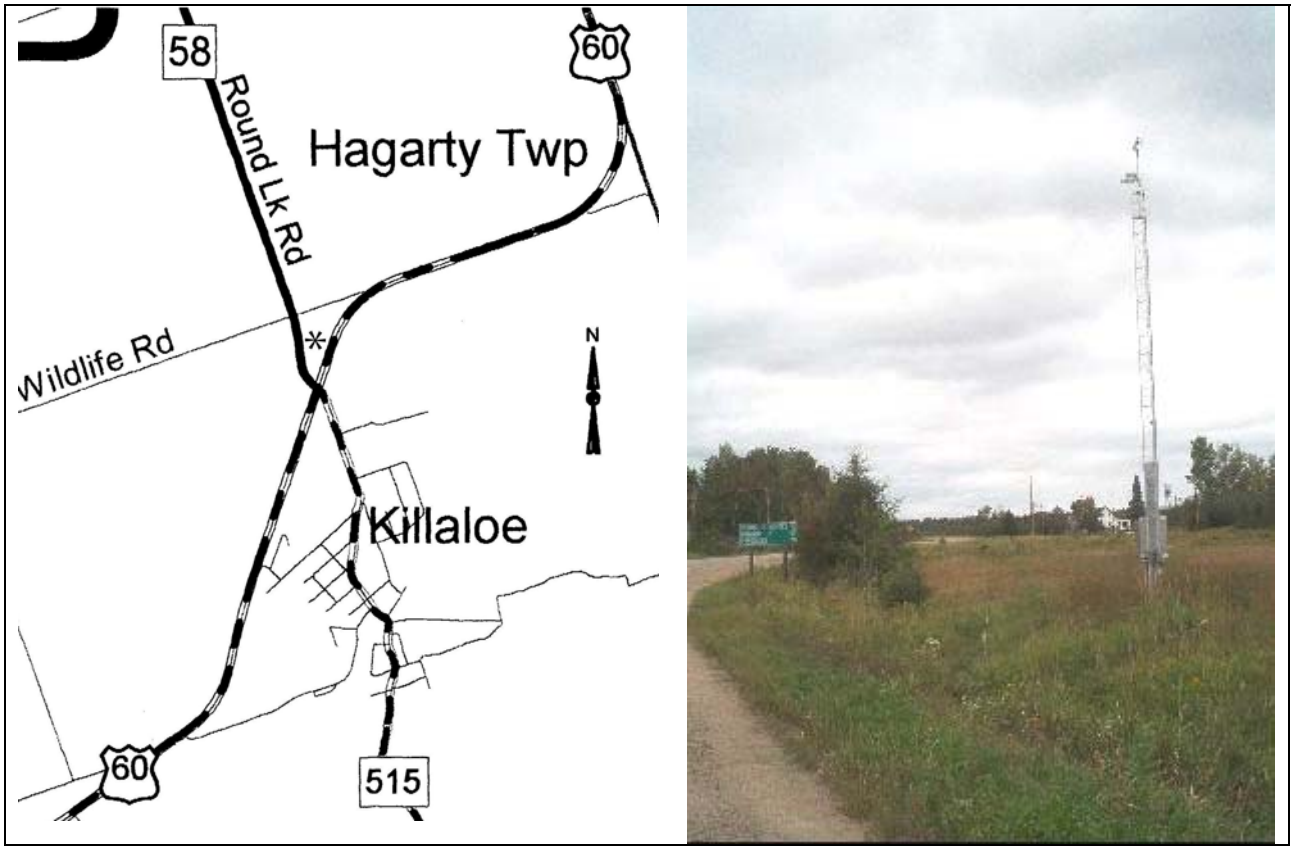
FEDERATION OF CANADIAN MUNICIPALITIES – APPLICATION # EF-3157

COUNTY OF RENFREW
RWIS NETWORK IMPLEMENTATION
POST-DEPLOYMENT PERFORMANCE EVALUATION



Prepared for the County of Renfrew, Ontario

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Executive Summary

In 2002, the County of Renfrew and the Federation of Canadian Municipalities co-funded the installation of a two-station Road Weather Information System (RWIS) network within the County. As part of the contract between the two parties, the County of Renfrew agreed to have a third party complete a post-deployment performance evaluation to track the effects of RWIS support on winter maintenance activities and expenditures: the County contracted Mark F. Pinet & Associates Limited to complete the post-deployment reporting. The goal of this report is to determine whether improvements in winter maintenance practices were realized and to support other Municipalities that may wish to install RWIS networks in the future.

Winter maintenance performance was measured as the difference between pre- and post-deployment of the network. For the purposes of this report, the benchmark data was assumed to be that obtained during the winter seasons of 2000/2001 to 2002/2003. Data assembled for benchmarking included salt and sand use (volumes and application rates), fuel consumption, collision statistics and winter maintenance expenditures. Similar data was collected for the 2003/2004 winter season (the first season with full deployment and a pre-wetting trial). To determine the benefit of RWIS in terms of maintenance activities and expenditures, the 2003/2004 measured values were compared to the benchmarks and previous trends.

As a result of the post-deployment performance evaluation/analysis, the following differences were noted at the end of the2003/2004 winter season:

- A 16% reduction in chloride use (from NaCl and Mg_2Cl) along route 606-04 due to pre-wetting maintenance strategies assisted by RWIS information.
- A 16% reduction in total winter season collisions (not involving animals) compared to the trend in the benchmark data (not corrected for winter severity)
- A 32% reduction in required winter patrol costs (not corrected for winter severity or route optimization program)
- A 30% reduction in diesel fuel consumption (not corrected for winter severity or route optimization program)

Several factors influenced each of these benefits, aside from the RWIS deployment, including severity of winter and route optimization. Greater confidence in the measurement of benefits will be possible once an evaluation methodology is implemented that can account for the major variables that control the changes in response. A standardized Winter Severity Index will greatly aid in assessment in the future.

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1. INTRODUCTION

In October of 2002, the County of Renfrew and the Federation of Canadian Municipalities joined efforts to fund a two-station Road Weather Information System (RWIS) network. As part of this contract a performance evaluation program would track the effects that RWIS supported operations had on overall winter maintenance expenditures and activities. The performance of the system was evaluated based on the performance of the RWIS network during the first full season of implementation in winter 2003/2004.

This report was prepared to allow the County of Renfrew and the Federation of Canadian Municipalities (FCM) to assess the effective 'return on investment' of the RWIS stations installed near the villages of Killaloe and Foymount. The report was specifically commissioned in response to FCM requirements for reporting on funded projects. This report will also provide other municipalities interested in installing RWIS networks a framework and an evaluation methodology with which to measure success. This report is not the final stage in the performance evaluation of the RWIS network implemented in the County of Renfrew, but rather is a starting point for their annual evaluation of winter maintenance techniques.

1.1 STAKEHOLDERS AND PROJECT TEAM

The County is involved in the project at all levels including management, supervisors, and operators. Decisions regarding installation and equipment relating to the RWIS are made by management. The area supervisors make maintenance decisions based on the processed RWIS information and operators use the feedback from supervisors to keep the roads clear and safe. The County received partial funding for the project from the FCM through the Green Municipal Enabling Fund. RWIS network design, deployment, and performance evaluations were performed by Mark F. Pinet & Associates Limited (MFPA).

2. BACKGROUND

After receiving reports on the detrimental effects of road salts in 2001, the County of Renfrew contracted MFPA to develop a Salt Management Plan based on the TAC Salt Management Guide, Synthesis of Best Practices, and MFPA's previous experience. The Salt Management Plan identified several actions that could be undertaken to reduce salt consumption while improving road safety. One of these recommendations was the installation of a RWIS network that would support the winter maintenance decisions and allow the County to access the Ministry of Transportation of Ontario (MTO) RWIS Network.

In October of 2002, the County of Renfrew applied for project funding from the FCM through the Green Municipal Enabling Fund (GMEF). GMEF was put into place to support studies that evaluate technical, environmental, and economic feasibility of innovative projects. The project involved the implementation and monitoring of two RWIS stations and is classified under the category of *Sustainable Transportation Services and Technologies*. The goal of the project is to improve air, water, and soil quality through reductions in road salt use and greenhouse gas emissions.

RWIS stations collect real-time environmental and pavement condition data to provide more comprehensive pavement forecasts for use by maintenance personnel and travelers. The data collected are sent to a post-processing Value-Added Meteorological (VAM) service that interprets the data and provides current and forecasted weather and pavement conditions. This information supports winter maintenance decision-making, allowing operators to conduct their work in a more efficient, safe, economic, and environmentally sensitive manner. In conjunction with RWIS installation, the County began trials using magnesium chloride (Mg_2Cl) for pre-wetting the sodium chloride (NaCl) rock salt. Advanced active pavement sensors were used to measure chemical concentrations when more than one type of anti-icing and/or deicing material was used. The proposed project was split into two components: RWIS station implementation and post-deployment analysis.

The first phase of the project was completed in February of 2003, with the commissioning of the RWIS stations in Foymount and Killaloe. The County began using the pavement forecasts developed from the RWIS data to assist in decision making in Winter of 2003/2004. The goals of the RWIS project, as identified by the County, are:

- reduce salt use by up to 20-30%[1]
- reduce occurrence of salt burn to roadside vegetation.
- reduce collision rates by up to 75%[2]
- reduce costs and reinvest the savings in infrastructure (sustainable development)

In accordance with the FCM agreement, additional issues are addressed in this report:

- determine fuel savings/greenhouse gas reductions from reduced fleet requirements for salt application.
- evaluate opportunities to reduce cost of road sensor application through installation at the time of construction/repair and design of a station that can be universally installed.
- compare the effectiveness of RWIS technology with other lower-technology anti-icing techniques, in terms of road safety and salt reduction.

[1] Environment Canada (2001). *The Science and the Environment Bulletin: Smarter Roads Means Safer Roads*. http://www.ec.gc.ca/science/sandejan01/article1_e.html
[2] AASHTO (1999). *Proceedings - 1999 AASHTO Lead States Workshop, RWIS/Anti-icing*. http://leadstates.transportation.org/99proceedings.pdf

2.1 CONDITIONS PRIOR TO RWIS DEPLOYMENT

To determine if the objectives have been met, the conditions prior to RWIS installation must be identified. The following assumptions characterise the pre-RWIS benchmark:

- winter maintenance decisions are made based on observed conditions and publicly available forecasts from Environment Canada.
- the County of Renfrew winter maintenance procedures are based on the Minimum Maintenance Standards and Levels of Service as defined by provincial agencies. These guidelines include strict direction not to apply salt prior to an accumulation of ice on the roadway. This is not consistent with recommended anti-icing strategies.
- pre-wetting capabilities and equipment exist within the fleet, but have exhibited poor performance during trials; occasionally resulting in increased greasiness of the road due to inadequate knowledge of pavement temperature and chemical concentrations.
- pre-RWIS conditions do not reflect the benefit of route optimization partially implemented in 2003/2004. This resulted in route changes and more efficient use of resources.

A summary of the average winter maintenance operations costs and conditions prior to RWIS deployment is provided in Table 1.

Table 1. County of Renfrew - Pre-RWIS Deployment - Condition Summary

Annual Condition	Average Annual Values (2000/2001 to 2002/2003)
Collision Statistics (not including those involving animals)	214
Mass of Salt Used	12,900 tons
Mass of Sand Used	8,000 tons
Total Winter Maintenance Costs	$ 2,360,000
Time to Mobilize	Data not available
Greenhouse Gas Contribution	432,000 kg

3. QUESTIONS TO BE ANSWERED BY THE PERFORMANCE EVALUATION

The primary goal of the performance evaluation was to allow the County and the FCM to track progress and return-on-investment of the RWIS system. The results would be judged by answering the following questions:

a) Have RWIS-supported winter maintenance operations resulted in a decrease in salt use? If so, by how much? (See Section 4.2.2)
b) Have RWIS-supported winter maintenance operations resulted in less damage to roadside vegetation? (See Section 4.2.3)
c) Have RWIS-supported winter maintenance operations resulted in a decrease in the number of collisions that result from adverse (i.e. icy) road conditions? If so, by how much? (See Section 4.2.4).
d) Have RWIS-supported winter maintenance operations resulted in winter maintenance cost savings? If so, how much and with respect to which operations? (See Section 4.2.5).
e) Have RWIS-supported winter maintenance operations resulted in a decrease in fuel use and Greenhouse gas emissions? If so, by how much? (See Section 5.1).

4. PERFORMANCE EVALUATION

The performance evaluation involved systematic analysis of actual system performance in comparison to previous trends. The results of the evaluation are to be used to improve future performance and identify potential areas for additional study and attention.

4.1 METHODOLOGY

The 2003/2004 winter season data was compared to the winters of 2000/2001 to 2002/2003 inclusive. Where possible, distinctions were made for the routes where RWIS and prewetting strategies were implemented. RWIS stations were installed at Foymount and Killaloe and anti-icing strategies were applied along route 606-04; part of the larger Pembroke Patrol area.

To make comparisons between subsequent winters, the data should first be normalized. Details regarding this are provided in section 4.1.2.

4.1.1 *Data Sources*

Measurement parameters for the RWIS performance evaluation were collected from patrol records, billing information, anecdotal evidence, Environment Canada online databases, and output from the RWIS stations themselves for the period when available.

4.1.2 *Normalizing the Data*

Comparing the data from one winter to another requires the use of a common reference base such as a Winter Severity Index (WSI). Unfortunately, no standard method for calculating winter severity has been developed. A WSI would take into account the factors that influence winter conditions including: precipitation type, precipitation amount, number of heating degree days, length of winter season, and number of precipitation events. Each of these factors influences the type and frequency of winter maintenance operations that must be carried out. For example, a year with mild temperatures and 15 freezing rain events will require different control activities than a colder winter with heavy snow falls and no freezing rain events. Therefore, without a standard WSI no rational comparison can be made between data collected over subsequent winters. The Transportation Association of Canada (TAC) is currently conducting research into the development of a standard WSI, but it is not yet complete. Consequently, the data presented in the remainder of this report may indicate that some conditions and costs have changed, since installation of RWIS, but the presented values ***do not*** take winter severity into account.

One aspect of winter severity that can be examined with respect to the County of Renfrew data is the number of treatable events. A treatable event is defined as a single storm, but does not take into account depths of accumulation, type of precipitation, or storm duration. The number of treatable events can be used to develop a "per storm" measure of winter maintenance operations, and assumes that every storm is handled in a similar way. The number of treatable events that occurred in the County of Renfrew each winter season since 2000 is summarized in Table 2.

Table 2. Number of Treatable Events in Renfrew County from 2000/2001 to 2003/2004.

	Years Being Studied			
Number of Storms for jurisdiction:	**2000-2001**	**2001-2002**	**2002-2003**	**2003-2004**
Route 606-04	86	85	96	91
Killaloe	90	91	105	88
Foymount	90	91	105	88
Pembroke	86	85	96	91
Cobden	82	87	102	86
Goshen	89	92	104	88
South West	97	96	108	90
Annual Average	**89**	**90**	**103**	**89**

4.2 ANALYSIS (POST-DEPLOYMENT CONDITIONS)

4.2.1 *Issues for Additional Consideration*

There are several issues to consider when examining and making comparisons with the post-deployment winter maintenance data. The first is that Renfrew undertook a plow route optimization project during the time of RWIS implementation. As a result, some routes changed jurisdictions and/or length. The routes that covered the areas where RWIS was installed were among those that changed, making it difficult to compare pre- and post-deployment performance for specific routes with RWIS coverage.

Another issue is that the updated winter maintenance procedures that involved RWIS and anti-icing were issued in December 2003 and were not fully implemented during the winter season. This means that the winter of 2003-2004 is not truly representative of RWIS supported practices. In addition, previous experience of MFPA indicates that it takes approximately three years for RWIS to become fully integrated into winter maintenance operations. This is due to several factors, including employee training, experience, and management confidence in the system.

It must also be noted that RWIS will often alert winter maintenance personnel to adverse winter road conditions that they may not have otherwise been aware of. This could result in an increased number of treatable events, fuel consumption, and salt requirements.

4.2.2 *Volume of Salt Used*

4.2.2.1 Hypothesis

Previous experience has shown that effective use of RWIS can potentially reduce annual salt use by approximately 20-30%. To reach this target, winter maintenance operators must consistently use the chemical concentration data and pavement condition forecasts to determine the exact salt application rates required along each route.

4.2.2.2 Methodology

The County of Renfrew assembled salt-use data sorted by patrol region for the winter seasons of 2000/2001 to 2003/2004; summarized in Table 3. The hypothesis will be considered verified if the salt us is consistently at least 20% less than previous years. To determine the actual change in salt use, the data from the benchmark years of 2000/2001 to 2002/2003 will be directly compared to that from 2003/2004.

Table 3. Salt Use for the County of Renfrew (Tons)

	Years Being Studied			
Route	**2000-2001**	**2001-2002**	**2002-2003**	**2003-2004**
Route 606-04	Included in Pembroke Patrol Totals			
Killaloe	Included in Cobden and South West Patrol Totals			
Foymount	Included in Cobden and South West Patrol Totals			
Pembroke	3116	2433	2302	2076
Cobden	2609	2386	2191	2546
Goshen	4134	4744	3909	3674
South West	4180	3644	3069	2237
Annual Totals	**14,039**	**13,207**	**11,472**	**10,533**

4.2.2.3 Analysis

The measured data is presented graphically in Figure 1. For route 606-04, where pre-wetting was implemented, comparisons were made between the total amount of chloride used (from both NaCl and Mg_2Cl) during 2003/2004 and the previous years. Application rates for previous years were assumed to be the same as for the Pembroke Patrol in 2003/2004, where route 606-04 is located.

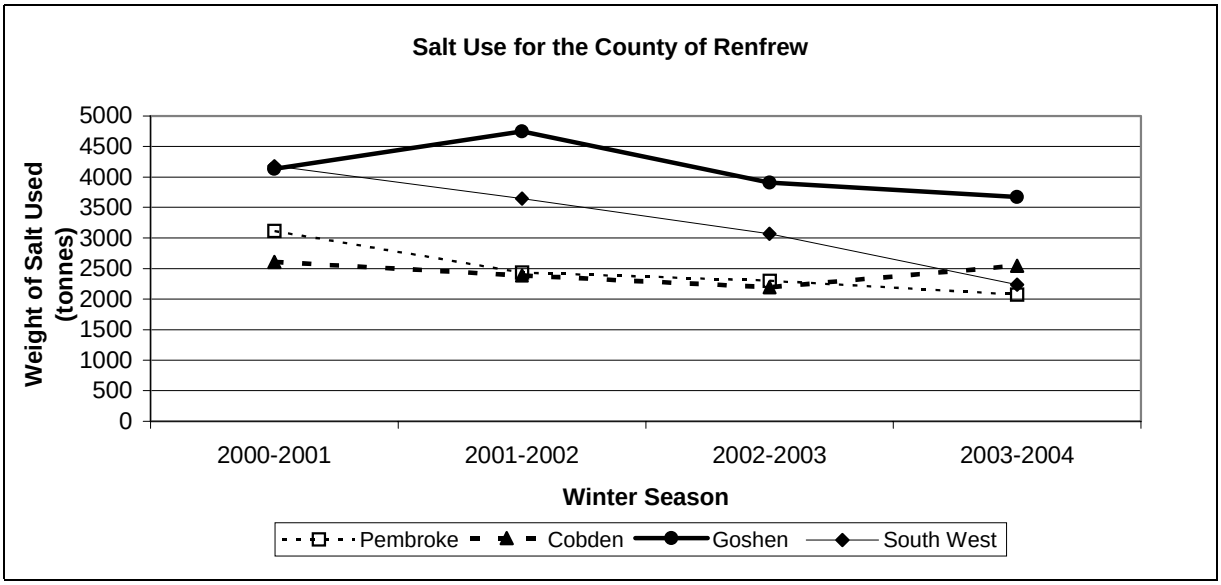

Figure 1. Salt Use, by Patrol Yard, for the County of Renfrew.

The yearly decrease in salt use within the Pembroke patrol region after deployment of the RWIS network was nearly 11% and was 10% in the Cobden and South West patrol regions, which include the RWIS stations at Killaloe and Foymount. The overall trend prior to RWIS installation was about 9% per annum. Therefore, the net reduction in salt use following deployment of the RWIS network was negligible. A larger change is expected during the 2004/2005 winter season as the updated operations plans progress. Linear interpolation was

used to determine the trends in salt use prior to RWIS installation in order to estimate the amount of salt that would have been used if RWIS-supported decision-making wasn't available. The data used to interpolate trends used in Table 4 is shown in Figure 2.

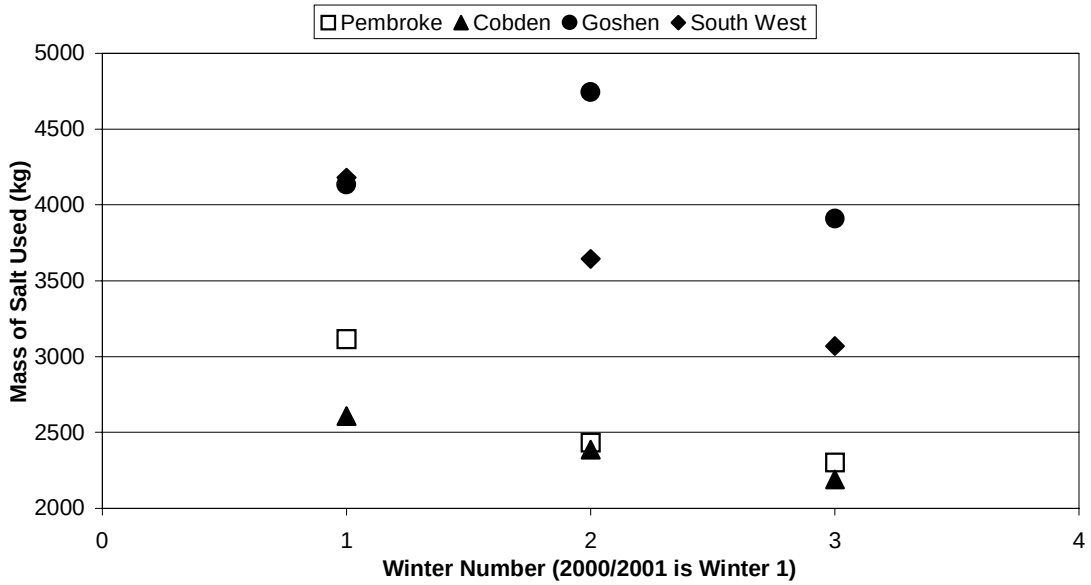

Figure 2. Short Term Trends in Salt Use.

According to this analysis, which does not take into account variation in winter severity or a variety of other factors, the estimates of salt usage are provided in Table 4.

Table 4. Predicted and Measured Salt Use Based on Short-term Trends

	Mass of Salt (Tons) for Winter 2003/2004		
Patrol Region	**Predicted Using the Trends from Figure 2**	**Actual Measured Usage**	**% Change from Predicted**
Pembroke	1803	2076	15.2
Cobden	1978	2546	28.8
Goshen	4038	3674	-9.0
South West`	2521	2237	-11.3
Combined Cobden and South West	4498	4783	6.3

The benefit of implementing pre-wetting strategies can be determined by examining the net chloride use, from NaCl and Mg_2Cl, on route 606-04. The standard application rate for salt in this region of the County is 113 kg/2-lane km. With 2701 2-lane km in route 606-04, the total annual NaCl used, without pre-wetting, would have been 335.2 tons, for a total chloride amount of 157.3 tons. With pre-wetting, Renfrew County applied 277.7 tons of NaCl and 15,613 L of Mg_2Cl to route 606-04, for a total chloride use of 132.5 tons. Pre-wetting

therefore resulted in a net savings of nearly 25 tons, or a 16% reduction, of chloride on a single route. It should be noted that safe and effective application of pre-wetting could not be properly accomplished without the RWIS system.

An alternative way to analyze the data is to examine the salt use on a "per storm" basis, as shown in Figure 3. This interpretation of the data indicates a trend of increased salt use in one of the regions covered by RWIS – the Cobden Patrol region. There was a decrease in salt use in the Pembroke (pre-wetting trial) and South West (RWIS) Patrol regions during the same season, but the pre-existing trends suggest that these decreases should have been greater. This may indicate that increased detection and prediction of adverse pavement conditions resulted in increased salt application or that the storm events were more severe.

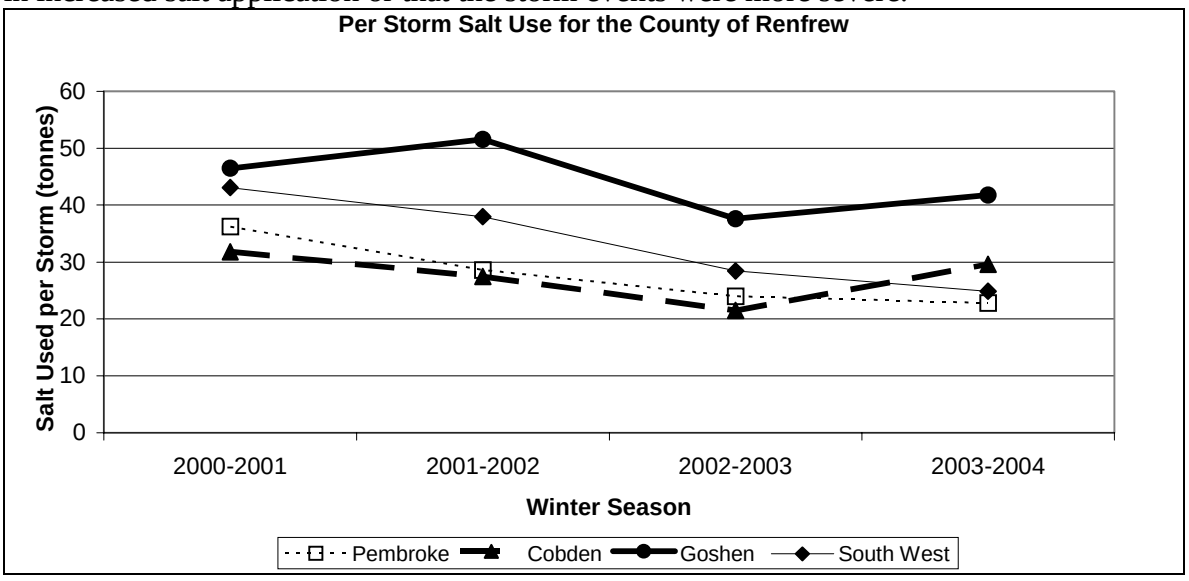

Figure 3. Salt Use Trends for the County of Renfrew Normalized by Storm Frequency.

4.2.2.4 Conclusions

It cannot be conclusively demonstrated that installation of the RWIS network directly resulted in reduced salt usage in the County of Renfrew. The inability to directly state that RWIS reduced salt use is a result of the fact that the RWIS is simply a tool that supports other activities that result in salt reduction. These other activities include: implementation of Salt Management Plans, operational plan reviews, Maintenance Decision Support Systems, pre-wetting, operator training, and changes in other equipment technology. Renfrew is involved in all of these activities to varying degrees. When all of these activities are fully implemented a significant decrease in salt use is expected across the County. While measured salt usage did decrease between 2002/2003 and 2003/2004, a pre-existing trend predicted similar or larger decreases. This trend may be attributed to plow route optimization and implementation of a Salt Management Plan (originally completed in April, 2002). A 16% decrease in chloride application along route 606-04 can be attributed to RWIS supported technologies. The

reduction on this route during the 2003/2004 season was accomplished using pre-wetting technologies that could only have been properly implemented with support from the RWIS system. As a result of this success, the County of Renfrew is expanding its pre-wetting strategies to encompass more routes during the 2004/2005-winter season. If the success on the first route is reproduced on the other routes then a similar reduction in chloride amount should be observed throughout the county.

4.2.3 *Reduction in Occurrence of Salt Burn to Roadside Vegetation*

4.2.3.1 Hypothesis

Improved salt application and pre-wetting techniques should result in reduced occurrences of salt burn to roadside vegetation. Applying the correct amount of salt at the optimum time will result in reduced salt use and road spray with lower chemical concentrations.

4.2.3.2 Methodology

Photographic and numerical evidence such as percentage of plants with salt burn and number of plants lost during winter season must be collected to identify a reduction in salt burn. This study would have to extend over several years because it takes several years for organisms to recover from previous damage effects must be closely monitored.

4.2.3.3 Analysis

No photographic or numerical evidence is available to support attainment of this project objective. However, from previous experience it is known that the new techniques being implemented use less salt and less salt is lost during application. This has the dual benefit of reducing the salt applied and keeping more of that salt off the vegetation.

4.2.3.4 Conclusions

Reduced salt use and more efficient application will result in reduced potential for salt burn. Reduced salt use trends, independent of RWIS implementation, can be inferred to have resulted in reduced salt damage to roadside vegetation. Effects of RWIS are inconclusive.

4.2.4 *Reduction in Collisions*

4.2.4.1 Hypothesis

Previous studies have indicated that using RWIS supported winter maintenance techniques such as improved forecasting and pre-wetting have the potential to decrease the number of collisions by up to 75%[3] (compared to expected pre-deployment numbers): it was hypothesized that there could be up to a 75% reduction in expected winter road condition-

[3] AASHTO (1999). *Proceedings - 1999 AASHTO Lead States Workshop, RWIS/Anti-icing*. http://leadstates.transportation.org/99proceedings.pdf

related collisions in the regions covered by the Foymount and Killaloe RWIS stations once the new winter maintenance techniques are fully implemented.

In addition to the safety benefits, this has the potential of significantly reducing costs to the general public, as noted in a report published by Environment Canada that states:

> A Traffic Safety Report (MTO, 2000) estimated that of all accidents, 0.31% result in fatalities, 23.8% result in injuries and 62.6 % result in property/vehicle damage … The estimated cost for these accidents is: $1,600,000 for a fatality, $28,600 for an injury, $5,700 for damages.[4]

For a winter season with 100 collisions, a 75% reduction could therefore result in a societal cost savings of $1.15 million.

4.2.4.2 Methodology

A reduction in collision rates due to effective use of RWIS supported decision-making can be estimated by analyzing the statistics for winter road condition-related collisions. This involves sorting the data by cause and analyzing only the collisions that were related to poor road conditions and not those involving animals. The number of these collisions should have decreased from the predicted value during the 2003/2004 winter season. The collision trends from 2001 to 2003 have to be examined to determine the number of collisions expected without RWIS supported maintenance and decision-making for the 2003/2004-winter season.

4.2.4.3 Analysis

Annual collision data was provided by the County of Renfrew and is summarized in Table 5. The data was not sorted by Patrol Area, so reductions in collisions cannot be correlated to pre-wetting or the routes where the new RWIS stations were installed.

Table 5. County of Renfrew Winter Season Collision Statistics.

	Number of Winter Season Collisions Per Year				
Road Condition	**2000/2001**	**2001/2002**	**2002/2003**	**2003/2004**	**Average**
Average Number of Treatable Events	89	90	103	89	92
Dry Surface[2]	56	62	96	74	72
Wet or Slippery[1,2]	98	158	171	174	150
Total (no animals)[2]	154	220	267	248	222
Total (including animals)	233	309	357	372	318

Notes: [1] Wet or slippery road conditions include wet, loose snow, slush and ice.

[4]McCormick Rankin Corp. and Ecoplans Ltd. For Environment Canada, (2003). *Case Study # 3: Accident Reduction on the 401/416 Ramp using Fixed Automated Spray Technology (FAST)*. http://www.ec.gc.ca/nopp/roadsalt/cStudies/pdfs/3%20-%20FAST%20-%2004%2003%2025.pdf

[2] Data does not include accidents involving animals.

The total collision data, not including collisions involving animals, is shown graphically in Figure 4. The trend line is based on the 2000/2001 to 2002/2003 winter data and indicates the total collisions that would have been expected during the winter of 2003/2004. Values were not normalized by winter severity

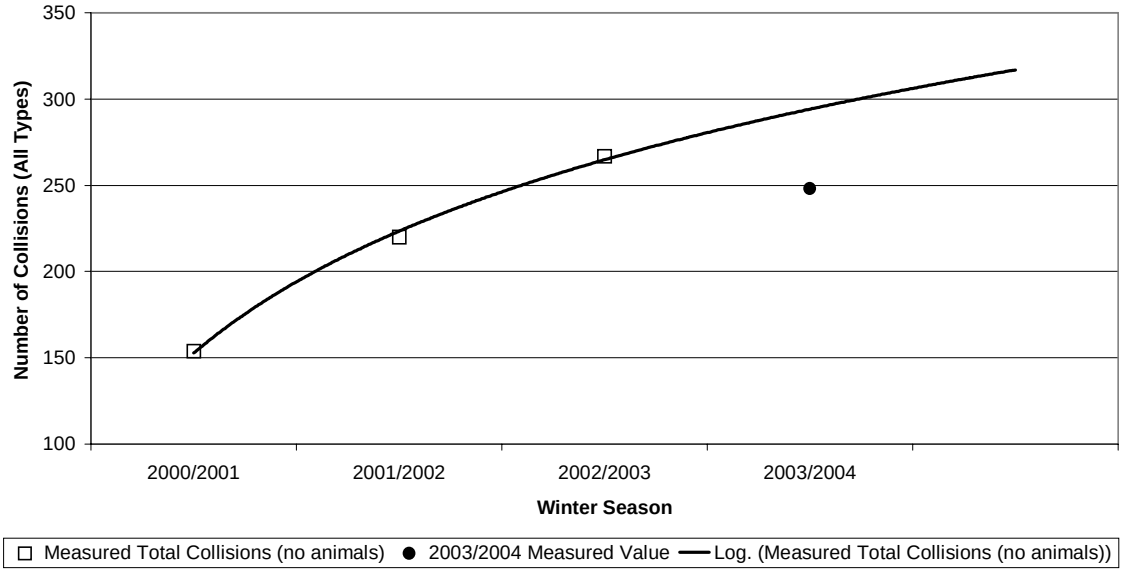

Figure 4. Total Measured and Predicted Collisions in Renfrew County.

Based on collision trends prior to 2003/2004 the total collisions predicted for the 2003/2004 winter season was 294, which does not involve consideration of winter severity. The actual measured value was 246 collisions, or about 16%, less than this predicted value. Similar analysis indicates that the collisions recorded for slippery conditions were 11.4 % less than predicted and collisions for dry conditions were 33% less than predicted. A logarithmic trend line was used for the slippery conditions and a linear trend line was used for dry conditions.

4.2.4.4 Conclusions

Collisions data collected for the 2003/2004-winter season indicates that 16% less collisions occurred than were predicted based on the trend over previous years. This reduction in collisions may be attributed to either RWIS implementation or changes in winter severity, which was not accounted for during this analysis.

4.2.5 *Winter Maintenance Costs*

4.2.5.1 Hypothesis

Total winter maintenance costs should decrease following implementation of RWIS as a result of an improved awareness of expected conditions, improved support for making winter maintenance decisions, and more efficient use of salt and deployment of vehicles.

4.2.5.2 Methodology

Annual data for the 2000/2001 to 2003/2004 winter seasons was compared to determine if any short-term trends existed in the annual expenditures prior to RWIS network installation. The pre- and post-deployment data was then compared to determine which areas have benefited from improved decision support.

4.2.5.3 Analysis

Table 6 provides summarizes the winter maintenance cost information over the past 4 years. These costs are highly dependant on the type of winter experienced. Factors like average temperature, humidity, and number of heating degree days all influence the type and frequency of necessary activities. One activity that is not influenced by winter severity, but is influenced by RWIS installation, is winter patrol.

Table 6. County of Renfrew winter maintenance costs.

	Years Being Studied			
Cost of:	**2000-2001**	**2001-2002**	**2002-2003**	**2003-2004**
Sanding ($)	99,401	84,404	86,684	79,665
Snow Plowing & Sanding ($)	370,774	253,227	404,242	339,980
Salting ($)	340,517	356,116	335,598	349,393
Snow Plowing & Salting ($)	1,618,611	1,124,189	1,000,223	996,011
Snow Fencing ($)	159,46	267,73	20,536	18,604
Spring Drainage ($)	68,071	22,238	46,790	46,223
Culvert Thawing ($)	2176	2319	85855	13778
Winter Standby ($)	Not Practiced	Not Practiced	Not Practiced	Not Practiced
Winter Patrol (Day) ($)	118159	115561	138169	94224
Winter Patrol (Night) ($)	85857	75348	71509	70773
Annual Totals ($)	**$2,719,512**	**$2,060,175**	**$2,189,606**	**$2,008,651**

The total annual winter maintenance costs in comparison to the 'per-storm' total winter maintenance costs is shown in Figure 5. It is evident from the parallel lines that winter maintenance costs are currently highly dependant on the number of storms and not necessarily the type or intensity of storm. Following full RWIS implementation, it is expected that these costs will become increasingly dependant on storm type, because data provided by the RWIS stations will help to tailor efforts to expected road conditions.

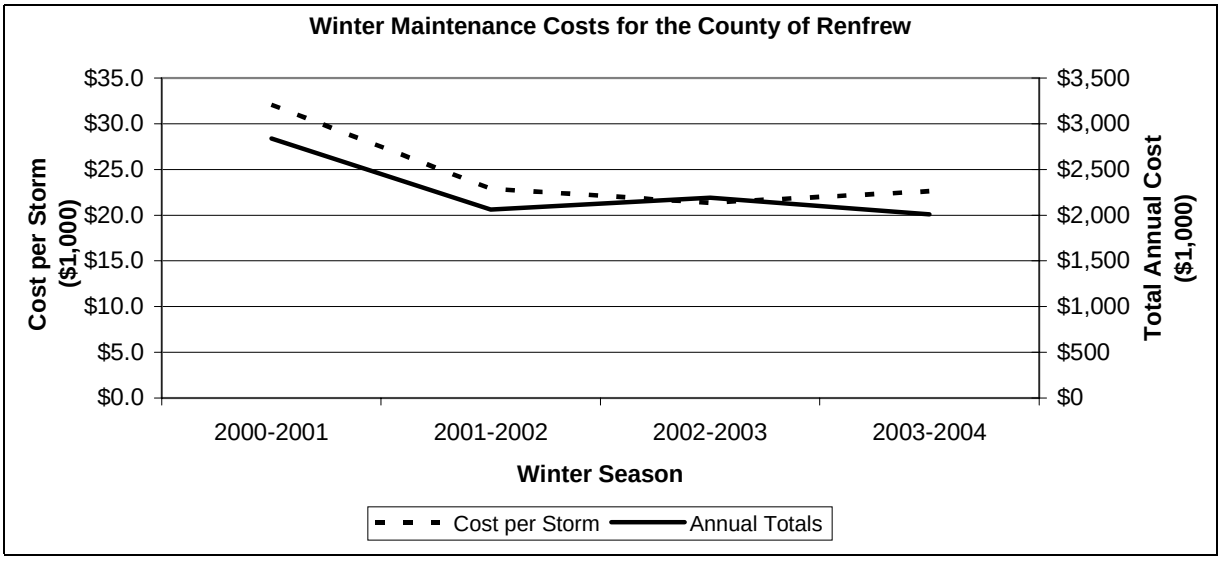

Figure 5. Trends in Winter Maintenance Cost for the County of Renfrew, 2000-2004.

4.2.5.4 Conclusions

For a variety of reasons it cannot be definitively shown that RWIS-supported decision making contributed to the reduction in costs. Several other initiatives were undertaken at the same time, such as route optimization, that likely had a much more significant effect. The RWIS system likely increased the number of patrols that were sent out due to increased detection of bad weather events. Ideally the better information provided would also increase the efficiency of these patrols, which would offset the cost of increased patrol frequency.

5. RESPONSE TO FEDERATION OF CANADIAN MUNICIPALITIES SCHEDULE A REQUESTS

5.1 CALCULATION OF FUEL SAVINGS/GREENHOUSE GAS REDUCTIONS FROM REDUCED FLEET REQUIREMENTS FOR SALT APPLICATION

Through anti-icing efforts and stricter adherence to standards, the County of Renfrew has attempted to reduce greenhouse gas emissions with RWIS support. This reduction can be estimated based on the total fuel usage recorded each winter for both pre- and post-deployment of the RWIS network. Fuel usage was normalized by number of treatable events and is shown in Table 7. Annual fuel use by region is presented in Figure 6 and Figure 7.

Table 7. County of Renfrew Fuel Consumption for 2000 to 2004.

Season	Number of Treatable Events	Gasoline Usage per Storm (L)	Trend from Previous Year	Diesel Usage per Storm (L)	Trend from Previous Year
2000-2001	89	381	N/A	1885	N/A
2001-2002	90	375	-1.6 %	1488	-26.7%
2002-2003	103	317	-18.3 %	1236	-20.4%
2003-2004	89	388	+22.4 %	1453	+17.6%

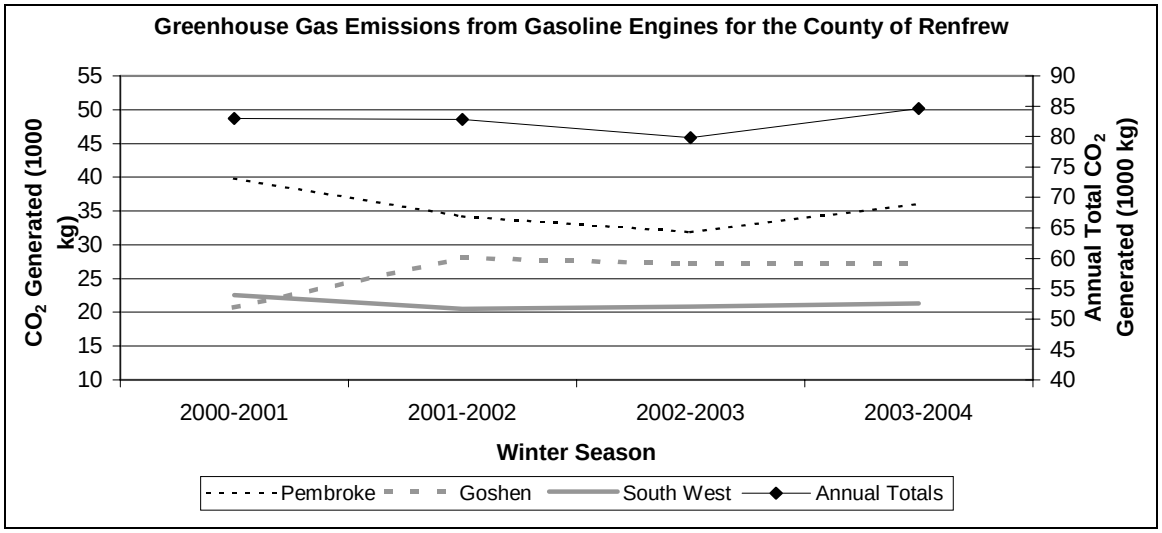

Figure 6. Greenhouse Gas Emissions Due to Gasoline Engines.

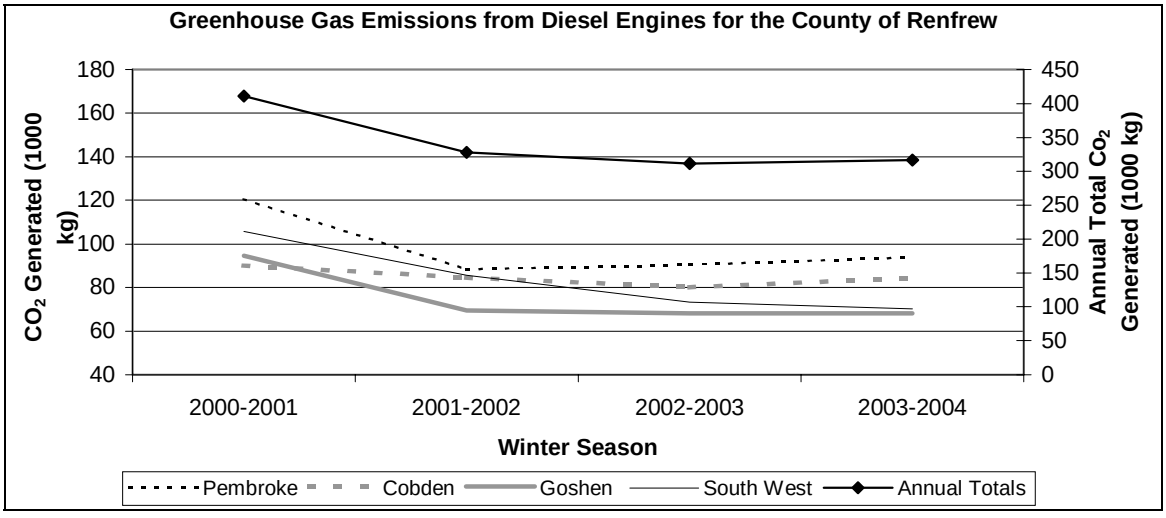

Figure 7. Greenhouse Gas Emissions Due to Diesel Engines.

The above figures indicate that Municipal Vehicle fuel consumption increased across the County following implementation of RWIS services. This may be attributed to the fact that RWIS strategies were used in addition to former practices, not to their exclusion, and that RWIS sensing capabilities alerted maintenance providers to adverse conditions that they might not have otherwise been aware of. A comparison was made between the winter seasons of 2000/2001 and 2003/2004, which had the same number of treatable events, and there was nearly a 30% reduction in diesel fuel consumption during the time RWIS was implemented, as shown in Table 8. The reduction in diesel fuel consumption was likely due to the route optimization program that was undertaken at the same time.

Once these observations are taken into consideration it is likely that emissions for the maintenance fleet will actually increase with the implementation of the RWIS system. However, a significant unmeasured secondary benefit could be realized when traffic congestion in the area due to winter storm events is reduced. This could result in a significant secondary reduction in greenhouse gas emissions.

Table 8. County of Renfrew Fuel Consumption Comparison for 2000/2001 and 2003/2004.

Season	Number of Winter Storms	Gasoline Usage per Storm (L)	Trend	Diesel Usage per Storm (L)	Trend
2000-2001	89	381	N/A	1885	N/A
2003-2004	89	388	+1.8 %	1453	-29.7%

5.2 EVALUATION OF OPPORTUNITIES TO REDUCE COST OF ROAD SENSOR INSTALLATION

Opportunities to reduce the overall cost of RWIS installations must be implemented at the network planning and purchasing stages: there are no cost reductions at the sensor installation stage because road sensors must be installed after road construction/rehabilitation has been completed to ensure that they are flush with the road surface.

Cost savings can be realized through :

- bulk-purchases - this is possible if an entire network was designed and installed at the same time, rather than one station at a time. Standard designs do not fit every situation and must be customized to local standards.
- Proper siting of the RWIS stations will result in forecasts accurate over a larger area, reducing the number of installations and greatly reducing the cost of the network.
- Cost/benefit studies on power sources should also be completed to determine whether solar power packages would be more cost effective than connecting standard power to the RWIS station. For example, remote locations could be better off with solar power than with a costly extension of the power grid.

- Training staff from the municipality to run the RWIS network and conduct annual servicing and routine maintenance could also result in cost savings.

5.3 COMPARISON OF THE EFFECTIVENESS OF RWIS TECHNOLOGY WITH OTHER LOWER-TECHNOLOGY ANTI-ICING TECHNIQUES.

Techniques used by winter maintenance providers to determine when anti-icing strategies include: RWIS networks or stations, truck-installed infrared pavement temperature sensors, and public weather forecasts. Each of these strategies has its own benefits and disadvantages, but the most important concern should be public safety. In this regard, RWIS has demonstrated the greatest advantage by providing winter maintenance providers access to detailed, local, real-time pavement condition forecasts, and information including temperature and chemical concentration. Truck-installed infrared pavement temperature sensors provide site-specific information on current pavement surface temperatures, but cannot be used for hind- or forecasting. Public weather forecasts provide information on air conditions, but due to radiant heating and heat latency pavement conditions are often significantly different.

According to a recent study performed by the US Army Cold Regions Research and Engineering Laboratory:

> Pavement temperature directly influences the formation, development, and breaking of a bond between fallen or compacted precipitation and the road surface as well as the effectiveness of chemical treatments. It is also important when high humidity levels are accompanied by low dew point temperatures. Under these conditions there will be a greater potential for formation of frost and black ice. Unless some external source of heat is provided, the pavement temperature will generally track air temperature with a time delay. For road sections without obstructions to a clear sky view, solar radiation during the day and exposure to the clear night sky will affect the road surface temperature to a greater extent than on sections influenced by air contact only. [5]

As such, accurate pavement conditions and forecasts are necessary for making decisions regarding when and at what concentration to apply salt or anti-icing chemicals. Application of dry chemicals too far in advance of a storm will result in excessive loss to the environment as a result of bouncing off the pavements during application or dispersion by vehicular traffic. Application of liquid chemicals is required enough in advance of the storm to ensure that the chemical reaches the pavement surface before it is too diluted by falling snow or rain to be

[5]Ketcham, Stephen A.; Minsk, David; Blackburn, Robert R.; Fleege, Edward J. (1996). *Manual of Practice for an Effective Anti-Icing Program: A Guide For Highway Winter Maintenance Personnel*. US Army Cold Regions Research and Engineering Laboratory: New Hampshire.

effective. The effectiveness of anti-icing chemicals is also highly dependant on chemical concentration, ambient humidity, and pavement temperature. This relationship is made evident by examining a phase diagram for standard road salt, NaCl, as shown in Figure 8.

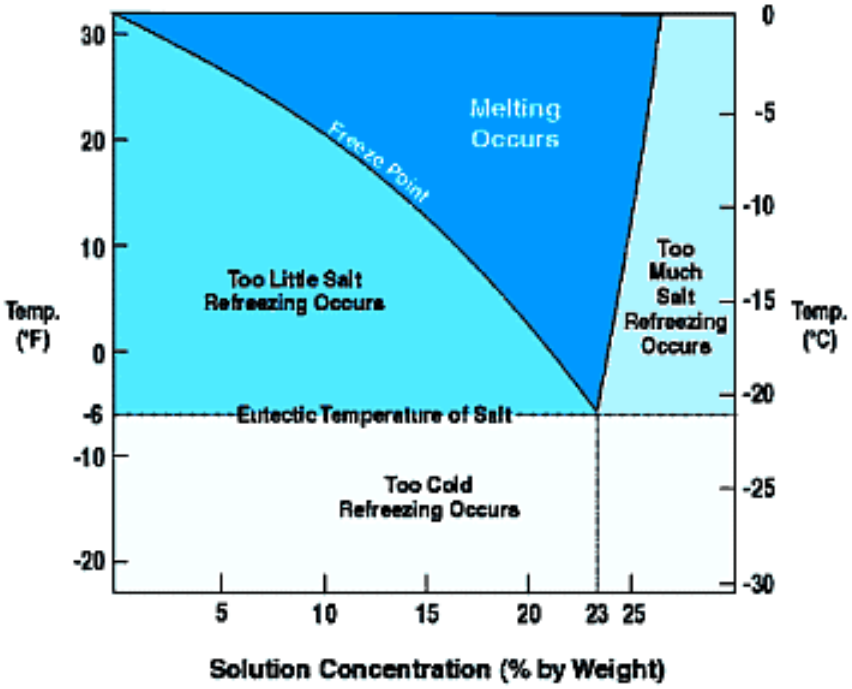

Figure 8. Binary phase diagram for NaCl and H_2O (Salt Institute, 2000)

The cost effectiveness of liquid anti-icing chemicals is dependant on the temperature at which they are applied. Typically, liquid anti-icing chemicals are used for pavement temperatures above –5 ^{o}C. Caution must also be exercised when placing these chemicals as some may increase the greasiness of the road if applied incorrectly. The County of Renfrew has experienced this in the past when applying calcium chloride to roads without accurate pavement temperature forecasts. Some hygroscopic anti-icing chemicals can pull water out the air, creating a hazard that would not otherwise have existed. In this regard, pairing accurate pavement condition forecasts with anti-icing strategies is imperative to maintain roadway safety. The successful use of RWIS combined with value-added meteorological services has been confirmed to reduce salt use by as much as 30%[6] from that provided by publicly available weather forecasts. Reductions in salt use from the use of infrared-thermometers technologies have not been confirmed.

[6] Environment Canada, (2000). Smart Roads are Safe Roads: Reducing Salt Use Through Road Weather Services. http://www.ec.gc.ca/press/000811-2_b_e.htm

5.4 THAT A LETTER OF SUPPORT BE PROVIDED TO FCM FROM THE PROVINCIAL MINISTRY OF TRANSPORTATION

The MTO actively employs an RWIS network to assist provincial personnel in making informed decisions regarding winter maintenance operations. The MTO has over 115 sites across the province, three of which are in Renfrew County. Figure 9 shows the site locations for the MTO RWIS stations in eastern Ontario. The sites within the County are at Pembroke, Renfrew and Arnprior. When paired with the two RWIS stations installed by the County of Renfrew these five stations would provide almost full coverage of the county road network. Gaining support from and access to the MTO RWIS sites in the region would prove to be an invaluable tool when making winter maintenance decisions within the County of Renfrew. The County of Renfrew has contacted the Ministry of Transportation Ontario to request their support with the County of Renfrew/FCM RWIS project.

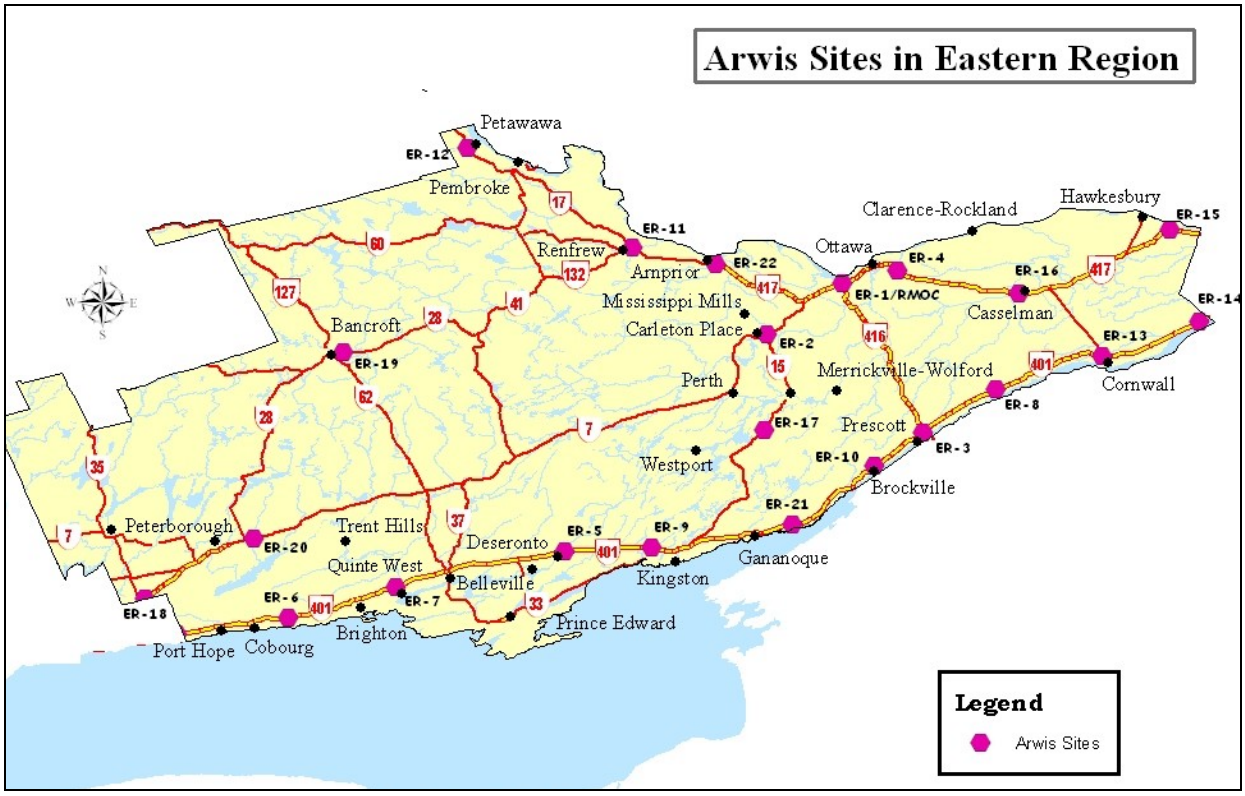

Figure 9. MTO RWIS sites in eastern Ontario (taken from the Ontario Good Roads Association web page)

5.5 CONTACT IS TO BE MADE WITH THE CITY OF MONCTON TO BENEFIT FROM LESSONS LEARNED

Moncton

Contact was made with the City of Moncton Department of Streets Maintenance and Operations. Information for their point of contact is provided below:
Contact Person: Alan Slater
System Accountant, Operations
Phone Number: 1-506-859-2634
Email Address: alan.slater@moncton.org

The City of Moncton currently ties into an RWIS station that is owned and operated by the Maritime Road Development Corp. (MRDC). The station is located at the intersections of Highway 2 and Highway 126, just west of the City. The operations department uses the site-specific atmospheric and pavement forecasts to assist in the decision-making process for their own fleet and that of their contractors. The City currently uses pre-wetting technologies, but is not involved in anti-icing practices.

6. CONCLUSIONS

Based on the preceding analysis, the following conclusions can be drawn with respect to the benefits realized by the County of Renfrew during the winter season that followed deployment of the first phase of their RWIS-network (2003/2004) and the tie-in to the provincial MTO network:

- A 16% reduction in chloride use (from NaCl and Mg_2Cl) along route 606-04 due to pre-wetting maintenance strategies assisted by RWIS information.
- A 16% reduction in total winter season collisions (not involving animals) compared to the trend in the benchmark data (not corrected for winter severity)
- A 32% reduction in required winter patrol costs (not corrected for winter severity or route optimization program)
- A 30% reduction in diesel fuel consumption (not corrected for winter severity or route optimization program)

Not all positive changes realized during the 2003/2004-winter season are directly attributable to RWIS deployment: the County of Renfrew has recently completed a Salt Management Plan, plow route optimization, and equipment upgrades.

7. RECOMMENDATIONS

The County of Renfrew should conduct an annual performance evaluation measuring salt use, collisions, winter maintenance costs, and greenhouse gas generation. This is especially important for the 2004/2005 winter season, which will be the first winter with full implementation of the updated operations and winter control guidelines make use of the decision-support available from the RWIS data-based forecasts.

This monitoring should involve collection of detailed data so that the County may make more definitive conclusions regarding the effectiveness of their RWIS network installation.

The data suggested for collection includes the following:

- Amount of solid and pre-wetted salt used per route.
- Number, cause, and location of winter collisions, along with a description of the road and weather conditions.
- Detailed winter maintenance costs by patrol yard (and potentially by route)
- Fuel consumption by activity (based on kilometer readings and fuel efficiency).
- Number of storms by region, including precipitation type and accumulation.
- Number of freezing rain events and a measure of accumulation.
- Monitoring of vegetation health (photographic and numerical records) along representative stretches within each patrol region.
- Time to mobilize (by patrol region) including time of day when the calls are made.
- Time to return to LOS by plow route.

The County should ensure that all staff are trained in the updated maintenance procedures and that decision-makers are taking full advantage of the RWIS-supported capabilities. Training sessions should take place prior to the expected start of the winter season and spot-checks should be made to ensure operators are adhering to the new policies. Post-storm reviews should be made to mark achievements and identify potential areas for improvement.

The County of Renfrew should investigate the use of automated patrol records for monitoring salt use, beat length, application rates, etc.

The County should complete its RWIS network by installing stations at the two additional sites indicated in the original network design.

The County should keep contact with Moncton in order to benefit from its experience.

This final report is respectfully submitted.
Mark F. Pinet & Associates Limited,

Mark F. Pinet, P.Eng. President
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