1	1

taxa. The estimated benefit: (1) assumes that the anticipated reduction in chloride loads is accurate; (2) recognizes that there are time lags between changes in application rates and concentrations in surface waters; (3) recognizes that chloride loads can be expected to generally increase in the future, regardless of implementation of the Code of Practice, and that aquatic species will more likely continue to be at an increasing risk; and (4) recognizes that other pollutants and stressors may override the influences of chlorides and further limit the distributions of aquatic organisms in heavily urbanized centers. Each of these points is discussed in greater detail below.

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, Gartner Lee Limited (GLL 2005) predicted about a 20% reduction in chloride loads and chloride concentrations. The City of Waterloo was further able to reduce total road salt application by 10% in the broader urban road network, and by 25% in the vicinity of well fields known to be susceptible to road salts (Stone *et al.* 2010). Municipal agencies, then, appear to be targeting a general reduction in the use of road salt by some 20–25%, and that level of reduction from historical loadings appears to be a reasonable expectation assuming that weather patterns also remain consistent into the future. As per Perera *et al.* (2010), road salt loadings are in part weather dependent, while changes in climate may result in a requirement to increase salt use per precipitation event, depending on air temperatures.

Despite the anticipated loading reductions, it is considered unlikely in the near term that chloride concentrations will significantly decrease in surface waters. Analysis of Ontario's long-term data set shows an increasing trend in chloride concentration in river waters in almost every region (Todd *et al.* 2009). Time trends in four watersheds, two rural and two urbanized, were examined, in particular by Todd *et al.* (2009). Chloride concentrations in the Skootamatta River near the village of Actinolite (surrounded by natural and agricultural lands) have increased from a 1980s baseline of ~2 mg/L to a present-day value of ~3 mg/L. Concentrations in the Sydenham River near Owen Sound (population ~15,000) have increased from a 1970s baseline of ~8–9 mg/L to a present-day value of ~12 mg/L. Chloride levels in Fletchers Creek in Brampton (outside Toronto) have increased from an average of ~100 mg/L in the 1970s to an average of almost 500 mg/L in 2008. Chloride concentrations in Sheridan Creek in Mississauga have increased from a 1970s baseline of almost 300 mg/L to a present day average of about 800 mg/L. Todd *et al.* (2009) further tested for statistical significance in trends over time across the province. They compared chloride concentrations in the period 1980–1985, to those in the period 2000–2004. For those stations for which there were adequate data to make the comparison, over 90% demonstrated a statistically significant increase in chloride concentration. The data, thus, overwhelmingly indicate that chloride concentrations in ground and surface waters are increasing, and those increases appear to be related to increasing densification of road networks.

The lack of reduction in chloride concentrations in surface waters is in part related to historical loadings that are now resident in groundwaters which provide a base flow to surface waters. Groundwater is a storage compartment for road salts (Kincaid & Findlay 2009; Mullaney *et al.* 2009), and has been identified as a particular challenge to short-term recovery of surface water concentrations by both Canadian and US researchers (Ramakrishna & Viraraghavan 2005; Wenck Associates Inc. 2006; Howard & Maier 2007; Cooper *et al.* 2008; Kincaid & Findlay 2009; Rubin *et al.* 2010). The University of Guelph, in association with the City of Toronto, has monitored chloride concentrations in rivers (Highland Creek, Rouge River, Don River, Humber River) in Toronto. Despite an estimated 26% reduction in normalized road salt application loadings (as estimated in this paper), concentrations of chlorides in the Toronto-area rivers has not measurably declined (Perera *et al.* 2010). Road densities increased over that period, while weather patterns varied, and total loading of chloride to streams has continued to increase. The long-term groundwater concentration of chloride was, further, estimated to be approximately 275 mg/L, or high enough to pose risks to aquatic organisms under long-term exposure scenarios.

There has been no calculation of the fraction of Canadian surface waters that will benefit from the implementation of the Code of Practice. Impacts are, currently, anticipated in heavily urbanized areas with high road densities, and in particular in surface waters that have low dilution (i.e., small watersheds or catchments) draining major roadways. The ecological benefits of implementation of the Code of Practice, therefore, are anticipated to primarily occur in the most densely populated urban areas where high chloride levels presently occur (Mayer *et al.* 1999; Morin & Perchanok 2000). The ecological benefits of the Code of Practice are, thus, most likely to occur in a relatively small fraction of the total land area in Canada.

The magnitude of the ecological benefit estimated here (14% of taxa) can be re-expressed in real numbers if we consider the number of species that might naturally occur in a watercourse. Of the some 10,000 aquatic species that occur in watercourses in North American (Morton & Gale 1985; Pennack 1989), inventories in Canadian waters typically produce about 100–200 individual taxa in a 'healthy' system if we consider fish, benthic invertebrates and macrophytes. If the calculations are correct, and implementation of the Code of Practice resulted in a reduction in chloride load of some 26%, and there was a benefit to some 14% of possible taxa, then the number of taxa in the watercourse may increase by as many as 14–28 taxa. Such an increase in diversity is clearly measurable assuming a statistically robust study design (EC 2002).

The ecological benefits of the Code of Practice may however be masked by other stressors. The ecological benefit from reducing chloride levels assumes that other 'urbanization-related' stressors are not also limiting the ecological diversity of a surface-water feature. Many urban centers, however, do release contaminants other than road salt into aquatic receiving environments. Metals and hydrocarbons, in addition to chlorides, contaminate runoff from roadways, at concentrations that are toxic to aquatic ecological receptors (Murakami *et al.* 2008). Nutrients, suspended particulate material, and pesticides from urban areas also enter surface waters (via stormwater runoff and treated sewage) at concentrations that pose additional risks to aquatic organisms (EC 2001). Storm flows from urban areas can also be erosive, leading to changes to physical stream habitats, and associated losses of the critical habitats of some species. The loss of riparian cover within watersheds leads to alterations in the hydrological cycle (greater storm flow volumes, increase in frequency of stream flashiness), which can lead to an increase in erosivity within watercourses (Booth & Jackson 1997). The lack of riparian zones further leads to increasing solar inputs to streams, resulting in warmer summer temperatures (Barton *et al.* 1985). There is thus the real potential that reductions in chloride levels will not result in real, measurable ecological benefit because of masking by other stressors. The masking effect is, however, hard to predict or quantify because we have a generally limited specific understanding of the tolerances of individual aquatic species to the numerous and various stressors that are present in urban system (see Stanfield & Kilgour (2006), for example).

We predict, herein, in the short term it is unlikely that we will observe any measurable and apparent ecological benefit of the Road Salt Code of Practice. Many watercourses, in the most salt-impacted regions (i.e., Toronto-area watershed, Mayer *et al.* (1999)), are already additionally impacted by other various urbanization related stressors. Increasing urban expansion and road densification is, further, leading to overall increases in chloride concentrations in surface waters. Further, although the Code of Practice is being implemented by many municipalities in Canada, it does not apply to commercial snow-plowing operations. Environment Canada considers it likely that commercial operators use larger amounts of salt to clear snow and ice from parking lots than typical municipal agencies would or do, in part because the commercial operators are compensated on the basis of use (Stone & Marsalek 2011). The lack of immediate ecological benefit should, however, not be used as an excuse to not implement the Code. The analyses here demonstrate that implementation of the Code of Practice will lessen the effects from what they might otherwise become as urban areas expand and road densities increase. Second, arguing that we should not address known risks associated with one substance because there are other known risks associated with another substance sets a dangerous precedence that could perpetuate risk legacies. The areas within which road salts pose significant ecological risks in Canada are relatively small and localized (i.e., to those areas that are heavily urbanized like the City of Toronto; Mayer *et al.* 1999). There are large areas in Canada where the risks associated with road salts can be considered negligible to the point that implementation of the Code of Practice would have a negligible benefit to ecological receptors. Kaushal *et al.* (2005) recently examined the association between chloride concentrations and percent imperviousness. They demonstrated, for watercourses in Baltimore that chloride concentrations in surface waters were generally <100 mg/L when percent imperviousness was <10–15%. That relationship could be used as one of several potential rules of thumb to identify areas where road salts are likely to pose a negligible risk to aquatic receptors.

CONCLUSIONS

The Code of Practice appears to have contributed to a reduction in the 'normalized' road salt application by about 26%. Despite increasing urbanization and densification of road networks, a 26% reduction in normalized application means in the long term that chloride levels will at least not be increasing by that amount. SSD in contrast predicted between 1 and 14% of taxa would benefit from a 26% reduction in chloride concentrations in surface waters. Thus, the Road Salt Code of Practice can be expected to benefit up to 14% of potential freshwater taxa over the long term. We predict that we will not in the near term observe ecological benefits of having implemented the Code of Practice because: (1) road salts pose ecological risks in limited areas (i.e., densely populated urban areas in southern parts of the country); (2) other urban stressors are expected to mask small ecological benefits associated with small reductions in chloride loads; (3) chloride loadings and concentrations are generally increasing in association with increasing urbanization. The lack of observed ecological benefit should not be used as an argument to not implement the Code of Practice in areas where road salts clearly pose risk to aquatic organisms.

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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**

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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.

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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.

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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

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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

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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 ($CaCl_2$) to a mixture of Magnesium Chloride ($MgCl_2$) 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

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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.

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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

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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.

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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.

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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.

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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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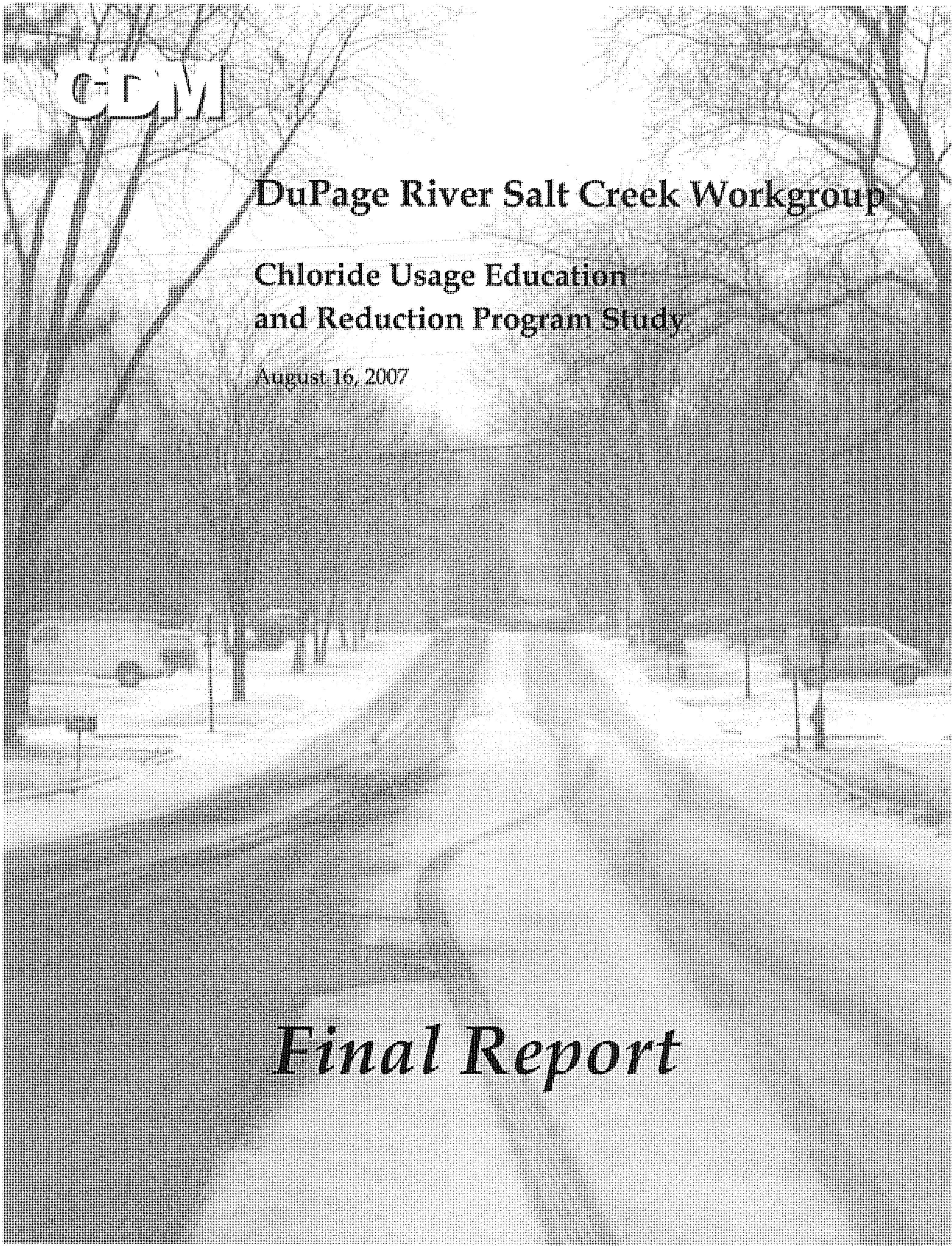
EXHIBIT 19

CDM

DuPage River Salt Creek Workgroup

Chloride Usage Education and Reduction Program Study

August 16, 2007



Final Report

Executive Summary

This Chloride Usage Education and Reduction Program Study addresses the quantity of chloride applied in the watersheds of Salt Creek and the East and West Branches of DuPage River. These watersheds are located in northeastern Illinois, centered in DuPage County. Portions of the watersheds also extend into Cook, Will and Kane Counties.

The study is motivated by recent limitations to the allocated total maximum daily load (TMDL) of chloride in the respective watersheds. In October 2004 the United States Environmental Protection Agency (USEPA) approved chloride TMDLs for Salt Creek and the East and West Branches of DuPage River (IEPA, 2004). The TMDLs call for reductions in chloride loading, specifically from winter road salt application in the watersheds.

In response to the TMDLs adopted for their watersheds, a group of communities, environmental organizations, publicly owned treatment works and other concerned parties came together to form the DuPage River Salt Creek Workgroup (DRSCW). The DRSCW appointed a Chloride Subcommittee, under whose direction this study was initiated to evaluate current road salting practices and to recommend alternative practices for the reduction of chloride loading to the watersheds, to help comply with the chloride TMDLs.

To determine current road salting practices in the watersheds, a questionnaire was sent to about 80 deicing agencies. Responses were received from 39 agencies, who reported a total annual salt use of 126,000 tons. Additionally, eight of approximately 130 private snow removal companies in the watershed area were contacted. Their typical annual salt use ranges from 7.5 to 500 tons per winter.

The total amount of chloride applied to the watersheds annually, in the form of road salt, was estimated from the questionnaire responses. The estimated load includes salt from municipalities, townships, the Illinois State Toll Highway Authority, and county transportation departments; private snow removal companies and the Illinois Department of Transportation are not accounted for. The estimated load is presented in **Table ES-1**.

Table ES-1: Estimated Current Chloride Load in Study Area

	Salt Creek	*East Branch*	*West Branch*	*Total*
Estimated Current Load, tons of Cl^-/yr	32,600	16,900	21,200	70,700

A literature search was conducted for this study that revealed a variety of potential measures that could reduce chloride loading to the watersheds. The measures were evaluated for feasibility and potential effectiveness in reducing chloride, and discussed with local deicing program managers for implementation. As a result of this study, the following measures to reduce chloride loading from deicing practices are recommended:

- Public education, staff training, and improved salt storage and handling practices.
- Watershed-wide implementation of pre-wetting and anti-icing programs.
- Consideration of alternative non-chloride products such as acetate deicers and beet and corn derivatives.
- Chloride monitoring in streams to demonstrate program effectiveness.

Several measures to reduce chloride loading were considered but are not being recommended for implementation. These include the use of sand instead of salt, the use of portable snow melting machines, and reduction in the level of service provided by winter road maintenance. For further details refer to the body of the report.

The overall expected reduction in chloride loading to the watersheds as a result of the recommended measures could range from 10 to 40% depending on the level of implementation. A 40% reduction in chloride loadings from deicing activities may not be enough to achieve the TMDL target reductions; other sources of chloride may need to be addressed.

The work plan for the second phase of the Chloride Usage Education and Reduction Program Study may include the following elements:

- Staff training, public outreach and education
- Improved implementation of pre-wetting
- Improved implementation of anti-icing

Capital investment will be necessary to implement new deicing measures or modify existing programs. These investments should result in improved deicing practices that maintain levels of safety and reduce salt (chloride) usage. The resulting reductions in salt needed for deicing will reduce purchase quantities and costs, providing a return on the capital and incentives for implementation. The return period will vary depending upon individual improvements and salt reductions achieved.

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Section 1 Introduction

This Chloride Usage Education and Reduction Program Study addresses the quantity of chloride applied in the watersheds of Salt Creek and the East and West Branches of DuPage River. These watersheds are located in northeastern Illinois, centered in DuPage County. Portions of the watersheds also extend into Cook, Will and Kane Counties (see **Figure 1-1**).

The study is motivated by recent limitations in the allocated total maximum daily load (TMDL) of chloride to the respective watersheds. In October 2004 the United States Environmental Protection Agency (USEPA) approved chloride TMDLs for Salt Creek and the East and West Branches of DuPage River (IEPA, 2004). The TMDLs call for reductions in chloride loading, specifically from winter road salt application in the watersheds.

In response to the TMDLs adopted for their watersheds, a group of communities, environmental organizations, publicly owned treatment works and other concerned parties came together to form the DuPage River Salt Creek Workgroup (DRSCW). The DRSCW appointed a Chloride Subcommittee, under whose direction this study was initiated to evaluate current road salting practices and to recommend alternative practices for the reduction of chloride loading to the watersheds, to help comply with the chloride TMDLs.

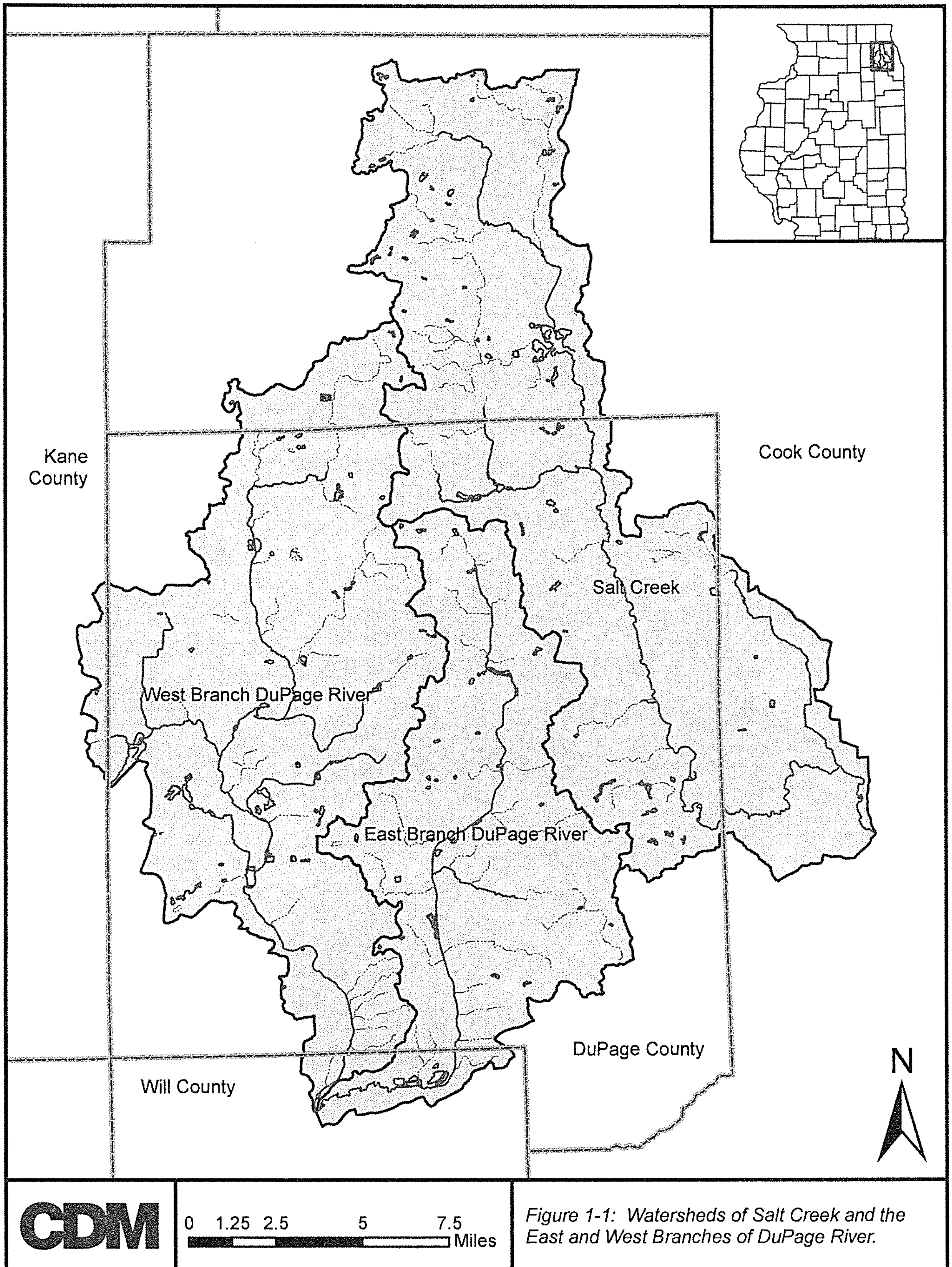

Figure 1-1: Watersheds of Salt Creek and the East and West Branches of DuPage River.

Section 2
Information Review

An information review was performed to obtain as much information as possible related to applicable regulations and guidelines, and road salting practices and their chloride contributions. The search for information was accomplished via a literature review, a questionnaire, and telephone surveys. This section summarizes the studies, articles, and brochures that relate to road salting regulations and practices in the DuPage River and Salt Creek watersheds, and available alternatives to existing practices that could result in reduced chloride loadings. The questionnaire was distributed to municipalities and agencies in the watersheds to obtain information related to their deicing practices. This information, as well as information gathered by other telephone surveys, is presented below, following a summary of the applicable regulations and guidelines.

2.1 Applicable Regulations and Guidelines

Chloride is an ionic form of the element chlorine, is found in many common salts, and is readily soluble. In its dissolved form, it does not degrade chemically or organically over time. Chloride should not be confused with chlorine, a soluble substance often used as a disinfectant. Reverse osmosis and distillation are potential methods of removing chloride from water.

Chloride has not always been viewed as a pollutant or contaminant of water. It is an essential part of the diet of humans and other animals, and the oceans have a normal, healthy, chloride concentration of about 21,000 mg/L. However, elevated concentrations of chloride in fresh water can threaten aquatic life as well as introducing a salty taste to sources of drinking water. The US Public Health Service and Health Canada both set the secondary drinking water chloride standard at 250 mg/L, and the US Public Health Service further recommends an ideal limit of 25 mg/L (Mangold, 2000).

The impact of chloride on aquatic life varies from species to species. In 1988 the USEPA conducted a broad literature search and established water quality criteria for chloride to protect aquatic life (USEPA, 1988). Data of sufficient quality were available to evaluate response (impacts) for three species: cladoceran (daphnia pulex), rainbow trout and fathead minnow. The published conclusion was that the four-day average and one-hour average chloride concentrations should not exceed 230 and 860 mg/L, respectively, if fresh water aquatic organisms and their uses are to be protected.

In 1972 the Illinois Pollution Control Board (IPCB) adopted a general use chloride water quality standard (WQS) of 500 mg/L. This standard lies between the acute and chronic chloride limits established by USEPA. Salt Creek and the East and West Branches of DuPage River are designated for general use; therefore, the 500 mg/L standard applies.

The TMDLs for these watersheds were specifically derived to achieve compliance with the 500 mg/L standard. In the West Branch watershed, a reduction of 35% is specified for chloride applied in deicing operations, and in the East Branch watershed the reduction is 33% (IEPA, 2004, East and West Branch TMDLs). The Salt Creek TMDL subdivided the watershed between Addison Creek and Salt Creek, which were targeted for 41% and 8% reductions, respectively (IEPA, 2004, Salt Creek TMDL). Throughout this report, the watersheds of Addison Creek and Salt Creek are collectively called "Salt Creek"; the overall Salt Creek reduction is 14%. Additional information on these reductions is provided in the TMDL documents.

2.2 Significant Sources of Chloride

The obvious first step in addressing the chloride levels in Salt Creek and DuPage River is to identify and prioritize the sources of chloride in the watersheds. With this objective, the Illinois Environmental Protection Agency (IEPA) spent considerable effort collecting and reviewing data, and modeling the watersheds.

Water samples were taken from the watersheds over the period from 1995 to 1999. During this time, there were five observed exceedances of the chloride WQS in Salt Creek. In the same period, one exceedance was observed in each of the East and West Branches of the DuPage River. All seven of these exceedances occurred in January, February or March. Furthermore, plots of observed chloride concentrations by month showed clear seasonal variation. In each watershed, the highest chloride concentrations occurred in winter months, while the lowest occurred in summer.

Modeling performed for establishment of the TMDLs included three sources of chloride: the background groundwater concentration, point source discharges and road salting.

- Groundwater provides base flow to the streams. The average groundwater chloride concentrations were 51 and 106 mg/L in the Salt Creek and East Branch watersheds, respectively. (Groundwater is not mentioned in the West Branch TMDL.)

- The range of observed chloride concentrations in point source discharges was 90 to 555 mg/L. These data were collected as part of The Conservation Foundation data collection program (IEPA, 2004, Salt Creek, East Branch and West Branch TMDLs). For modeling, the point source discharges were assigned a constant concentration for each watershed: 300 mg/L in the Salt Creek watershed and 400 mg/L in the East and West Branch watersheds.

- Chloride loading from road salting was based on 14 snowfall events, accounting for the length of road surface in each watershed and assuming a standard salt application rate. For Salt Creek and the East Branch, the rate assumed was 800 lb per lane-mile per storm, a value based on literature from other major cities. For the West Branch, local data from four communities yielded an average rate of 1,300 lb per lane-mile per storm.

The conclusion of the TMDL reports was that "[the] primary contributor to the [chloride WQS] exceedances is application of road salt for snow and ice control purposes. However, due to the sporadic nature of deicing activities, on a yearly basis, the chloride mass contributed to the West Branch DuPage River watershed is larger from point sources than nonpoint sources." (IEPA, 2004, West Branch TMDL) The conclusions regarding Salt Creek and the East Branch are the same.

Road salt is almost entirely sodium chloride, which is composed of 39.3% sodium and 60.7% chloride, by mass. (An anti-caking agent containing cyanide is usually added to road salt; the cyanide may pose a water quality concern, but is outside the scope of this study.)

In the TMDL reports, the contribution of chloride from non-point sources was calculated directly from "salt applied for deicing purposes, since that is the most direct measurement of chloride applied to the watershed." (IEPA, 2004, East Branch TMDL) For reference, the chloride TMDL allocations are summarized in **Table 2-1**.

Table 2-1: TMDL Chloride Allocations for Point and Non-Point Sources

	Salt Creek	*East Branch*	*West Branch*	*Total*
Point sources, tons of Cl^-/yr	28,700	34,100	19,300	82,100
Non-point sources, tons of Cl^-/yr	13,300	5,200	13,700	32,200

Source: IEPA, 2004, Salt Creek, East Branch and West Branch TMDLs.

As of June 7, 2007, questionnaire responses were received from 39 municipalities and agencies who reported a total annual salt use of 126,000 tons. Approximately 88,000 tons of this salt (53,000 tons of chloride) are applied within the boundaries of the East and West Branch and Salt Creek watersheds. The responses represent approximately 69% of the total watershed area.

Additionally, 8 out of approximately 130 private snow removal companies in the watershed area were contacted and interviewed. The typical annual salt use of these companies ranges from 7.5 to 500 tons per winter (4.5 to 300 tons of chloride per winter).

An informal look at the quantity of salt used by residential homes was conducted as part of this study. Sales quantities were obtained from retail suppliers in a typical area community with a population of approximately 20,000. Total of annual salt sales for driveway deicing and water softener use is estimated at over 250 tons per year for the typical community. This figure is a rough estimation and more detailed study should be performed for any meaningful calculations.

2.3 Storage and Handling Practices for Salt

The Salt Institute has published a Salt Storage Handbook (Salt Institute, 2006) with recommended practices and design guidelines for salt storage facilities. Also, the

Transportation Association of Canada (TAC) has published detailed best management practices (BMPs) for road salt storage (TAC, 2003) and a training manual for salt program managers and staff (TAC, 2005). The key measures presented in these documents are listed below. Results from the deicing questionnaire that describe how these BMPs are implemented locally are included where appropriate:

- The site should be located down gradient of any water supply wells.
- Drainage from the site should not enter any water body or fresh water supply, and should be properly controlled and contained. Drainage is controlled or collected by about half of the questionnaire respondents. Two questionnaire respondents have storage sites within 100 feet of a water body, and fifteen more have sites within 1,000 feet.
- Salt should be stored on impermeable pads that slope away from their centers at about ¼ inch per foot (2%). Five questionnaire respondents do not store their salt on impermeable pads.
- Salt stockpiles should be protected with structural roofs or temporary covers. All but one of the questionnaire respondents keep their salt in a storage structure.
- Areas used for loading and handling salt should be protected from precipitation and wind. Thirteen questionnaire respondents said their salt is exposed or partially exposed to the elements, and only seven said their loading areas are completely covered.
- Salt should be handled as little as possible, to avoid particle breakdown and loss of material. Care should be taken to minimize spillage and clean up spilled salt.
- Frozen or clumped blocks of salt should be either set aside to be dried and crushed, or added to brine tanks.
- Preferably, vehicles should be washed indoors to contain the wash water. Wash water should be put through an oil and grit separator, and either added to brine tanks or disposed of properly. All but three questionnaire respondents wash their vehicles indoors.
- Liquid storage facilities require further considerations such as secondary containment, protection from freezing, protection from vehicle impacts, backup power supplies, reuse of wash water, etc. Twenty-eight questionnaire respondents mentioned having tanks for liquid deicing chemicals.

The costs associated with poorly managed sites can be considerable. Environment Canada has published a case study from Heffley Creek, a small community in British Columbia, Canada (Environment Canada, 2004, "Remediation vs. Salt Storage…"). In 1993, Heffley Creek residents complained of a salty taste in their water, and investigations revealed that leakage from the local salt storage site had contaminated the groundwater. In the following ten years, the Province of British Columbia incurred over $2 million in remediation costs, including site remediation, replacement of drinking water sources and claims from local residents for property damage. The population of Heffley Creek is around 700.

2.4 Application Practices for Salt

Salt has been used to control snow and ice on U.S. streets since the 1800s (Cheshire, 2006). From the time of its first use there have been complaints about its effects: it made sleighing impossible and also damaged footwear and clothing. Although it still has undesirable effects, most notoriously corrosion, it is now the most popular deicing material in North American cities.

In response to concerns about its effects on infrastructure and the environment, several guidelines and recommendations for salt application have been published. The Salt Institute has produced a handbook for snowfighters (1999) and an online snowfighters training program (2000); TAC published the Salt SMART Learning Guide, offering best management practices for Spreading, Maintenance, Application Rates & Timing (SMART) of road salt (TAC, 2005); and Minnesota's Department of Transportation (MN/DOT) published a handbook for snowplow operators (MN/DOT, 2005). A few key recommendations from these documents are listed below. Results from the deicing questionnaire that describe how these practices are implemented locally are included where appropriate:

- A clear level of service (LOS) should be established for each route or area, based on usage levels or regulation. This LOS should be communicated to staff and to the public.
- Staff should be trained in proper spreading procedures, record-keeping and the environmental impact of their work. Operators are trained annually (or more often) by 32 of 39 questionnaire respondents.
- Equipment should be maintained and inspected before and during the snow season, with spare parts available at all times.
- Spreader routes should be optimized to eliminate leftover salt and "dead-heading" (driving without spreading).
- The spreaders should be covered to prevent loss of salt in wind and precipitation.
- The spreaders should be equipped with instrumentation to monitor current conditions and salt usage.
- Spreading equipment should be calibrated regularly and records should be kept of salt use in each truck and each route. Actual usage should be compared against the prescribed spreading rates to catch over-use and inefficiencies. Weigh-scales on the spreading equipment and at the entrance to the storage area make record-

keeping simple. Salt usage records for each truck are kept by 22 questionnaire respondents.

- Spreading rates should be based on the best available information, including the current road conditions, LOS and weather forecast. Communication with operators should be clear.

Implementing best management practices can lead to considerable cost savings and chloride reduction. The City of Toronto, for example, spent about $100,000 on staff training, fleet instrumentation and a salt management plan. As a result, their annual salt use was reduced by 25% over two winter periods, translating into annual savings of about $1,800,000 (Environment Canada, 2004, "City of Toronto…"). In Quebec, the Town of Otterburn Park reduced their salt use by a factor of six, between 1995 and 2000, by training staff, improving plowing practices, revising the LOS policy and pre-wetting salt (Environment Canada, 2004, "Salt Reductions…"). Their benefit-to-cost ratio for was 2.8:1 for the changes that were implemented.

2.5 Alternative Snowfighting Methods

Spreading granular salt is not the only way to control snow and ice accumulations on roadways. The earliest human technique was plain manual effort. Manual efforts were subsequently replaced and supplemented with hand-tools, powered machines, fire and chemical agents. This section presents the methods, other than granular salting, currently used in the North American snow belt.

2.5.1 Mechanical Methods

Plowing snow off the roads is standard practice in almost every city. It is good practice to plow just before salting or to add a plow blade to a salt-spreading vehicle so that the salt is applied to a bare or near-bare surface. Otherwise salt can be wasted by melting heavy snow, or can be plowed off the roadway before it reaches the road surface (TAC, 2005).

If enough snow accumulates between melting events, the mounds of snow at the sides of roadways can inhibit continued plowing efforts. If this occurs, one alternative is to transport the snow to a disposal facility where it can be piled or dumped. Since the plowed snow carries salt, grit, oils and other pollutants, the snow disposal facility must be engineered to control the release of these contaminants. The City of Ottawa, Canada, has an average annual snowfall of 7.7 feet and disposes over 2,000,000 yd^3 of snow each winter, on average. To manage the logistical, fiscal and environmental challenges, they are now implementing a snow disposal program that includes phasing out unacceptable disposal sites, upgrading old sites and designing and constructing new ones. (Environment Canada, 2004, "Engineered Snow Disposal…")

An old and widely used practice is spreading abrasives, such as sand or cinders, on the roadway. Although abrasives supply some traction for traffic, contain no chlorides, and are more visible than salt, they have many drawbacks (Salt Institute, 1985):

- Abrasives do not break the bond between pavement and ice.
- They can be covered up or mixed with snow and become useless.
- They can reduce traction on road surfaces after the snow and ice are gone.
- They can chip paint and pit windshields.
- They can clog drains and smother roadside vegetation.
- They may require costly cleanup efforts after a storm or storm season.

2.5.2 Chemical Methods

Two important variations on road salting exist: anti-icing and pre-wetting. Here are the definitions used by Environment Canada (2003):

- "Anti-icing is the application of a deicer to the roadway before a frost or snowfall to prevent melted snow and ice from forming a bond with the road surface."
- "Pre-wetting is the addition of a liquid to solid deicers or abrasives before application to quicken melting and improve material adherence to the road surface."

Anti-icing is a preventative measure, as deicing agents are applied to roads before snow or ice appears. Clearly, the timing of the application is critical, and anti-icing strategies depend on information systems and forecasting of road conditions. A simple anti-icing program is the application of salt brine to the roads when a storm is forecasted. The brine may or may not dry before the storm comes, but as soon as snow falls or frost begins to form the brine will activate and prevent a bond forming between the ice and the pavement.

Anti-icing is becoming widely accepted and offers many advantages, including cost and material savings, improved level of service, and reduction in accidents. A further environmental benefit is that liquid anti-icing brines do not contain the cyanide anti-caking agent commonly added to road salt (Mangold, 2000).

The MN/DOT Field Handbook reports that anti-icing uses about 25% of the material at a tenth of the cost of conventional deicing (MN/DOT, 2005); this is supported by the experience of the McHenry County Division of Transportation (Devries, 2007).

A thorough review of cost savings and other benefits achieved through anti-icing is given by O'Keefe and Shi (2005). Colorado saw an overall cost savings of 52% after implementing anti-icing, while Oregon realized cost savings of 75% for freezing rain events. In Montana, anti-icing reduced sand use by 41%, and overall Montana saved 37% in costs per lane mile with anti-icing, including costs for labor, equipment, and materials. Reductions in the rate of accidents range from 8% to 83%, and result in significant cost avoidance (O'Keefe and Shi, 2005).

The Michigan Department of Transportation conducted anti-icing trials along US-31 over the winter of 1999-2000. Anti-icing was performed on the test section with M50 liquid deicer (see table below), while the control section was deiced with rock salt alone. The test section and the control section were each 32 lane-miles. On the control section 536 tons of rock salt were used, while on the test section 325 tons of rock salt and 6450 gallons of anti-icing liquid were used. The reduction in rock salt alone was therefore 39%; however, taking into account the chloride in the anti-icing liquid, the reduction in chloride was 38% (Kahl, 2002).

One objection to anti-icing is that it necessitates a change in operational strategy by having trucks on the roads before a storm rather than during or after. The City of Chicago, for example, found the change in operations difficult during an anti-icing trial (Keating, 2001). The U. S. Department of Transportation (USDOT, 1996) has published a manual to help managers implement anti-icing programs.

In a few instances, anti-icing has been reported to cause some slipperiness on the roads. However, slipperiness can be caused by other contaminants on the road, and may be attributable to driver perception; professionals in the field unanimously agree that anti-icing improves public safety (O'Keefe and Shi, 2005).

Anti-icing agents are most commonly liquids, but can also be pre-wetted solids. A variety of anti-icing and deicing agents is presented in **Table 2-2**.

Pre-wetting is a variation on the usual practice of spreading solid salt and/or abrasives during a storm event, and does not require a significant change in snowfighting strategy. The Wisconsin Transportation Information Center (WTIC, 2005) and others (Mangold, 2000; MN/DOT, 2005) report that a conventional application of dry salt wastes about 30% of the material due to wind- and traffic-induced scatter. This waste can be reduced to only 4% by pre-wetting the material before spreading it (WTIC, 2005; TAC, 2005). Materials savings due to pre-wetting have been found as high as 53% (O'Keefe and Shi, 2005). Pre-wetted salt also acts more quickly than dry salt because there is no delay waiting for a brine to form. The liquid pre-wetting agent is applied at a rate of approximately 10 gallons per ton of dry salt (Wisconsin Transportation Information Center, 2005), which is equivalent to 20-30 lb of dry salt added per ton.

A drawback of pre-wetting is the cost of equipment modification for onboard pre-wetting capability. However, MN/DOT (2005) points out that pre-treatment can be used instead of pre-wetting. Pre-treatment involves mixing a liquid deicer with the salt stockpile before it is loaded into spreader trucks. This precludes the need for equipment modifications.

Environment Canada reported four case studies in which anti-icing and pre-wetting played a role in cost and material savings in winter road maintenance:

- Cypress Bowl, a ski area in British Columbia, achieved a cost savings of 34% through anti-icing, pre-wetting and training, and their chloride usage was reduced by 73% (Environment Canada, 2004, "Implementation of Anti-Icing…").
- The Town of Otterburn Park, Quebec, reduced their salt use by a factor of six by implementing better practices including pre-wetting (Environment Canada, 2004, "Salt Reductions…").
- The City of Kamloops introduced anti-icing and pre-wetting and achieved reductions in wintertime accidents, snow and ice control costs, and abrasives (Environment Canada, 2004, "Winter Maintenance Innovations…").
- A 10% salt reduction was achieved in Brooklyn, Nova Scotia, through pre-wetting alone (Environment Canada, 2004, "Utilizing Technological Advances…").

Table 2-2 summarizes various chemical products available as anti-icing and deicing agents. Information was obtained from Keating (2001), Caraco and Claytor (1997), the MDSS consortium (2006), Fischel (2001) and product manufacturers' websites. For a comprehensive literature review and comparative analysis of several chloride- and acetate-based deicers, see Fischel (2001).

Table 2-2: Chemical Anti-Icing and Deicing Products

Product	*Estimated Cost*[1]	*Cl⁻ by mass*	*Eutectic Temperature*[2]	*Other Characteristics*
Rock salt (NaCl)	$20-40 / ton or $0.03-0.10 / gal	61%	-6°F	Very corrosive; harmful to vegetation; can attract wildlife
Calcium chloride ($CaCl_2$)	$200-340 / ton	64%	-60°F	Extremely corrosive; exothermic melting; dissolves in atmospheric moisture; harmful to vegetation
Magnesium chloride ($MgCl_2$)	$260-780 / ton	75%	-27°F	Corrosive; can attack concrete
Potassium Chloride (KCl)	$240 / ton	48%	12°F	Corrosive
Calcium magnesium acetate (CMA)	$650-2000 / ton	0%	-18°F	Low toxicity; non-corrosive; can cause O_2 depletion
Potassium acetate (CF7®)	$2.60-3.90 / gal or $600 / ton	0%	-76°F	Non-corrosive; can cause O_2 depletion
Urea	$280 / ton	0%	+10°F	Endothermic; degrades to ammonia, then nitrate; working temperature same as CMA
Ice Slicer®	$58-64 / ton	Some	-6°F	Granular and reddish, with naturally occurring complex chlorides (Mg, Ca, Na and K chlorides); 20-70% less corrosive than rock salt; harmful to vegetation

Product	*Estimated Cost[1]*	*Cl⁻ by mass*	*Eutectic Temperature[2]*	*Other Characteristics*
CG-90® Surface Saver®	$185-250 / ton	63%	-5°F	Handles like road salt; 76% NaCl, 22% $MgCl_2$ plus corrosion-inhibitor
Caliber® M1000	$0.55-1.50 / gal	23%	-86°F	Corn derivative liquid deicer plus 30% $MgCl_2$; corrosion inhibitor; can cause O_2 depletion
GEOMELT® 55	$1.25-1.90 / gal	0%	-44°F	Organic anti-icer/ deicer; 4x less corrosive than water; can be mixed with brines or solid salts
M50 (Ice Ban®, Magic Minus Zero®)	$0.70-0.85 / gal	11%	-78°F	Organic deicer plus $MgCl_2$ solution (15% $MgCl_2$ by weight); less corrosive than water; oxygen demand equivalent to CMA; pH < 4.0
MagicSalt®	1.4 times rock salt	61%		Rock salt treated with M50; effective down to -35°F; use 30 to 50% less than plain rock salt

[1] The estimated material costs were based on the references cited above as well as a web search of product sales. The costs may vary regionally and with time.

[2] The eutectic temperature is the lowest temperature at which the deicing agent can remain in liquid form. The minimum working temperature is loosely defined and tends to be higher; for example, rock salt's eutectic temperature is -6°F, but its minimum working temperature is approximately 16 to 20°F.

Some of the deicing products listed in **Table 2-2** contain little or no chloride, but introduce concerns with biochemical oxygen demand (BOD) in receiving waters. These include the acetate products as well as the organic process derivatives.

Responses to the questionnaire indicated that most agencies in the watersheds are using rock salt pre-wetted with calcium chloride. Two agencies use sand, three use magnesium chloride, four use CMA, two use potassium acetate, and one uses GEOMELT® 55.

The Pacific Northwest Snowfighters (PNS) Association has developed standards for deicing chemicals, and publishes a list of approved substances on its website (PNS, 2006).

2.5.3 Thermal Method

Stationary snow melting machines are used in some municipalities, including New York, as an alternative to hauling snow long distances to disposal sites. New York has 20 diesel-fueled snow melting machines, each capable of melting 60 tons of snow per hour. Sanitation Commissioner John Doherty said the machines cost approximately $200,000 each (Barry, 2006), not including fuel and maintenance costs. The City of Naperville rented a stationary snow melting machine over the 2006-2007 winter season to reduce hauling costs.

The City of Toronto uses five portable snow melting machines as part of its winter road maintenance. These vehicles lift snow into a heated onboard tank where the snow is melted at a rate of 150 tons per hour. The melted snow is subsequently discharged into street-side storm drains. According to Gary Welsh, Toronto's Director of Transportation Services, the machines cost approximately $1 million each (Keating, 2001).

Stationary or portable melting machines have been used to address snow quantity issues, but with respect to reducing chloride loadings, they are not highly effective as an alternative to traditional deicing practices.

2.5.4 Instrumentation and Data Collection

While information systems are not an "alternative method of deicing," they work together with other snowfighting practices by informing agencies' decisions on winter maintenance and improving the effectiveness of deicing practices. The systems in North America range from elementary to advanced, and include the following:

- Load scales at storage facilities and in spreader trucks
- Benchmarking of salt usage on municipal routes
- Maintaining records of salt use by route, by storm and by winter
- Ground speed sensors and digital spreaders on salt trucks
- Real-time salt application monitoring with Automated Vehicle Location systems
- Pavement temperature sensors on trucks and in-ground installations
- Regional and local weather forecasts
- Road condition monitoring and forecasting, including networks of monitoring stations called Road Weather Information Systems (RWIS)

Two of Environment Canada's case studies describe implementation of advanced systems. In Nova Scotia, 19 RWIS stations had been installed by January 2004. The RWIS is allowing the Department of Transportation and Public Works to take a proactive approach to winter road maintenance, and together with pre-wetting practices, has led to a reduction in salt usage (Environment Canada, 2004, "Utilizing Technological Advances…").

The Ministry of Transportation of Ontario recognized the interchange ramp of Highway 401/416 as an accident-prone point in winter. In response, they installed RWIS and Fixed Automated Spray Technology (FAST), which automatically applied deicer to the ramp when conditions warranted. No further winter-related accidents have occurred at that location (Environment Canada, 2004, "Accident Reduction…").

Illinois has a state-wide network of 51 RWIS stations, which save the state millions of dollars each year in snow removal costs (Dameron, 2004).

2.6 Deicing Questionnaire Summary

In November 2006 and April 2007, the DRSCW distributed a questionnaire to about 80 municipalities and public works agencies. The purpose of the questionnaire was to obtain baseline information about the current deicing practices throughout the DuPage River and Salt Creek watersheds. The questionnaire asked for information about deicing practices and strategies under the following categories:

- Snow removal policy
- Anti-icing and deicing methods
- Deicing and snow removal equipment
- Salt storage
- Equipment maintenance
- Management and record-keeping
- Participation in a potential pilot study

As of June 7, 2007, 39 responses had been received. The following sections summarize the responses in each of the above categories. A blank questionnaire and all responses are included on the CD accompanying this report (**Appendix A**).

2.6.1 Snow Removal Policy

The questionnaire asked for the agency's snow removal policy and the length of roadway served. All 39 agencies provided policies. Most snow removal policies are based on achieving bare pavement within a certain amount of time following the end of the storm; the time allowances vary from 4 to 24 hours. In some cases, primary roadways are prioritized. The length of roadway served varies between 55 and 1,400 lane-miles, and the total of all the responses is approximately 10,000 lane-miles.

2.6.2 Anti-Icing and Deicing Methods

The second section of the questionnaire asked whether agencies used anti-icing, and what substances or products they employed for anti-icing and deicing. Out of the 39 respondents, 14 mentioned anti-icing practices; in most cases the anti-icing program is limited to occasional pre-salting or liquid spreading in priority locations. For deicing agents, 38 agencies use solid rock salt and 34 use liquid calcium chloride. Five agencies use salt brine (NaCl). Calcium magnesium acetate (CMA) is used by four agencies. Abrasives, liquid magnesium chloride and liquid potassium acetate are each used by two agencies. One agency uses an agricultural deicing product.

Pre-wetting is practiced by approximately 29 agencies. This figure was inferred from whether the agencies either use pre-wetted materials or own equipment for spreading pre-wetted solids.

2.6.3 Deicing and Snow Removal Equipment

The third section asked what equipment was used for deicing and snow removal efforts. Snow plows were reported in use by 34 agencies, and the remaining agencies are also assumed to use snow plows. Mechanically-controlled and computer-controlled spreaders for deicing agents are both widely used: 32 agencies have mechanically-controlled equipment and 23 have computer-controlled. Equipment for spreading liquids is used by 15 agencies. End loaders and bobcats were frequently mentioned on the "Other" line.

2.6.4 Salt Storage

The next section asked for some basic information about how salt was stored. Out of the 38 agencies using salt:

- 33 store salt on an impervious pad;
- 37 keep the salt in a "storage structure";
- 25 said their salt is not exposed at all to the elements;
- 15 said drainage from their storage area(s) is controlled or collected; and
- 7 said their loading area(s) are covered or contained.

The number of storage areas owned and maintained by each agency ranges from 1 to 3, with the majority having just one. Seventeen of the agencies store salt within 1,000 ft of the nearest water body, and two agencies store it within 100 ft.

2.6.5 Equipment Maintenance

The next section asked how the snowfighting equipment was washed. For 36 agencies the equipment is washed at an indoor station draining to the sanitary sewer. Three agencies wash equipment outside where the water can drain to a sanitary sewer, and five mentioned outdoor washing in areas not drained to a sanitary sewer.

2.6.6 Management and Record-Keeping

The sixth section asked for information about the management of the deicing programs. Operators are trained annually (or more often) in 32 agencies. Four of the remaining agencies train at the start of employment, and the other three did not specify a training schedule.

The rate of salt application is established by the director or supervisor in 33 agencies, and by the operators in five agencies. The spreading rate is controlled by the operator in 24 agencies, controlled automatically in 14 agencies and set at a fixed rate in 7 agencies.

Twenty-two agencies keep records of salt usage per truck, twenty-eight keep records for each storm, and twenty-three keep records for each winter. Each agency provided an estimate of the average amount of salt they used per winter; the total of their estimates is 126,000 tons per winter.

2.6.7 Participation in a Potential Pilot Study

The final question asked whether the agency would consider participating in future pilot studies or demonstration projects for alternative deicing equipment or practices. Twenty-three indicated a willingness to participate.

2.7 Private Snowplowing Business Practices

On March 29, 2007, nine municipalities in the study area were contacted to ask about license requirements for private snow plowing businesses. The municipalities were Addison, Bartlett, Bloomingdale, Carol Stream, Downers Grove, Elmhurst, Lisle, Naperville and Palatine. Snow plowing businesses are not required to hold a license anywhere except in Addison and Palatine. Licenses in those municipalities are for the office location only, and do not regulate how deicing practices are conducted.

Between March 30th and April 4th, 2007, eight private snow removal contractors in the study area were contacted. Private contractors tend to serve commercial, industrial and residential customers, clearing parking lots and private drives rather than roads. Based on surveying those contractors, their salt use ranges from 7.5 to 500 tons per winter, and averages approximately one ton per acre of parking lot per winter. Private contractors are not usually required to hold a business license in the area they serve unless they have an office location in the served area. Many of their customers require them to hold insurance. Based on a business search, there are approximately 130 private snow removal services in the study area.

Section 3
Analysis of Alternatives

3.1 Baseline Condition

The analysis of any alternative practices must begin with a baseline condition. The amount of chloride applied annually to the watersheds for deicing was estimated from the responses to the deicing questionnaire. Since some of the municipalities and agencies who responded lie partly outside the watersheds, a geographical analysis of the data was conducted using Geographic Information Systems (GIS) tools.

The total amount of salt used in the watersheds is different from the total amount reported on the questionnaires, for several reasons. First, some areas within the watershed were not represented by a questionnaire response, but salt is being applied there. Second, some questionnaire responses represent municipalities that apply some of their salt outside the watersheds. The following paragraphs describe the assumptions and calculations involved in estimating the total amount of deicing salt (and chloride) applied annually in the watersheds.

The watersheds are composed of both incorporated and unincorporated areas. The incorporated areas make up 266 of the total 355 square miles of watershed area (approximately 75%). Some municipalities, such as Wheaton, are completely within the watershed boundaries, while others, such as Bartlett, lie partly outside. Forty-five municipalities have at least one square mile of incorporated area within the watersheds, and small corners (less than one square mile) of other municipalities are also included. The remaining 89 square miles of unincorporated area are under the jurisdiction of township authorities.

Municipalities, townships and other agencies were treated separately. The annual salt use of each municipality that returned a questionnaire was plotted against its incorporated area (see **Figure 3-1** below). There is a strong correlation between annual salt use and incorporated area ($R^2 = 0.80$). The best fit line through those data was used to estimate the annual salt use for each municipality not represented by a questionnaire. For example, one city which did not return a survey has an incorporated area of approximately 13 square miles, so its estimated salt use is approximately 3,500 tons annually. (One outlier was omitted from the statistical analysis, as illustrated in the figure.)

For each municipality, the annual salt use was multiplied by the fraction of incorporated area lying within the watersheds, to estimate the amount of salt applied within the watersheds. For example, 39.6% of Bartlett's area lies within the watersheds. Bartlett reported an annual salt use of 2,200 tons of salt; therefore, 872 tons (39.6%) was assumed to be used within the watersheds.

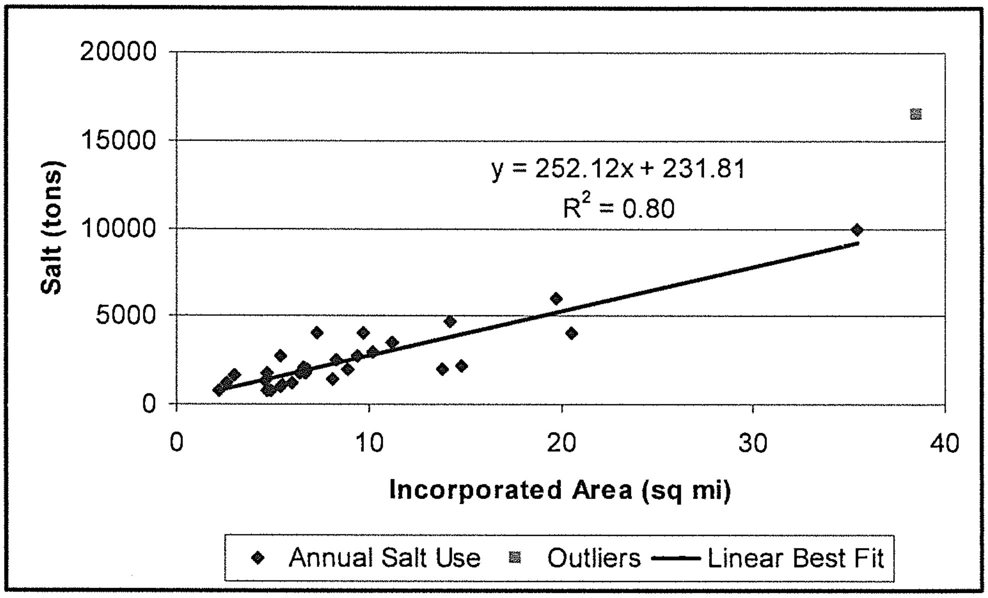

Figure 3-1: Annual salt use by municipalities that responded to the questionnaire. Salt use in other communities was estimated from the best fit line.

Six townships returned questionnaires indicating their typical annual salt use. The average amount of deicing salt applied annually is 1,025 tons. The annual salt use of townships that did not return questionnaires was therefore estimated as the average, 1,025 tons.

It was assumed that townships only apply deicing salt in unincorporated areas. For townships whose unincorporated areas were partly outside the watersheds, the annual salt use figures were reduced using the same method employed with the municipalities. For example, Winfield Township has 20.64 square miles of unincorporated area, of which 88.7% is within the watersheds. Winfield Township reported an annual salt use of 600 tons of salt; therefore, 532 tons (88.7%) was assumed to fall within the watersheds.

In addition to municipalities and townships, three other agencies returned questionnaires: Illinois State Toll Highway Authority (ISTHA), DuPage County Department of Transportation (DuDOT) and the Forest Preserve District of DuPage County.

ISTHA reported using an average of 8,900 tons of salt annually in DuPage County. (ISTHA did not provide averages for other counties.) Since DuPage County and the watersheds mostly overlap, the annual salt contribution to the watersheds from ISTHA was estimated using the ratio of the watershed area to the area of the county (355 to 336 square miles); thus, ISTHA's estimated contribution was 9,400 tons. In the same way, the 20,000 tons of salt used annually by DuDOT is scaled up to 21,100 tons to be representative of salt applied by county transportation departments across the watersheds. The Forest Preserve District of DuPage County uses no rock salt.

No estimate of salt use was obtained from Illinois Department of Transportation.

The total amount of road salt applied to the watersheds annually is approximately 117,000 tons, taking into account the salt applied by municipalities, townships, ISTHA and DuDOT. The equivalent amount of chloride is 70,700 tons. This total is broken down between Salt Creek and the East and West Branches of DuPage River as shown in **Table 3-1** (DRSCW Baseline).

The TMDLs for Salt Creek and the East and West Branches of DuPage River estimated baseline chloride loadings for each watershed by assuming 14 snowfall events per winter and applying a standard salt application rate (IEPA, 2004, Salt Creek, East Branch and West Branch TMDLs). The area of road surface in each watershed was adjusted for expected future development. For Salt Creek and the East Branch, the salting rate assumed was 800 lb per lane-mile per storm, a value based on literature from other major cities. For the West Branch, local data from four communities yielded an average rate of 1,300 lb per lane-mile per storm.

Using a watershed model, the TMDLs calculated the required reductions in chloride for each watershed. The TMDL baseline chloride loadings (TMDL Baseline) and road salt allocations are shown for reference in **Table 3-1**.

Table 3-1: Estimated Current Chloride Loading from Road Salt in the Study Area, Compared with TMDL Road Salt Chloride Allocations

	Salt Creek	*East Branch*	*West Branch*	*Total*
DRSCW Baseline, tons of Cl^{-}/yr	32,600	16,900	21,200	70,700
TMDL Baseline, Tons of Cl^{-}/yr	15,500	7,800	21,100	44,400
TMDL Target, tons of Cl^{-}/yr	13,300	5,200	13,700	32,200

3.2 Potential Strategies to Reduce Chloride

There are a variety of potential strategies to reduce the chloride applied as road salt within the East and West Branch of DuPage River watersheds and the Salt Creek watershed. Since the effectiveness of a given strategy is dependent on the specifics of implementation and on the current local practices, the potential reductions in chloride can only be approximately estimated.

In the case study reported by Environment Canada (2004, "City of Toronto…"), salt management planning efforts and staff training led to a 25% savings in annual salt use. Such large savings just through planning and training may or may not be repeatable in the DuPage and Salt Creek watersheds; however, for the purposes of this study it is assumed that staff training and improved storage and handling practices may lead to a chloride savings of up to 10%.

Alternative products can be very effective in reducing chloride application. Acetate-based deicers, such as calcium magnesium acetate, contain no chloride; therefore, the potential chloride savings is 100% if deicing is done entirely with these products. Organic deicers, such as those based on corn and beet derivatives, also contain no chlorides. They are typically mixed with liquid chlorides for anti-icing and pre-wetting use, but have improved performance as compared to liquid chlorides alone (Devries, 2007).

As described in Section 2, pre-wetting generally reduces the amount of salt applied by approximately 30%. Based on the questionnaire responses, approximately 74% of agencies in the watersheds are currently pre-wetting their salt. If the remaining 26% of agencies also implement pre-wetting practices, a savings of 5,400 tons may be achieved (8%).

The reported savings from anti-icing are more varied and less well documented; however, the chloride savings of 38% achieved by Michigan Department of Transportation is taken as representative. Based on the questionnaire responses, up to 36% of agencies in the watersheds are currently using anti-icing, although most programs are limited. Chloride savings of up to 17,200 tons (24%) could be achieved if the remaining 64% of agencies also implement anti-icing programs.

If the recommended measures are aggressively implemented, the overall expected reduction in chloride loading could be 40% or potentially more. Considering that some agencies may not participate and that some measures may not be as effective as in other studies, a conservative expectation may be a 10-20% overall reduction.

Chloride can be saved by other strategies which are not being recommended, but are mentioned here for completeness:

- Switching from road salt to abrasives (sand) would eliminate chloride, but would add significant cleanup costs and introduce concerns about air quality.
- Rather than applying salt to melt snow, hot water and snow-melting machines might be employed. Snow-melting machines cost about $1 million each.
- A reduction in the level of deicing service expected from winter maintenance programs could reduce the amount of salt required. Changes in public policy would have to be carefully considered.

Section 4
Recommended Measures

The recommended measures to reduce chloride loading due to winter deicing activities fall into these categories:

- Public education and staff training
- Salt storage and handling
- Alternative application methods
- Alternative products
- Monitoring to demonstrate program effectiveness

These recommended measures are explained in more detail below, followed by potential funding sources for implementing the recommendations.

4.1 Public Education and Staff Training

A public education campaign can increase the community's awareness of water quality issues, and increase community support for chloride-saving initiatives. The campaign can provide information about what homeowners and businesses can do to reduce chloride use, as well as describe the practices and objectives adopted by their municipal leadership. Elements of a public education program could include:

- Flyers or fact sheets for public distribution. The mailing lists used by environmental groups may be useful for targeted outreach. Mailings could be prepared in a general form that is adaptable to individual community programs.
- Presentations or fact sheets targeted to municipal government officials. A mayors' caucus may be an appropriate forum.
- Public access television spots.
- Newspaper articles or advertisements.
- Declaration of "Limited Salt Use Areas" to highlight water quality protection.

Staff training has been shown to reduce the quantity of salt used (Environment Canada, 2004, "City of Toronto…"). This training may be implemented as part of the municipality's NPDES Phase II permitting requirements. Elements of a staff training program could include:

- Annual refresher training for municipal applicators, covering the impacts of their work on water quality, the harmful effects of salt on environment and infrastructure, proper spreading techniques and equipment, proper storage and handling of salt, record-keeping policies, and clear guidance regarding the appropriate amount of salt to be used in each situation. Videos may be a useful training medium.

- Initial training for new employees. Properly trained veteran employees can give additional on-the-job training. Training programs are also offered by the American Public Works Association and Northeastern Illinois Public Safety Training Academy.

Similar training could be required for private snow removal contractors. This training could be enforced by making it a requirement for a business or operating license or by general permit, where such businesses are currently licensed or permitted.

4.2 Salt Storage and Handling

Proper salt storage and bulk handling practices can limit the amount salt entering the environment before it is applied to road surfaces. The BMPs developed in other states and in Canada provide excellent guidance. Any new storage facilities built should adhere to these BMPs (see Section 2 - Information Review). Standard designs used by local agencies (for example, Illinois Department of Transportation) may be appropriate for adoption by municipal public works departments.

Existing storage facilities should be considered for improvements, particularly if the salt is partially exposed to the elements, drainage is uncontrolled, or salt is not stored on an impervious pad.

Current bulk handling practices should be reviewed and compared to the most up-to-date published BMPs. Annual staff training should include reviews of proper handling practices and the reasons for them. In particular:

- Salt should be handled as little as possible to avoid particle breakdown and loss of material. Care should be taken to minimize spillage and clean up spilled salt.

- Records should be kept of the salt used on each route, during each storm, by each vehicle and by each applicator. The records should be examined regularly to confirm that the target salt application rates are being maintained, and significant discrepancies should be corrected by training or equipment maintenance, as appropriate.

The combined measures of education, training and improved storage and handling practices may lead to a chloride reduction of up to 10%.

4.3 Alternative Application Methods

4.3.1 Pre-wetting

Approximately 74% of agencies in the DuPage River and Salt Creek watersheds pre-wet their deicing salt. Pre-wetting results in cost and material savings, and should be implemented by every deicing agency. A further savings of 5,400 tons (8% across the study area) may be achieved by full implementation of pre-wetting.

4.3.2 Anti-icing

Anti-icing is widely promoted as a cost-effective and environmentally conscious practice (MN/DOT, 2005). If anti-icing were implemented throughout the watershed, potentially 17,200 tons of chloride (24%) could be saved annually.

All deicing agencies should strongly consider implementing an anti-icing program. Anti-icing requires staff training and equipment modification or purchase. Many resources are available on the internet and from Federal and State departments to assist managers in starting an anti-icing program.

Accurate weather forecasts are critical for implementing anti-icing practices. Deicing agencies may wish to take advantage of the Illinois state-wide RWIS network or develop their own information systems. Agencies without access to adequate forecasts can implement a less desirable option, called "just-in-time" anti-icing. This requires maintenance personnel to monitor conditions such as moisture levels and temperature for signs that an event is approaching, and immediately deploy crews when snow or ice is expected.

4.4 Alternative Products

Using non-chloride deicing products could be effective at reducing short term winter month chloride water quality exceedances. Long term pilot testing of an alternative non-chloride deicing product in a select drainage shed would be necessary to determine effectiveness.

Acetate deicers completely eliminate chloride from deicing operations. However, they are relatively expensive, and may be economically prohibitive on a watershed scale.

Organic deicers provide another non-chloride alternative. These proprietary products are comparatively expensive, but can be used in small quantities as pre-wetting agents or in combination with other deicing liquids. Carol Stream is using a beet-based deicer and reports a reduction in accidents (Scaramella, 2006). The McHenry County Division of Transportation also uses a beet-based additive, which they combine with liquid chloride salts for anti-icing and pre-wetting (Devries, 2007).

The acetate deicers and the organic process derivative deicers are both biodegradable, and therefore may impose an oxygen demand on receiving waters.

4.5 Monitoring to Demonstrate Program Effectiveness

Chloride concentrations in local streams should be monitored both before and after implementing the preceding recommendations so that the effectiveness of any chloride reducing measures can be demonstrated. A technical memorandum outlining a recommended monitoring program has been delivered to DRSCW.

4.6 Prioritization of Recommendations

The relative priority of the recommended measures is given below.

- Chloride concentration monitoring in streams
- Storage and bulk handling improvements
- Staff training and public outreach
- Further implementation of pre-wetting
- Further implementation of anti-icing
- Follow up chloride concentration monitoring in streams to demonstrate effectiveness

4.7 Potential Sources of Funding

The TMDL describes chloride concentration "spikes" that exceed water quality standards in the winter months, suggesting that periodic, short term loadings from winter roadway deicing activities contribute to short term chloride water quality exceedances. Data indicates substantial compliance with water quality standards outside of these winter month periods.

These findings support increasing allocation of resources to controlling chlorides from deicing operations over other sources of chlorides, such as further control from point sources. If incremental phased improvements in control of deicing chloride contributions result in reduced winter month spikes, other sources of chlorides should be assessed for further resources.

It should be emphasized that the net impact of the recommended measures on winter maintenance budgets is expected to be positive. Funding will be necessary to carry the cost of implementing the recommended measures. This funding is potentially available from the following sources:

- Application could be made for funding through the IEPA / USEPA 319 Grant Program.
- Funding may be available locally from municipal government, public works agencies, or research grants through universities.
- In British Columbia, Canada, many studies and pilot programs have been funded by the provincial auto insurance agency, motivated by the potential savings in collision damage claims. Potential funding available from similar sources in this area could be investigated.

Section 5
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