ALTERNATIVE SNOW AND ICE CONTROL METHODS FIELD EVALUATION

Final Report

FHWA-OR-RD-98-03

by

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16. Abstract

This document is the result of a two-year study to evaluate the emerging technologies in snow/ice control and determine their economic and operational effectiveness. Operational, environmental and economic factors were evaluated to compare Oregon's "plow and sand" strategies to emerging chemical-based anti-icing strategies. The strategies examined included the use of calcium magnesium acetate (CMA) and magnesium chloride ($MgCl_2$) known for their effectiveness, low corrosion, and low environmental impact. The ten evaluation sections in this study represented the various climate conditions found throughout the state.

Results show that an anti-icing strategy, with either CMA or $MgCl_2$, is effective and cost-efficient under a wide range of climatological and traffic conditions when compared to traditional "plow and sand strategies."

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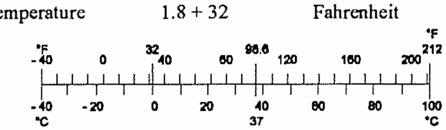
SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	millimeters squared	mm^2
ft^2	square feet	0.093	meters squared	m^2
yd^2	square yards	0.836	meters squared	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	kilometers squared	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	meters cubed	m^3
yd^3	cubic yards	0.765	meters cubed	m^3
NOTE: Volumes greater than 1000 L shall be shown in m^3.				
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams	Mg
		TEMPERATURE (exact)		
□F	Fahrenheit temperature	5(F-32)/9	Celsius temperature	□C

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	millimeters squared	0.0016	square inches	in^2
m^2	meters squared	10.764	square feet	ft^2
ha	hectares	2.47	acres	ac
km^2	kilometers squared	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	meters cubed	35.315	cubic feet	ft^3
m^3	meters cubed	1.308	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.205	pounds	lb
Mg	megagrams	1.102	short tons (2000 lb)	T
		TEMPERATURE (exact)		
□C	Celsius temperature	1.8 + 32	Fahrenheit	□F



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TERMS USED IN THIS REPORT

ANTI-ICING	The timely application of freeze point depressants (chemicals) to surface of the pavement to inhibit or weaken the bond between the ice and the pavement.
DEICING	An operation where a treatment of a deicer is applied to the top of an accumulation of snow, ice or frost that is bonded to the pavement surface.
LIGHT SNOW	Snowfall less that 12 mm (1/2 inch) per hour.
HEAVY SNOW	Snowfall more that 12 mm (1/2 inch) per hour.
PACK SNOW	Snow that has been compacted due to traffic action (**syn** = snow bottom, sheet snow).
LIGHT ICING	Ices formed without measurable precipitation. Freezing drizzle, freezing fog and "black" ice may be included in this category.
FREEZING RAIN	Ices formed from measurable precipitation.
SANDING MATERIALS	Crushed or natural minerals used to enhance traction (**syn** = abrasives, grit, sand).
CINDERS	Scoriaceous materials used as sanding material.
ROCK SALT	Sodium Chloride applied to the road in a solid form (**syn** = salt, road salt).
LIQUID CMA	Calcium magnesium acetate used as a 25% (by weight) solution for application to the roadway.
MAGNESIUM CHLORIDE	$MgCl_2$ in an aqueous solution 25% - 30% by weight (**syn** = mag chloride).
$MgCl_2$	See Magnesium Chloride.
PM_{10}	Airborne particles 10 microns or less in diameter (**syn** = fugitive dust, reentrained dust, aerosol dust).
RWIS	Road and weather information systems that provide real-time information on pavement temperatures, surface conditions and meteorological data.

EXECUTIVE SUMMARY

INTRODUCTION

Historically Oregon's snow and ice control strategies have relied on plowing, sanding and limited amounts of salt. Oregon has recently experienced severe winters and the traveling public is starting to expect a higher standard of road service and safety. In addition, airborne particulate and silting resulting from the use of sand is a growing concern.

In an effort to address these problems Oregon participated in the Federal Highway Administration's Test and Evaluation Program #28 (TE 028), "Anti-Icing Technology". A two-year study was developed to evaluate emerging technologies for snow and ice control, evaluate the feasibility of using these strategies, and examine their economic, environmental and operational impacts.

Conventional strategies using crushed aggregate, cinders, and sand cost between $9 and $38 per lane kilometer ($15 to $65 per lane mile).

Oregon's experience with sanding materials confirms the TE 028 findings of environmental problems related to the use of sanding materials. Oregon's DEQ showed that in some areas sanding materials contribute 10% to 25% of the total airborne particulate matter. Oregon's fish and wildlife agencies have identified siltation problems from sanding materials creating hazards for salmon, steelhead, and trout. The U. S. Forest Service is concerned about residual sanding materials choking out roadside vegetation. Even after clean up, 50% to 90% of the sanding material remains somewhere in the environment. Additionally, sanding materials recovered during clean up have been found to contain traces of heavy metals and petroleum residues. In the future, this might serve to classify this material as a hazardous waste. If this occurs, disposal costs will escalate because of the specialized handling requirements.

In view of the above, ODOT examined deicing/anti-icing strategies for this project based on the following criteria:

- the ability to use existing equipment as-is or with low cost modifications;
- the availability of chemicals already known to be effective deicing/anti-icing materials with low environmental impact;
- experience and information available from other state highway agencies to minimize the risk of failure on start-up,
- reduction of overall costs.

METHODOLOGY

Calcium magnesium acetate (CMA) and magnesium chloride (MgCl2) were selected as candidates for the study. Oregon Department of Environmental Quality reviewed these and had no objections to their use in the study.

This study focused on anti-icing. Anti-icing is the prevention of the strong bond between accumulated ice and snow with the pavement surface; using liquid chemicals and solid and liquid chemicals mixed with sand. Ten test sections representing the various climatic conditions throughout the state were selected. The sections included urban areas with airborne dust problems, mountain passes, and sections with personnel who had previous experience with deicing and anti-icing chemicals.

The equipment used in this study included liquid chemical spreaders, modified truck-mounted herbicide applicators, 500-gallon tanks on pickup trucks, 1,000-gallon slip-in units for larger trucks, along with conventional V-bottom, slip-in sanding units. To prepare the crews responsible, six to eight hours of training on the theory and practice of anti-icing with chemicals was provided.

As a part of this project and the TE 028 study, the Research and Public Affairs units from ODOT developed a statewide public relations campaign to explain the purpose, scope and impact of the deicing and anti-icing studies. This provided the public information about the use of alternative snow and ice control methods.

Application of the chemicals was relatively easy. Timing of the application was much more difficult due to the limited accuracy of site-specific weather information. The application time and the amount of chemicals applied were based on data from Road Weather Information Systems (RWIS). RWIS data fell far short of ideal in its ability to measure pavement temperatures.

The crews gained experience and confidence in chemical control of snow and ice. This confidence led to an aggressive approach to the deicing/anti-icing process. The capacity of the spreading equipment was critical. When crews attempted to treat more roadway than the equipment could reasonably cover, the results were poor. When insufficient chemical was spread, it diluted quickly and then refroze before the crews could apply more chemical.

Liquid $MgCl_2$ (magnesium chloride) and CMA (calcium magnesium acetate) were stored in above-ground tanks. Storage tanks with circulation systems performed better by minimizing settlement in the tanks and by maintaining a consistent, well-mixed product.

RESULTS

This study has shown that timely application of deicing/anti-icing chemicals can not only prevent the ice-pavement bond, but can also prevent accumulation of snow and ice on pavement surfaces. This is particularly true with light snows occurring at temperatures above -4°C (25°F). The pre-treatment of the pavement before a storm establishes a layer of chemical under the pack snow. As the temperatures increase, the chemical layer under the pack snow melts, allowing easy removal of snow.

Chemicals applied to existing ice or pack snow (deicing) is most effective when the temperatures are in the range of -4 to -2°C (25 to 28°F) and rising. However, this process requires significantly more chemical due to high levels of dilution during the top-down thaw.

Most maintenance crews using anti-icing procedures reported reduced sand usage. Economic analysis showed sanding practices to be 4 to 15 times more costly than $MgCl_2$ and from "equal to" to 4 times more expensive than CMA.

CONCLUSIONS AND RECOMMENDATIONS

CMA and $MgCl_2$ are cost-effective as anti-icing and deicing strategies. ODOT should adopt deicing and anti-icing strategies that use CMA or $MgCl_2$. These strategies should be developed on a section-by-section basis using the FHWA "Manual of Practice for an Effective Anti-icing Program".

The use of these alternative chemical strategies can significantly reduce the use of sand.

Liquid chemicals are significantly better than solid chemicals for anti-icing due to their greater flexibility in both application and timing. Liquid chemicals, unlike sanding materials, tend to stay on the pavement and are not displaced by traffic or wind.

In order to maximize the effectiveness of deicing/anti-icing chemicals, the capabilities of available equipment and the forecasted weather conditions should be considered when selecting the section for treatment and application parameters. Equipment that can apply the chemical precisely is essential for effective and efficient use of the chemicals. Crews applying the chemicals should have thorough training in the principles and concepts involved in the chemical control of snow and ice. ODOT should also implement an aggressive public information campaign. The campaign can have significant positive effects on the acceptance of alternative strategies.

**ALTERNATIVE SNOW AND ICE CONTROL METHODS
FIELD EVALUATION**

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1.0 INTRODUCTION

1.1 HISTORY

Oregon's first snow and ice control program utilized rock salt for maintaining a “bare pavement” policy. This was changed in 1978, when the traction device statute took effect, allowing the State to mandate use of chains on selected roadways. In order to obtain compliance with this new regulation the State had to turn to the use of snowplows, sanding materials and limits on the amount of snow and ice control chemicals used. This gave Oregon its current reputation as a "no-salt" state.

Oregon typically spends $12-$14 million for snow and ice removal each year. Severe winters, such as that of 1992/1993, raised questions from the public about prevailing snow and ice control methods. Newspaper articles, letters to the editor, and public comment indicated that the traveling public wanted a higher standard of winter maintenance service than that presently provided. This was due, in part, from people coming to Oregon from states that have “bare pavement policies”. These states use large amounts of chemical deicers, creating much higher expectations of winter maintenance services than long-time Oregon residents would typically have.

Oregon’s latest snow and ice control strategies were developed under the Strategic Highway Research Program (SHRP) from 1988 to 1993. The SHRP had a subprogram devoted to winter maintenance. This program defined “anti-icing” as “the timely application of chemical freeze point depressants to a pavement surface to inhibit or weaken the formation of the bond between the pavement and ice” *(Blackburn, 1994)*. SHRP found successful anti-icing is very dependent on incoming weather. In response, SHRP used field trials to evaluate “roadway weather information systems” (RWIS) and the amounts of chemicals needed to successfully combat various storm conditions.

1.2 RECENT DEVELOPMENTS

The Federal Highway Administration (FHWA) extended the SHRP field trials to 6 more states in their Test and Evaluation Program #28, “Anti-Icing Technology” (TE 028). The TE 028 project provided the critical background needed for Oregon’s successful participation in the FHWA’s program. This participation gave Oregon an opportunity to evaluate some of the latest strategies in the practice of snow and ice control.

Oregon’s current deicing/anti-icing strategies were no longer meeting the desires of the motoring public. Several areas in Oregon are experiencing problems in meeting the PM_{10} standards for air pollution. (The PM_{10} standard refers to airborne particles 10 microns or less in diameter.)

As a result, some maintenance units began to experiment with the use of aqueous magnesium chloride ($MgCl_2$), a liquid chemical used for deicing. However, this created its own problems. Concerns were raised by the Oregon Department of Transportation's Bridge Section regarding the corrosion potential of magnesium chloride. These and other recent developments in the technology and practice of snow and ice control coupled with increased environmental concerns about the use of sanding materials (abrasives) provided the focus for a comprehensive look at Oregon's snow and ice control strategies.

2.0 PRESENT METHODS

The Oregon Department of Transportation (ODOT) is presently divided into 5 geographic regions with 16 maintenance districts. The various maintenance districts have developed their own strategies to address the needed level of service for their roadways. These strategies rely principally on the use of mineral sanding materials (abrasives) for traction enhancement and on plowing during snow and ice events. The Portland districts indicate sanding is a secondary priority to the plowing of snow. During extreme weather conditions, maintenance crews cover as much of their roadway as they can with their resources.

2.1 OPERATIONS

A survey questionnaire about sanding practices was sent to all ODOT maintenance sections to establish current levels of use and practice. The definitions of weather conditions used in the survey and in this study are as follows:

- Light Icing: Includes freezing fog and "black" ice. This includes ice formed without measurable precipitation. Freezing drizzle may be included in this category.
- Freezing Rain: Ice formed from measurable precipitation.
- Light Snow: Snowfall less than 12 mm (1/2 inch) per hour.
- Heavy Snow: Snowfall more than 12 mm (1/2 inch) per hour.

The responses from the maintenance sections showed that Oregon uses three kinds of sanding materials: crushed aggregate, scoriaceous volcanic rock (cinders), and naturally occurring alluvial sand deposits. Table 2.1 shows the sanding material gradations reported in the survey. Characteristics, costs and problems reported with the different aggregates are shown in Table 2.2.

Table 2.1 - Sanding Material Gradations

Nominal Gradation		Cinders	Crushed Aggregate	Natural Sand
1.6 mm - 0	(#10 - 0")		X	X
6 mm - 0	(1/4" - 0")		X	
6 mm - 1.6 mm	(#10" - 1/4)		X	
10 mm - 0	(3/8" - 0")	X	X	
10 mm - 1.6 mm	(#10 - "3/8")	X	X	
10 mm - 6 mm	(3/8" - 1/4")	X		
13 mm - 0	(1/2" - 0")	X	X	
16 mm - 0	(5/8" - 0")	X		

Table 2.2 Sanding Material Sources and Characteristics

Source	Cost m^3	Cost yd^3	Characteristics	Problems
Crushed Aggregate Crushed and screened to size from natural rock sources	$10 - $20	$8 - $16	Angular to sub-angular particles Retains moisture.	May freeze in stockpiles and sanders. Sources hard to develop due to environmental concerns
Cinders Scoriaceous materials, sometimes crushed and screened to size. Mined from local deposits	$5 to $13	$4 to $10	Lightweight, porous, rounded particles. Free draining.	Rarely freezes in stockpiles and sanders Sources hard to develop due to environmental concerns
Natural Sand Natural sand from alluvial deposits, screened to size	$8	$6	Sub-angular to rounded particles. Retains moisture	Hard to find natural deposits that can meet gradation. May freeze in stockpiles and sanders

Further development of sources of sanding materials will be economically and practically impossible due to environmental zoning restrictions on the mining sites. Recycled sand (available only in the Portland area) costs about $13 per cubic meter ($10 per cubic yard).

A variety of equipment is used to apply sanding materials including tailgate spreaders, hopper sanders, and tag-along sanders. The type of equipment used depends on the location of the section and what equipment was assigned to that section. In addition, application rates varied significantly due to local crew preferences. Table 2.3 breaks down the average application rates for all 16 maintenance districts by the type of roadway facility and the weather condition being fought.

Table 2.3 Average Sanding Rates
m^3 per 3.5 m lane km *(cubic yards per 12' lane mile)*

	Weather Event			
Facility Type	**Light Icing**	**Freezing Rain**	**Light Snow**	**Heavy Snow**
Freeway	0.4 *(0.9)*	1.1 *(2.3)*	0.7 *(1.5)*	0.7 *(1.5)*
Primary	0.5 *(1.0)*	0.8 *(1.8)*	0.6 *(1.3)*	0.6 *(1.3)*
Secondary	0.5 *(1.0)*	0.7 *(1.5)*	0.5 *(1.0)*	0.5 *(1.0)*
Average	0.5 *(1.0)*	1.0 *(2.0)*	0.6 *(1.3)*	0.6 *(1.3)*

When sanding materials are used, clean-up is required to meet safety and operational concerns. Clean-up can be achieved by a variety of sweeping, pickup and disposal operations. These may include sweeping or blading the material off the edge of the pavement to reshaping the ditch slopes. The debris and sanding materials retrieved are usually placed in roadside fills. However, some cities, such as Portland, have implemented a recycling program for sanding materials. Table 2.4 shows the average costs of roadway clean up by shoulder type and facility type. Average clean up costs range from \$3 to \$26 per cubic meter (\$2 to \$20 per cubic yd) of applied material, averaging about \$8 per cubic meter (\$6 per cubic yd.). These costs can range up to \$70 per cubic meter for high traffic volume facilities.

Table 2.4 - Average Sanding Clean-up Costs
per m^3 of applied sand *(per y^3 of applied sand)*

Facility Type	Shoulder Type			
	Concrete Barrier	**Guardrail**	**Curbed**	**Gravel or Dirt**
Freeway	\$26 *(\$20)*	\$20 *(\$15)*	\$20 *(\$15)*	\$3 *(\$2)*
Primary	\$26 *(\$20)*	\$13 *(\$10)*	\$13 *(\$10)*	\$3 *(\$2)*
Secondary	\$25 *(\$19)*	\$10 *(\$8)*	\$13 *(\$10)*	\$3 *(\$2)*
Average	\$26 *(\$20)*	\$16 *(\$13)*	\$16 *(\$12)*	\$3 *(\$2)*

2.2 ENVIRONMENTAL ISSUES

The Intermodal Surface Transportation Efficiency Act (ISTEA) ties highway funding to a State's compliance with the Federal Air Quality Act of 1976 commonly referred to as the Clean Air Act (CAA). A central component of the CAA is the PM_{10} standard. Oregon's Department of Environmental Quality (ODEQ) has determined that dust from the use of sanding material may be a source of PM_{10} airborne particulate pollution.

Klamath Falls, LaGrande, Lakeview and Oakridge have been identified as air quality "non-attainment" areas. Under the CAA, this means that these cities have exceeded the PM_{10} standard. This is thought to be partly due to dust particles generated from degrading sanding materials. For example, volcanic cinder sanding are friable. This material becomes part of the PM_{10} measurement for a given area.

Typical analysis of PM_{10} materials by the Oregon DEQ has shown road dust is 10% to 25% of total emissions. Air quality studies done by other states, such as the one done at the University of Colorado at Denver (UCD), show street sand may contribute as much as 45% of the PM_{10} particles (*Chang et al., 1994)*. UCD attributed the higher contribution to PM_{10} emissions to the higher use of volcanic cinder sanding materials in the Denver area.

In some instances, sanding materials recovered from roadways have been found to contain substances that, conceivably, could qualify these materials as hazardous. Table 2.5 shows a typical analysis of street sweepings as reported in the UCD study (*Chang et al., 1994*). The level of contaminants found in the sanding material appears to be correlated to the delay in clean up. This delay may create different disposal needs. For example, the Washington DOT has disposed of sanding material picked up along Washington's roadway at the Arlington, Oregon "Hazardous Materials Disposal Site" because of substances found in the sanding materials.

Table 2.5 - Average Concentrations of Heavy Metals in Street Sweepings

Heavy Metal	Street Sweeping mg/kg
Cadmium	3.4
Chromium	211
Copper	104
Iron	22000
Lead	1810
Manganese	418
Nickel	35
Zinc	370

Source: US Environmental Protection Agency

There is also a need to be concerned with water quality problems caused by deicing/anti-icing strategies. Many states are reducing their use of sodium chloride (road salt) due to water quality problems. These problems are primarily related to ground and surface water contamination by salt-laden runoff from roadways. However, the use of sand and other chemicals also present a problem to waste water discharge management. These add to the sediment load and change the chemical balance of the discharge, which could affect wetlands. Hazardous contaminants, such as those identified in Table 2.5, can leach out of the sand and, through runoff, end up in the water (*Chang et al., 1994*). Additionally, the U.S. Forest Service has identified siltation from sanding materials as a problem for anadromous salmon and steelhead runs as well as for other resident salmonids.

The U.S. Forest Service is also concerned about esthetic ramifications of snow and ice control methods, including sanding materials remaining along the roadside and the death of roadside vegetation. Soils may be altered by the application of sanding materials and vegetation can sometimes be smothered. It was noted by maintenance crews that after clean-up, 50% - 90% of the applied sand is still somewhere in the environment.

2.3 OTHER ECONOMIC COSTS

In addition to the various costs described in Tables 2.2 and 2.4, many other costs can be associated either directly or indirectly with the use of sanding materials. The delay cost for commercial vehicles is estimated by the trucking industry to be $60 per hour (Wilhelm, 1993). Delay is particularly critical to industries that use "just-in-time" deliveries instead of maintaining large inventories of parts.

Furthermore, sanding operations are a source of complaints and claims against ODOT. Complaints range from cracked windshields to loose sand on dry roadways. These sanding and sweeping claims can amount to approximately $50,000 per year (DAS Risk Management, 1993).

2.4 SAFETY AND OTHER ISSUES ASSOCIATED WITH SANDING MATERIALS

2.4.1 SAFETY

Motorist safety is the major goal of winter maintenance activities. Any improvement in safety, either perceived and/or real, reflects positively on the agency. Experience has shown that sanding materials have different levels of effectiveness in various winter conditions.

For example, preliminary results of the TE 028 project show that applying sand to glare or sheet ice resulted in little or no improvement in traction or surface friction. In addition, a study for the Ontario Ministry of Transportation *(Comfort, 1994)* states, "the tests thus indicate that little improvement in surface friction resulted from applications of the sand on bare ice." The lack of improvement is due to the inability of the ice to hold the sand particles on the roadway. Wind or turbulence from traffic displaces the material, thereby limiting its effectiveness. Drivers' perceptions of increased safety may result in increased speed, which may not be justified by actual increases in traction.

Sanding is more effective on packed snow than on ice. Sand particles are able to partially embed themselves into it. This keeps the sanding material on the road and provides increased surface friction.

Another factor in sanding materials' effectiveness is the gradation of the material. A study by the Cold Regions Research Engineering Lab (CRREL) indicates Oregon's present sanding material could be improved to increase traction by modifying the gradation to add more fine particles (*Blaisdell and Borland, 1992*).

2.4.2 OTHER ISSUES

Once the ice or snow melts, the sanding materials create some problems. Sanding material on the pavement is a hazard to both bicyclists and to motorists. Unexpected patches of loose materials on the pavement surface can cause a loss of control or damaged property.

Sanding materials also affect the road surface. In some areas, the fine particles generated by sanding materials are clogging the pores of open-grade (AC) asphalt concrete mixes. This is not a universal problem. For example, mountain passes using cinders known to create a large amount of fine particles have not reported clogging problems.

Sanding materials present a number of problems on bridges as well. The materials clog the deck drains, causing water to pool on the surface, thereby creating hazardous surface conditions. Some bridge ramps in the Portland area are not sanded because of known problems with clogging. In addition, sanding materials removed from expansion joints must be physically removed from the site rather than thrown over the side of the bridge.

3.0 ALTERNATIVE METHODS

3.1 CHEMICAL SELECTION

As a part of the TE 028 program, ODOT evaluated various deicing and anti-icing strategies. The following criteria were developed to determine which strategies should be used for the present study:

- Existing equipment, either as-is or with low-cost modifications, should be utilized
- Chemicals known to be effective, yet which have low environmental impact must be available
- Experience and information must be available from other state highway agencies

After reviewing information about the operational and environmental characteristics of a variety of chemicals, two were selected. The Oregon Department of Environmental Quality (ODEQ) reviewed the selected chemicals and had no objections to their use. Neither chemical requires an application permit from the state or federal government.

One of the chemicals selected was liquid magnesium chloride with a corrosion inhibitor. It was chosen for its accessibility and apparent effectiveness. There was a sufficient amount of available literature to indicate that $MgCl_2$ has a low environmental impact. However, magnesium chloride has corrosive properties, and may impact structures.

The other chemical selected for this study was calcium magnesium acetate. CMA was chosen for its overall effectiveness, its low environmental impact, and because it is not corrosive. Another advantage of this chemical is that liquid CMA storage facilities do not require secondary containment.

3.2 STRATEGY DEVELOPMENT

The strategies selected for this study focused primarily on anti-icing with liquids. Specific strategies were developed for each location with this goal in mind. Adherence to the specific strategy is necessary for optimum success in anti-icing.

Anti-icing is defined as the timely application of freeze-point depressant chemicals to the surface of the pavement to inhibit or weaken the bond between ice and the pavement. This bond is extremely strong, sometimes stronger than the pavement itself.

Deicing, on the other hand, is the application of chemicals to melt existing ice that is already bonded to the pavement surface (*Blackburn, 1994*).

Anti-icing and deicing chemicals are generally applied in one of three ways. Liquid chemicals, or brines, are sprayed on the pavement. Solid chemicals are applied in a dry, solid state using conventional spreader equipment. Sometimes liquid chemicals are used to wet either sanding materials or solid chemicals prior to or during the roadway application. This procedure is referred to as pre-wetting.

Chemicals can be used in a variety of ways including mixing the deicing and anti-icing chemicals with sanding materials. This is not a new concept in that salt has been traditionally added to sand to keep it from freezing in the sander and the stockpile.

The SHRP H-208A project demonstrated that liquid chemicals can be used successfully in anti-icing strategies (*Blackburn, 1994*). This was confirmed by ODOT personnel who were experimenting with liquid chemical application strategies at the same time as the nine states involved in the SHRP project. Other SHRP investigations reported that the application of liquid anti-icers caused a rapid rise in surface friction values (*Alger et al., 1993*).

In Minnesota, the use of sand was reduced by 40% or more because the sand was less likely to be blown off the roadway when it was pre-wetted with chemicals (*Keranen, 1994*). In cases where ice was already present, the presence of the chemical caused the sand to partially embed itself in the icy substrate, thus improving the retention of sand on the surface.

Experiences in the TE 028 project in the Portland area showed that pre-wetting solid CMA with liquid CMA was a useful tactic on ice that had bonded to the pavement. Solid chemical mixed with a liquid chemical was also included in the SHRP study with some success (*Blackburn et al., 1994*). This mixture maintains a high concentration of the chemical on the pavement surface when there is significant frozen moisture present and during periods of heavy precipitation.

3.3 IMPLEMENTATION

3.3.1 SITE SELECTION

Oregon can be divided into seven geographic/climate regions as shown in Figure 3.1. Figure 3.2 shows the location of the evaluation areas selected for this study. Table 3.1 gives further climatological information regarding these seven areas.

Table 3.1 - Geographical and Climatological Regions in Oregon

Region	Low Temp. °C *(°F)* Avg.	Low Temp. °C *(°F)* Extreme	Elevation m *(feet)*	Daily Snow mm *(in)* Avg.	Daily Snow mm *(in)* Heavy	Traffic AADT* (1000's)
1. Coast and Coast Range	10 *(45)*	-12 *(10)*	0 - 600 *(0 - 2000)*	25 *(1)*	150 *(6)*	0.5 - 5
2. Willamette Valley	5 *(40)*	-15 *(5)*	0 - 450 *(0 - 1500)*	50 *(2)*	200 *(8)*	2 - 100
3. Southwestern	5 *(40)*	-15 *(5)*	150 - 1250 *(500 - 4000)*	50 *(2)*	300 *(12)*	0.5 - 40
4. Cascade Passes	-5 *(25)*	-24 *(-10)*	450 - 1600 *(1500-5500)*	150 *(6)*	600 *(24)*	1 - 3
5. Columbia Gorge	-1 *(30)*	-24 *(-10)*	0- 300 *(0 - 1000)*	25 *(1)*	300 *(12)*	3 - 30
6. Central Basin	-1 *(30)*	-28 *(-20)*	300 - 1250 *(1000-4000)*	50 *(2)*	150 *(6)*	0.5 - 10
7. Eastern Mountains	-5 *(25)*	-32 *(-25)*	450 - 1600 *(1500-5500)*	25 *(1)*	300 *(12)*	1 - 3

Source: OSU Atmospheric Sciences *Average Annual Daily Traffic

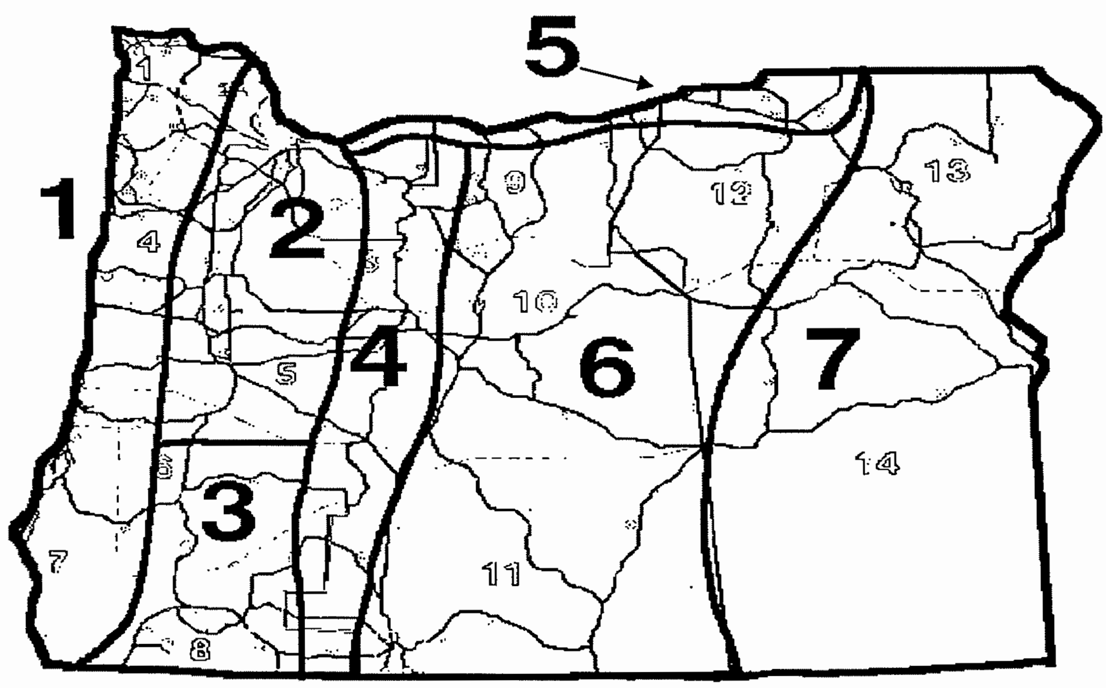

Figure 3.1 - Oregon Climate Zones

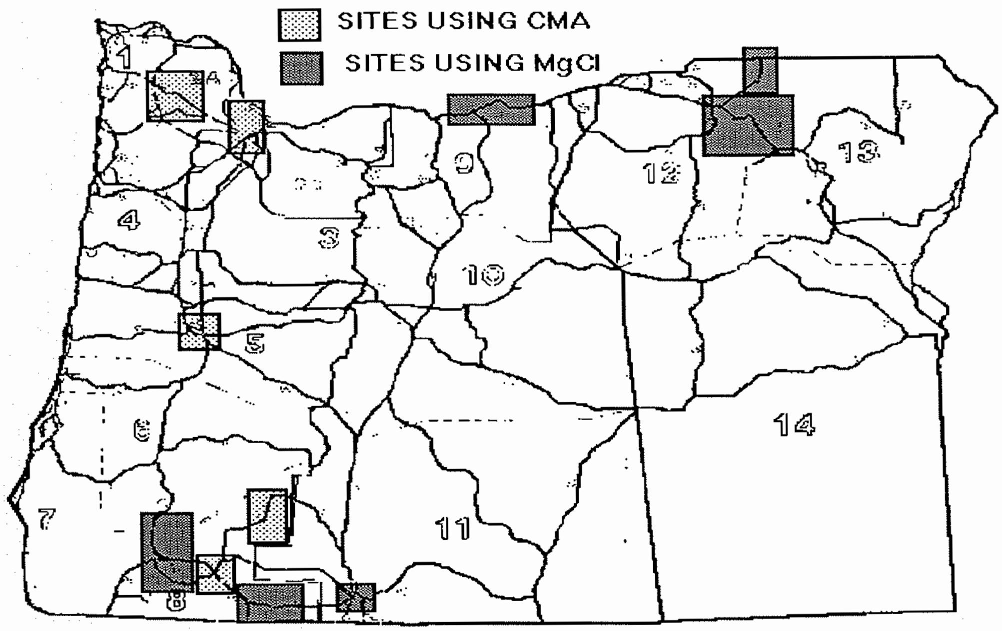

Figure 3.2 - Evaluation Sites

Table 3.2 - Evaluation Sections

Dist.	Section	Highway	Max. Elev. m *(ft)*	AADT (15)	Zone	Chemical
2A 2A	Manning Manning	Wilson River OR6 Sunset US26	610 *(2000)* 660 *(2200)*	4,000 7,000	1 1	CMA CMA
2A	Sylvan	Sunset US26	210 *(700)*	127,000	2	CMA
2A	Baldock	Terwilliger I-5	200 *(650)*	105,000	2	CMA
2B	N. Portland	I-5 & I-405	60 *(200)*	80,000	2	CMA
5 5 5	N. Eugene N. Eugene N. Eugene	I -5 I-105 Beltline Road	90 *(300)* 90 *(300)* 90 *(300)*	40,000 50,000 25,000	2 2 2	CMA CMA CMA
8 8	Ashland Ashland	Siskiyou Pass I-5 Green Springs OR66	1220 *(4000)* 1550 *(5000)*	13,000 4,000	3 4	$MgCl_2$ CMA $MgCl_2$
8 8	Central Point Central Point	Jacksonville OR238 I - 5	760 *(2500)* 360 *(1200)*	6,500 38,000	3 3	$MgCl_2$ CMA
8 8	Grants Pass Grants Pass	Redwood US199 I-5	660 *(2200)* 915 *(3000)*	7,000 17,000	3 3	$MgCl_2$ $MgCl_2$
8	Prospect	Crater Lake OR62	1220 *(4000)*	4,000	4	CMA
9 9	Arlington Arlington	I-84 US 97	60 *(200)* 610 *(2000)*	9,000 2,000	5 6	$MgCl_2$ $MgCl_2$
11	Klamath Falls	US 97, OR 140, OR 62 & OR 39	1220 *(4000)*	5,000	6	$MgCl_2$
12 12	Pendleton Pendleton	Milton Freewater OR11 Pendleton Area	325 *(1300)* 305 *(1000)*	10,000 9,000	5 5	$MgCl_2$ $MgCl_2$
12	Meacham	I-84	1515 *(5000)*	8,000	7	$MgCl_2$

*Average Annual Daily Traffic

3.2.1 TRAINING AND EQUIPMENT

After selecting the test sites, the responsible crews were given at least four hours of initial training, followed by two to four hours of refresher training. This training covered the theory and practice of anti-icing with chemicals. ODOT's Research Unit provided significant assistance in problem solving and passing on the latest information from other states and countries. In some cases, assistance was also provided by personnel from Washington DOT, FHWA, the Cold

Regions Research and Engineering Laboratory (CRREL), as well as the chemical vendors themselves.

Liquid chemical spreaders used in Arlington, Moro and North Portland sections were purchased from Spray Center Electronics of Spokane, Washington, and Epoke of Denmark. These units were very effective because they could control ground speed and application rate.

Pendleton, Ashland, and Manning used modified truck-mounted Norstar herbicide applicators which consisted of 1,000-gallon tanks and control systems. These units were modified in the Salem Fabrication Shop by adding a separate pumping system and spreader bar to handle the chemicals. These units had some limitations. The maintenance crews were unable to precisely control the application rate of the chemical because the add-on system was not directly controlled from the ground speed unit.

The other areas used equipment of 500-gallon tanks on pickup trucks built in the maintenance section shop or 1,000-gallon slip-in units fabricated in the Salem shops. These units were not as accurate as the commercially built spreaders. These shop-made machines are very limited in their ability to apply precise amounts of chemical to the roadway due to lack of ground speed application controls. Conventional V-bottom, slip-in sanding units were used to apply chemical-sand mixes.

Many maintenance crews ran into some equipment difficulties when attempting to implement the test strategies. Spray bars were not adjustable for height, and spray nozzles sometimes became clogged. Additionally, chemical application equipment was difficult to load.

3.3.3 PUBLICITY

As a part of this study and the FHWA TE 028 study, ODOT Research and Public Affairs Units developed a statewide public relations campaign to explain the purpose and scope of both studies. This provided the public an opportunity to obtain information and ask questions concerning the use of chemicals for snow and ice control.

A press conference was held in November of 1993, followed by numerous interviews and press releases to disseminate information as the studies progressed. Crew members and research staff also made themselves available for interviews. In addition, presentations were given to various city, county and state officials.

This campaign was successful in informing the motoring public of what was happening and what to expect in the test areas. The lack of negative comments from the press and public when alternative strategies were not completely successful reflected the success of the campaign.

3.3.4 ROAD WEATHER INFORMATION SYSTEMS

A critical factor for the successful use of deicing/anti-icing chemicals is the ability to accurately predict the weather. Oregon had few Road Weather Information Systems (RWIS) which were designed to accurately monitor the weather at specific points. The RWIS central processing unit (CPU) in the Portland area hosted the Quartz Creek (US 26) and the Fremont Bridge (I-405) remote processing units (RPU), which were upgraded with software and new sensors. District 2A, 2B, Manning station, and the North Portland station had direct access to the RWIS system.

The upgrades included SCAN*PLUS© software which gives the user a suite of color graphic programs to visualize the incoming RWIS data in real-time. An overlaying map shows the sensor locations. Data of particular importance is highlighted. The program is also capable of graphically representing data trends and history.

The maintenance crews reported that the new software and CPU improvements made the RWIS information easier to understand. The long-term history page was useful for planning strategies for chemical application. These history pages also allowed post-storm comparisons between the crews' perceptions of weather conditions and actual ones.

The evaluation of the upgraded RWIS hardware and software were positive, stimulating interest in expanding the number of sites statewide.

4.0 OPERATIONAL EVALUATION

Pre-treatment of the pavement before a storm establishes a layer of chemical under a snow pack. As the pavement warms, the chemical layer undercuts the packed snow. The pack, which has not bonded to the pavement, is easily removed, saving time and money. Traffic also helps break up the pack. Crews in the mountain passes, such as the Siskiyou, found anti-icing to be a very effective strategy.

Chemicals can also be applied to existing ice or pack snow. While this can be an effective strategy when the temperatures are in the range of -4° to -2° C (25° to 28° F) and rising, more chemicals are needed due to dilution of the chemicals. The North Portland crew successfully used solid CMA in combination with liquid CMA to remove an accumulation of ice on I-5 during the study.

Many different considerations were taken into account when evaluating the performance of deicing and anti-icing strategies. These included the application rates of the chemicals, the effects on snow and ice control, and the effect on the level of service to the commuter. Appendices A and B contain summaries of post-season interviews with the test crews.

4.1 CHEMICAL APPLICATION

Application was relatively simple. However, the timing of the applications was much more difficult to manage. At times, some of the maintenance crews waited until ice was forming before they applied the chemical. This affected the chemicals' effectiveness, and was contrary to the anti-icing strategy.

The limited accuracy of detailed, site-specific weather information made precise timing of applications difficult. In those sections that had direct access to road weather information systems (RWIS), decisions were more accurate and activities were better matched to the weather conditions. However, even in the areas where RWIS data was available, the micro-forecast capabilities fell far short of ideal.

The ease and accuracy of chemical applications with the new equipment was a significant factor in overall success. The capability of the spreading equipment to precisely apply chemicals at varying rates to match vehicle speeds gave the crews much more confidence in the chemical control of snow and ice. This confidence led to an aggressive approach to the process.

Problems occurred when crews attempted to treat more roadway than the equipment could reasonably cover, which resulted in an inability to maintain effective working concentrations of chemical on the pavement surface.

When solid CMA was combined with sand (one part solid CMA to two parts sand, by volume), the loads had to be used within an hour or the chemical tended to cake and clog the sander. In general, crews that had some experience with the application of solid chemicals in the past thought the liquids were easier than the sand-chemical mixtures to control and apply. Liquid applications also tended to remain on the roadway. Solid applications were susceptible to scattering by traffic and wind.

4.2 CHEMICAL STORAGE

High-density polyethylene (HDP) tanks were preferred due to their low cost and corrosion resistance. Chemicals stored in aboveground tanks with circulation systems had the fewest problems.

Mild or stainless steel tanks used for storing $MgCl_2$ showed some corrosion. In addition, $MgCl_2$ left varying amounts of residue in the bottom of the tanks. The residue was crystallized $MgCl_2$, $MgSO_4$, and/or lignin sulfonate depending on the brand of $MgCl_2$. Also, $MgCl_2$ tanks require secondary containment.

Dry CMA was stored in a covered sand shed with a dry area to prevent caking.

CMA was successfully liquefied in the truck tanks at a cost of about $0.24 per liter ($0.90 per gallon). Table 4.1 shows proportions for a 25% solution in both metric and English measurements. Systems with large piping and a heavy-duty pump capable of handling a slurry worked the best. Note that CMA requires no secondary containment.

Table 4.1: Mixing Table For CMA 25% Solution

WATER		WATER		CMA		TOTAL		YIELD	
L	*gal*	kg	*lb*	kg	*lb*	kg	*lb*	L	*gal*
189	*50*	189	*417*	71	*157*	260	*574*	227	*60*
379	*100*	379	*834*	144	*317*	523	*1148*	458	*121*
568	*150*	568	*1251*	213	*471*	781	*1722*	685	*181*
757	*200*	757	*1668*	285	*628*	1042	*2296*	912	*241*
946	*250*	946	*2085*	356	*785*	1302	*2870*	1143	*302*
1136	*300*	1136	*2503*	427	*942*	1563	*3445*	1370	*362*
1325	*350*	1325	*2920*	498	*1099*	1823	*4019*	1601	*423*
1514	*400*	1514	*3337*	570	*1256*	2084	*4593*	1828	*483*
1703	*450*	1703	*3754*	642	*1413*	2345	*5167*	2055	*543*
1893	*500*	1893	*4171*	713	*1570*	2606	*5741*	2286	*604*
2082	*550*	2082	*4588*	784	*1727*	2866	*6315*	2513	*664*
2271	*600*	2271	*5005*	855	*1884*	3126	*6889*	2740	*724*
2460	*650*	2460	*5422*	927	*2041*	3387	*7463*	2971	*785*
2650	*700*	2650	*5839*	998	*2198*	3648	*8037*	3198	*845*

4.3 EFFECTIVENESS

Most of the maintenance crews reported economic savings and reduced usage of sanding materials during the study. Accurate comparisons were difficult to obtain due to the variability between winters. Many of the sections also reported reduced labor costs. This reduction was primarily from reduced overtime, which does not translate into reductions of full time equivalencies. Indirect costs are reduced through a reduction in traffic delays.

The overall effectiveness of deicing/anti-icing techniques is also dependent on pavement type. The effects of a chemical application may be evident for up to ten (10) days on open graded pavements due to the high voids. On the other hand, Portland cement and dense graded pavements do not retain the chemical well.

Anti-icing was extremely effective in preventing the formation of ice under light icing conditions. However, the method was less effective when there was significant precipitation which could dilute the chemical. Heavy applications of liquid CMA can keep snow from packing on the road surface, providing sufficient traction to allow traffic to flow without the use of chains. For example, during a heavy snowfall in Portland, liquid CMA was applied at 129 liters per lane kilometer (55 gallons per lane mile) and again at 153 liters per lane kilometer (65 gallons per lane mile) forming a mixture resembling corn meal which would not pack. The application of solid CMA mixed with sand has shown varied results. This strategy worked better with light precipitation than with heavier snowfalls, and was only effective with sufficient moisture on the pavement to keep the sand/CMA mixture in place.

The chemical techniques may also reduce the number of accidents during winter storms. It was not possible to determine the rate of accident reduction with any reliability during this study. Typically, five to ten years of data is necessary to determine statistical significance. However, anecdotal information from the highway crews and local towing companies did indicate a reduction of accidents on the evaluation sections.

5.0 EXTERNAL EVALUATIONS

To properly assess the relative impacts of winter maintenance activities on the environment, the study information was presented to the Oregon Department of Environmental Quality (ODEQ) and the Federal Regional Interagency Executive Council (RIEC). These agencies were asked to assist ODOT in evaluating the environmental impact and corrosion caused by winter maintenance activities. These entities were chosen because they represent the widest spectrum of stakeholders when considering environmental impacts.

The REIC represents:

- Bureau of Indian Affairs
- Department of Fish and Wildlife
- Environmental Protection Agency
- US Forest Service
- Bureau of Land Management
- National Marine Fisheries
- National Park Service

RIEC has chartered an advisory committee representing state, local, tribal, and public interests. The committee's work on identifying possible environmental problems, to date, is shown in Appendix D.

5.1 ENVIRONMENTAL IMPACT

When considering the environmental effects of snow and ice control strategies, four areas of major concern are: air quality, water quality, plant life, and esthetics. Table 5.1 compares the major known impacts of various snow and ice control strategies examined in this study.

5.2 CORROSION

Further assistance was sought from Oregon State University to study the corrosiveness of various chemicals in the study. A contract was established with Oregon State University to develop a model of chloride diffusion which simulated the application of chloride-bearing deicing and anti-icing chemicals to bridge decks. Although the results of this work are not available at the time of this printing, they will be published as part of a future report, "Effect of Chloride Ion Migration on Cathodic Protection Systems."

Table 5.1 - Environmental Impact of Winter Maintenance Materials

Material	Air Quality	Water Quality	Plant Life	Esthetics
Sand - crushed	Causes problems with PM_{10} emissions.	Siltation in runoff poses a problem to streams. May carry absorbed heavy metals and hydrocarbons into stream water.	Tends to accumulate in roadside environment smothering plants.	Tends to accumulate on roadside. Quarrying is also a problem.
Sand - cinders	Degrades easily causing major problem with PM_{10} emissions.	Siltation in runoff poses a problem to streams. May carry absorbed heavy metals and hydrocarbons into stream water.	Tends to accumulate in roadside environment smothering plants.	Tends to accumulate on roadside. Quarrying is also a problem.
Road salt (NaCl)	Slight problem with dust.	Chloride accumulation in both ground and stream water is a problem to aquatic life.	Sodium and chloride are a problem to roadside vegetation.	Sodium in ground and stream water is an esthetic problem.
CMA	No known problems.	Biodegradation of CMA theoretically can reduce dissolved oxygen in shallow, unflushed receptors adjacent to the roadway. This effect has not been observed in field tests.	Possible mobilization of heavy metals in heavily contaminated soils. This effect has not been observed in field tests.	No known problems.
$MgCl_2$	No known problems.	Chloride accumulation in both ground and stream water is a problem to aquatic life.	Possible mobilization of heavy metals in heavily contaminated soils. This effect has not been observed in field tests. Chloride is a problem to roadside vegetation.	No known problems.

6.0 ECONOMIC EVALUATION

The economic evaluation of alternative snow and ice control methods can be expressed as a ratio of benefits to costs (B/C). A ratio greater than one indicates a net savings to the agency. This ratio will vary from section to section depending on local weather, and costs for materials and equipment. The benefits and costs are either direct, which can be easily measured, or identifiable indirect ones, which are not as easily quantified.

6.1 DIRECT COSTS

Direct costs of snow and ice control strategies include labor, materials, equipment, clean-up, and are normally based on costs per lane mile.

Labor costs can be broken into two categories: permanent labor costs (FTE's); and extra labor costs which include temporary labor and overtime. Despite the erratic nature of winter maintenance operations these costs per lane mile do not tend to vary dramatically from year to year.

Materials costs vary from section to section. This is due to the transportation costs associated with the materials. In 1994, CMA cost were roughly $908 to $953 per Mg ($825 to $875 a ton) in 20-ton delivered lots. Liquid CMA can be made at the maintenance shed for about $0.24 per liter ($0.90 per gallon), including labor. Liquid $MgCl_2$ is available at $0.08 to $0.12 per liter ($0.30 to $ 0.45 per gallon) which is delivered in 2,000 to 4,000 gallon lots.

Equipment costs and availability have changed dramatically over the past two years. For example, at the beginning of the study, a dedicated spreader capable of accurately applying liquid chemicals at highway speeds cost about $28,000. Costs for a similar unit today run from $4,000 for a retro-fitted unit on an existing tanker, to $17,000 for a multi-purpose slip-in unit that can also be used for landscape, road maintenance, and vegetation control tasks.

The annual cost of equipment per lane mile can be estimated by distributing the purchase price of the equipment over five years and dividing by 160 lane kilometers (100 lane miles). 160 lane kilometers (100 lane miles) is the amount of road that can reasonably be covered during an event by a single unit without over-extending the capacity of the equipment.

Cost of the equipment ÷ useful life (5 yrs.) ÷ 160 lane km/100 lane miles (6-1)

As an example, a $12,000 piece of equipment would calculate as shown in the following equation:

$12,000 ÷ 5 years ÷ 100 lane miles = $24.00/per year/per lane mi.
$12,000 ÷ 5 years ÷ 160 lane km = $15.00/per year/per lane km.

Clean-up costs can significantly affect the B/C ratio. Chemical control of snow and ice with liquids does not require clean up activities other than normal equipment washing. However, those sections using chemical/sand mixes still had to clean up the sand. Even then the amount of clean up was less than with traditional sanding due to the smaller volume of sand required.

6.2 INDIRECT COSTS

When calculating the benefits/costs ratio, indirect costs are quantified as much as possible and added to direct costs. Indirect costs are primarily related to the corrosion of vehicles and structures. Corrosion occurs only with the application of chloride-based chemicals.

Vehicle corrosion is a user cost which is the relative measure of atmospheric corrosion, as opposed to the corrosion of embedded steel. Relative atmospheric corrosion measurements can be obtained from Washington DOT corrosion tests. These tests show road salt (NaCl) at about 43 mils penetration per year (mpy), magnesium chlorides with corrosion inhibitors at 7 to 8 mpy, deionized water at 0 mpy, and CMA at –1mpy. These numbers are somewhat relative in that the test shows corrosion relative to deionized water. TRB, in 1991, determined that with the improvement of vehicle undercoatings, vehicle corrosion was no longer a significant problem *(TRB Special Report #235, Comparing Salt and Calcium Magnesium Acetate, 1991).*

There are also indirect costs related to bridge decks and other structural components affected by the use of chloride-bearing chemicals. These components include expansion joints, deck drains, and substructures where the chemicals leak through the cracks and joints. These components will need special maintenance over the life of the structure to mitigate any corrosion damage.

6.3 DIRECT BENEFITS

Direct benefits of the alternative strategies can be measured in terms of labor, cost of materials, and cost of clean-up.

It was assumed for purposes of this report that permanent labor costs are the same for both conventional and alternative methods. The short length of this study and the relative inexperience of the crews with alternative methods did not provide sufficient data to make significant conclusions regarding labor savings. Some supervisors thought that, in the future, the improvement of productivity could lead to a reduction in temporary labor and overtime. Crew supervisors in some states involved in the TE 028 project felt that the alternative methods would ultimately reduce labor costs.

Because of the variability in winters, it is hard to draw relevant comparisons from overall sand usage from year to year. To get an idea of how much sand is actually being saved, the crews were asked to compare the number of passes made by sanders in areas treated with chemicals to the number of passes made in areas that had not been treated. Analysis of crew reports showed that a single application of chemical could, depending on the type of precipitation, replace 3 to 6 applications of sand. In economic terms, depending upon the chemical cost and weather conditions, benefit/cost ratios ranged from 1:1 to 15:1. The results of this analysis are shown in Tables 6.1 and 6.2. These tables do not include the costs associated with storing the materials or the cost of the equipment. However, average clean-up costs for the sanding materials are included.

Table 6.1 - Comparative Costs - Liquid CMA vs. Sand

	Light Icing		Freezing Rain		Light Snow		Heavy Snow	
Liquid CMA								
Chemical cost \$ per liter *(gal)*	\$ 0.24	*(\$ 0.90)*	\$ 0.24	*(\$ 0.90)*	\$ 0.24	*(\$ 0.90)*	\$ 0.24	*(\$ 0.90)*
Rate l/ln/km *(gal/ln/mi)* [2]	59	*(25)*	117	*(50)*	94	*(40)*	106	*(45)*
# of applications [3]	1	*(1)*	2	*(2)*	2	*(2)*	2	*(2)*
Treatment cost \$ per lane km *(\$ per lane mi)*	\$14	*()*	\$56	*(\$90)*	\$45	*(\$72)*	\$51	*(\$81)*
Sand								
Sand cost \$ per m^3 *(\$ per yd^3)* [1]	\$ 0.80	*(\$16)*	\$20.80	*(\$16)*	\$20.80	*(\$16)*	\$20.80	*(\$16)*
Rate m^3/ln/km *(yd^3/ ln/mi)* [2]	0.48	*(1)*	0.95	*(2)*	0.60	*(1.25)*	0.60	*(1.25)*
# of applications [3]	6	*(6)*	3	*(3)*	5	*(5)*	5	*(5)*
Treatment cost \$ per lane km *(\$ per lane mi)*	\$60	*(\$96)*	\$59	*(\$96)*	\$62	*(\$100)*	\$62	*(\$100)*
Ratio liquid CMA to sanding	**4.29**		**1.05**		**1.38**		**1.22**	

Table 6.2 - Comparative Costs - Liquid $MgCl_2$ vs. Sand

	Light Icing		Freezing Rain		Light Snow		Heavy Snow	
Liquid $MgCl_2$								
Chemical cost \$ per liter *(\$ per gal)*	\$ 0.08	*(\$ 0.30)*	\$ 0.08	*(\$0.30)*	\$ 0.08	*(\$ 0.30)*	\$ 0.08	*(\$ 0.30)*
Ratio l/ln/km *(gal/ln/mi)* [2]	47	*(20)*	94	*(40)*	94	*(40)*	94	*(40)*
# of applications [3]	1	*(1)*	2	*(2)*	2	*(2)*	2	*(2)*
Treatment cost \$ per lane km *(\$ per lane mi)*	\$4	*(\$6)*	\$15	*(\$24)*	\$15	*(\$24)*	\$15	*(\$24)*
Sand								
Sand cost \$ per m^3 *(\$ per yd^3)* [1]	\$20.80	*(\$16)*	\$20.80	*(\$16)*	\$20.80	*(\$16)*	\$20.80	*(\$16)*
Rate m^3/ln/km *(yd^3/ ln/mi)* [2]	0.48	*(1)*	0.95	*(2)*	0.59	*(1.25)*	0.59	*(1.25)*
# of applications [3]	6	*(6)*	3	*(3)*	5	*(5)*	5	*(5)*
Treatment cost \$ per lane km *(lane mi)*	\$60	*(\$96)*	\$59	*(\$96)*	\$61	*(\$100)*	\$61	*(\$100)*
Ratio liquid $MgCl_2$ to sanding	**15.00**		**3.93**		**3.93**		**4.00**	

Notes: 1. Includes average clean up costs 2. From sanding survey data 3. Crew interviews

6.4 INDIRECT BENEFITS

Indirect benefits are those which can be identified, but not quantified. These include benefits to the environment, to traffic, clean-up and other general agency benefits.

Environmental benefits of the alternative strategies relate primarily to the reduction in the use of sand.

With lower PM_{10} emissions, an agency is more able to meet the requirements of the Federal Clean Air Act (CAA). This is important because CAA compliance is directly linked to federal aid for highways. Areas that are determined to be out of compliance with the PM10 emissions standards will not be able to increase roadway capacity without addressing the reduction of those emissions. By reducing the PM_{10} emissions associated with snow and ice control strategies, agriculture and other industries also indirectly benefit from the agency's efforts. If the agency is contributing towards fewer emissions, nonattainment areas may stand a better chance of achieving compliance with the CAA.

The reduction of sand and silt entering roadside streams has significant environmental benefits to the anadromous fisheries in Oregon. Siltation of spawning beds is known to be detrimental to these species. Any reduction in the siltation of the streambeds will benefit various fish species, such as the Umpqua River Sea Run Cutthroat Trout, which is listed as endangered. Furthermore, the reduction in roadside sand improves the esthetics and does increase the impact on vegetation. It may also reduce dust raised by vehicles during dry periods.

The benefits to traffic are detailed in two studies from Marquette University. (*Hanbali, 1992; Hanbali and Kuemmel, 1992*). These papers address accident reduction and user costs associated with using alternative deicing and anti-icing strategies. Kuemmel studied the use of chemicals for winter maintenance and concluded that for two-lane highways, "winter maintenance reduced traffic accident costs from 'before' to 'after' by 88% and reduced the average cost of an accident by 10%." For multi-lane divided freeways, he concluded that "winter maintenance reduced traffic accident costs from 'before' to 'after' by 85% and reduced the average cost of an accident by 30%."

Hanbali concluded in his 1994 study "the average direct savings to a two-lane highway user is 45 cents per vehicle kilometer of travel... The average direct savings to a multi-lane freeway user is 20 cents per vehicle kilometer of travel" (*Hanbali, 1994*). These figures translate into 73 cents per vehicle mile traveled (VMT) for a two-lane highway user and 32 cents per VMT for a multi-lane freeway user.

Reduced sanding can lessen the need for other types of clean-up activities not covered in the sanding survey. For example, bridge deck scupper drains, catch basins, and expansion joints all require cleaning when sand is used. Disposal of sanding materials may also be a problem in some areas. Another benefit is the reduction in sanding-related insurance claims and a lower number of claims paid. All claims, paid or unpaid, require staff time for investigation and disposition.

The image of the agency is also significantly improved when the public sees the agency as actively working to control snow and ice. The publicity campaign conducted during the study helped to further this image. The more positive image of the agency may also be contributed to the improved levels of service.

7.0 DECISION FACTORS

In the implementing of anti-icing in Oregon, the decision-makers seemed to regularly consider factors in all three areas shown in Tables 7.1, 7.2, and 7.3.

Decisions regarding the use of alternative chemical-based strategies for snow and ice control can be separated into three areas: global or agency level, operational or section level, and road segment level.

The costs and benefits are separated even further into two categories: measurable, or those that can be quantified; and non-measurable, or those that are observable but not readily quantifiable in economic terms.

Many of the non-measurable factors are customer-driven, but the measurable factors are more agency/operations-driven. As transportation agencies nationwide become more and more customer-driven, there will be many cases where the non-measurable factors will outweigh the measurable ones in the decision-making process.

When implementing alternative snow and ice control methods, global decision factors should be considered at the highest management levels of the agency (see Table 7.1). In most cases, important elements such as public perception, environmental and corrosion-related damage are generally not measurable in economic terms.

Table 7.1 - Global Decision Factors

Benefits		Costs	
Measurable	**Non Measurable (Unknown to date)**	**Measurable**	**Non Measurable (Unknown to date)**
Reduced vehicle operating cost	Public perception	Labor	Vehicle damage from corrosion
Reduced delay	Better community services availability	Equipment	Structural damage from deicing materials
Reduced accidents	Maintenance of business	Materials	
Reduced operation cost	Reduced environmental impact	Training	

After management's consideration of global decision factors, local maintenance sections should then consider operational decision factors such as the costs and delays associated with alternative snow and ice control methods (see Table 7.2). These factors are usually easier to measure in economic terms. A comprehensive evaluation of existing snow and ice control practices will assist maintenance crews in determining whether operational changes will have a significant benefit.

Factors such as level of service and traffic volume are also important. Consideration of these factors may override neutral or negative evaluations of the other decision factors mentioned in Table 7.1 and Table 7.2.

Table 7.2 Operational Decision Factors

Benefits		Costs	
Measurable	**Non Measurable (Unknown to date)**	**Measurable**	**Non Measurable (Unknown to date)**
Reduced vehicle operation cost	Public perception	Labor	Vehicle damage from corrosion
Reduced delay	Reduced environmental impact	Equipment	Structural damage from deicing materials
Reduced accidents		Materials	
Reduced operating cost		Training	
Reduced sanding-related costs			

The selection of chemicals is a site- or section-based decision. In many cases, a maintenance section will decide to use a single chemical that addresses the majority of needs and concerns for that particular area. Once again, the customer-related and generally non-measurable factors may override more measurable economic factors in making a decision about which chemical to apply.

Table 7.3 - Chemical Decision Factors

Benefits		Costs	
Measurable	**Non Measurable (Unknown to date)**	**Measurable**	**Non Measurable (Unknown to date)**
Reduced operating costs	Public perception	Labor	Vehicle damage from corrosion
	Reduced environmental impact	Equipment	Structural damage from deicing materials
		Materials	
		Training	

Other Factors

Climate	Geography	Environmental sensitivity	Structural sensitivity

8.0 RECOMMENDATIONS AND CONCLUSIONS

Anti-icing/deicing should be the first strategy considered when developing a plan for a winter storm. Chemicals can have significant effect in preventing the build-up or formation of ice or snow, or in undercutting existing ice or snow pack as soon as the temperature begins to rise. In order to accommodate problems in traffic flow, blockages, and known problem areas, deployment of personnel and equipment should be planned accordingly. Because equipment capacities and weather conditions, in combination, can limit the amount of roadway that can be treated without experiencing refreezing problems, the extent of the selected treatment areas should be carefully matched to the capabilities of available equipment and weather conditions.

The Oregon Department of Transportation should adopt deicing/anti-icing strategies using calcium magnesium acetate (CMA) or magnesium chloride ($MgCl_2$) as an alternative to traditional sanding methods and in concert with existing practices. Anti-icing/deicing can also significantly reduce the amount of sanding materials used, thereby reducing costs and negative effects on the environment.

The selection of which strategy to use should be done on a site-by-site basis When sections are developing strategies, many factors such as the availability of accurate weather information equipment and environmental and structural effects of the selected strategy need to be considered.

Presently, Oregon lacks sufficient RWIS to provide high-quality, short-term weather forecasting for all maintenance sections. Accurate weather information, while not essential, will maximize the effectiveness and cost-efficiency of anti-icing techniques. Oregon's RWIS should be expanded to provide real-time data to the operators. Other available should be used to supplement the RWIS system when trying to obtain an accurate weather forecast.

In addition, equipment that is capable of precisely applying the chemicals is necessary to realize the maximum benefit from the strategy. Spray bars on the equipment should be adjustable for height. Streamers (1/4-inch or larger) or quick-charge spray nozzles should be made standard for all equipment to reduce the risk of clogging and maintenance on the equipment. Finally, liquid chemical application equipment should be designed so that all loading can be accomplished with the operator standing on the ground.

Furthermore, all equipment and storage facilities should be capable of storing or spreading any of the available chemicals. They should include re-circulation and loading features that will prevent the chemical from becoming aerated and developing foam.

Liquid chemicals were found to be significantly better than solid chemicals for anti-icing/deicing strategies due to greater flexibility in their application and timing. Liquid chemicals can be applied well in advance of freezing conditions, leaving sufficient amounts of chemical on the pavement surface. Solid chemicals require the presence of moisture to avoid displacement due to traffic and wind.

CMA is more cost-effective if it is liquefied on-site.
Due to its corrosive properties, magnesium chloride should only be considered where the risks to pavement and structural corrosion are limited.

Using solid and liquid CMA in combination with traditional sanding strategies has been effective against freezing rain conditions and as a spot deicing strategy. While a mixture of solid CMA with sand is generally effective, it is less flexible in terms of the timing of the application when compared with chemicals alone. This is due to problems with keeping the sand/CMA mixture dry and the need to have precipitation present before application.

The mixing of liquid chemicals with sanding materials should be investigated further as an alternative strategy.

To further the success of these alternative methods, each maintenance crew should have a comprehensive understanding of the principles of chemical anti-icing/deicing procedures.

In addition, an aggressive public information campaign can have significant positive effects on the acceptance of alternative strategies by telling motorists what to expect, and by ensuring the quality of the information regarding environmental effects.

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APPENDIX A

CREW INTERVIEW SUMMARIES
WINTER 1993-1994

DISTRICT 2A - PORTLAND WEST HILLS AND MANNING

District 2A used solid and some liquid CMA for anti-icing purposes. This maintenance section, among others, felt that the "super sack" (one-ton sack which can easily be used with a forklift) packaging was very easy to work with and would recommend it for others.

Portland West Hills

The Baldock (I-5 Terwilliger area) and Sylvan (US 26 - Canyon Road) areas used solid CMA mixed with sanding material. The crews started with a 60% CMA:40% sand mixture by volume, blended in a stockpile. When the crew later shifted to a 50:50 mixture, no difference in performance was noted. Problems were noted when dry CMA was mixed with wet sand. This mixture tended to solidify in the sanders if the crews did not get it on the road within 30-45 minutes from the time of loading. Otherwise chipping was required to remove the compacted sand/CMA mixture from the sander.

The success of the two sections was limited due to a mild winter and problems with weather forecasting accuracy. The crews noted that the chemical did prevent refreeze and frosting for some time. They also reported that the chemical reacted more slowly than expected, but did leave half-dollar-size melted spots in the snow after an hour or so.

Baldock Maintenance Section was successful in keeping I-5 in a "wet pavement" condition during a late afternoon snow and evening freezing conditions. A single treatment with some follow-up yielded ice-free pavement through the next morning even though nighttime temperatures dropped to the 25°F to 28°F range. Adjacent areas during this time had ice on the pavement.

Manning - Coast Range

This section contains the Sunset (US 26) and Wilson River (OR 8) summits as well as the Vernonia (OR 47) area. The maintenance crews started with applications of dry CMA mixed with sand, reporting little benefit. When the crew started mixing liquid CMA in their spray units, problems with the seals developed, possibly due to residual grit from the mixing operation. A mixture comprised of 1,040 pounds of dry CMA to 500 gallons of water cut light ice effectively and lasted for 24 hours.

The maintenance crews in the Manning-Coast Range District felt they could effectively use the weather information provided by the RWIS at Quartz Creek and the forecast consultant to improve their operational decision making.

District 2A sections are working on the necessary equipment to make their own liquid CMA for the upcoming winter and will probably switch to the liquid product.

DISTRICT 2B - NORTH PORTLAND

The North Portland maintenance section personnel have provided valuable information. While the winter of 1993-94 was mild, two events (a freezing rain and a light snow) during the winter allowed the crews to evaluate the system as a whole. Field crews noted that both liquid and solid CMA worked effectively in the temperature range of the Portland area. Solid CMA, however, shows potential for providing higher concentrations quickly when used in freezing rain situations (150-200 lb./lane/mile).

The purchasing of CMA for delivery in time for the winter season was difficult due to problems associated with the bidding process. During the course of this study, the manufacturer established a distribution center in Vancouver, Washington due to the increasing demand for CMA.

Although temperature sensors on the Fremont Bridge were monitored via laptop computer, and a weather forecasting service was available, there was no warning of at least one major event (freezing rain). Quality, short-term, local weather forecasting is not yet available in the Portland area.

Initially, The Epoke SW2000 spreader experienced control system problems and was inoperative. Once it was finally operational, it worked well. It took a little over an hour to treat the 50 lane miles (80.5 kilometers) in the test area.

DISTRICT 8 - SISKIYOU PASS AND JACKSONVILLE HILL

In District 8, the chemical treatment worked well, appearing to provide significant savings in the cost of sanding material. Preliminary figures show as much as a 10:1 benefit/cost ratio when using magnesium chloride as a deicer chemical. Adequate equipment and more accurate weather forecasting would improve overall crew effectiveness and facilitate the timely applications of chemicals.

Siskiyou Boulevard – Using magnesuim chloride, Ashland required an application rate from 30 to 50 gallons/lane mile. The chemical was applied as soon as ice and/or frost started to form: Temperatures during this time were in the mid- to high- 20°F (-7°C) range. The application melted the existing ice, reduced frost on bare pavement, and lasted up to three days. The need for sanding materials in the area was reduced or eliminated.

Treatment for heavy frosts and ice on various structures was the main concern on Green Springs (OR66). Application rates, depending on weather conditions, were approximately 100 gallons for eight lane miles (29.4 liters per kilometer). Shady corners, where ice and frost frequently occur, were treated with the chemical. The treatment was effective for up to two days without any further applications, except in temperatures lower than 20°F (-7°C). Under these conditions, the corners would still refreeze despite the application of the chemical.

On the Siskiyou Pass (I-5), the chemical was applied on light-packed snow or on bare pavement as an anti-icing treatment. When a hole developed in the pack, the chemical, along with the movement of traffic, broke up the snow pack allowing the plows to remove the broken snow. In one instance, after the chemical was applied on the snow pack, a freezing rain occurred. The application of the chemical on top of snow pack may have exacerbated conditions, as the road became very slick and had to be closed. Sanding remedied the situation.

In this section, crews reported that vehicle accidents were reduced and traffic delays were kept to a minimum. It was noted that on the days when the chemical-spreading equipment was broken down, there was a perceived increase in accidents.

DISTRICT 11 - KLAMATH FALLS

Klamath Falls was one of the areas in this study that had a mandate to reduce the use of sanding materials due to PM_{10} emissions. In response, District 11 purchased "clean" sand at a price of $15 per yard compared with conventional cinder sand at $5 per yard. With respect to the PM_{10} problem, the district suggested that if a sweeper was available, the sanding material could be swept up after an occurrence. This would reduce the amount of sanding material left on the road to be broken down into air particulates.

District 11 applied magnesium chloride mainly to frost-covered road surfaces and icy bridges. A converted agriculture sprayer was used to apply the chemical to the roadway. Road surfaces included both open and dense-graded asphalt concrete. No difference was observed in performance of the chemical on these two types of surfaces.

Bare pavement could be maintained on South Sixth St. and Washburn Way when temperatures were in the mid to high 20°F (-7°C) range. When the application occurred between 3 and 4 a.m., the intersections would typically be bare within an hour after the sun started warming the pavement, thereby reducing traffic delay and accidents.

Problems occurred after one particular snow when the weather cleared and the temperature dropped to the low- 20°F (-7°C) range and below. The applied chemical had an adverse effect as the liquid chemical froze on the road. Sanding was required to remedy the situation.

A sludge build-up occurred inside the storage and applicator tanks throughout the winter. In addition, the chemical plugged up filters and nozzles causing further handling problems. The biggest complaint from maintenance crews was the need for suitable spray equipment to accomplish the desired effects - mainly a truck with a spray unit that was capable of applying the chemical at a controlled rate and a reasonable speed. Due to the lack of proper equipment and limited personnel, the night crew felt that the time needed to apply the chemical would have been better utilized by using conventional sanding methods which could cover a greater area in the same amount of time.

DISTRICT 12 - PENDLETON AND LAGRANDE

The chemical was applied to frost-covered roads or icy bridges with a North Star Spray unit. Treatments were found to be more successful if the temperatures were in the mid to high 20° F (-7°C) range. In this temperature range, bare pavement was established within one hour after application. Unlike traditional methods, the chemical along with traffic movement successfully caused snow pack to break up.

Proper concentration of the chemical on the roadway is one of the essential elements of successful treatment. Colder temperatures require both a higher concentration and greater quantity of chemical to establish the desired results. However, the liquid deicer is not recommended for use in temperatures below 20°F (-7°C).

Similar to Klamath Falls, problems were encountered with plugged spray nozzles and filters due to crystallization of the chemical. Another problem with the equipment was its inability to apply the chemical at a suitable pace. The slow application-vehicle speeds were a hindrance, especially on I-84. The maintenance crews did not notice any savings in the amount of sanding materials used.

APPENDIX B

CREW INTERVIEW SUMMARIES
WINTER 1994-1995

DISTRICT 2A - BALDOCK

CHEMICAL: Calcium Magnesium Acetate (CMA)

STRATEGY: Dry CMA mixed with sand

RESULTS: Fair with light snow.

PROBLEMS: Lack of proper storage.

SAVINGS: Money: None identified
Labor: None identified

COMMENT: Will continue to use the product.

DISTRICT 2A - MANNING

CHEMICAL: Calcium Magnesium Acetate (CMA)

STRATEGY: Liquid CMA (On-site liquefaction)

RESULTS: Poor when used to cut ice. No obvious effect on snow at 30 GPLM (gallons per lane mile).

PROBLEMS: Poor retention. Refreezing

SAVINGS: Money: None
Labor: None

STRATEGY: Dry CMA mixed with sand

RESULTS: Fair when applied before the storm at 250 lb./ln. mi.

PROBLEMS: None

SAVINGS: Money: Some (indeterminate)
Labor: Some (indeterminate)

COMMENT: We will continue to experiment with CMA under different application conditions. Perhaps we should try other anti-ice products as well. National Pollution Discharge Emission Standards (NPDES) regulations require that we apply less sanding materials in the future.

DISTRICT 2A - SYLVAN

CHEMICAL: Calcium Magnesium Acetate (CMA)

<u>STRATEGY: Dry CMA mixed with sand</u>

RESULTS: Spotty

PROBLEMS: Dry storage

SAVINGS: Money: None Identified
Labor: None Identified

COMMENT: Will continue to use product.

DISTRICT 2B - EAST PORTLAND

CHEMICAL: Calcium Magnesium Acetate (CMA)

<u>STRATEGY: Liquid CMA</u>

RESULTS: Good on light icing. Did not use on snow.

PROBLEMS: Lack of storage facilities.

SAVINGS: Money: Cheaper than ethylene glycol.
Labor: None identified

COMMENT: Budget reductions will make it difficult to expand operations.

DISTRICT 2B - NORTH PORTLAND

CHEMICAL: Calcium Magnesium Acetate (CMA)

STRATEGY: Liquid CMA (On-site liquefaction)

RESULTS: Effective against light icing at rates from 20 gal/ln/mi. and upward. Effective with pack snow if applied early and at high rates (60 - 120 GPLM). The snow developed a "corn meal" consistency and would not pack. Maintained traffic through an 8" snowfall.

PROBLEMS: Deployment of resources prior to storm. Poor timing on weather forecasts.

SAVINGS: Money: None identified
Labor: Some

STRATEGY: Dry CMA mixed with liquid CMA

RESULTS: Effective against existing ice. Technique was used to cut ice spots on the freeway at a temperature of 26°F.

PROBLEMS: None

SAVINGS: Money: None identified
Labor: Some

COMMENT: Will have to continue with the use of chemicals because we have shown the public that it can improve the situation.

DISTRICT 5 - NORTH EUGENE

CHEMICAL: Calcium Magnesium Acetate (CMA)

STRATEGY: Liquid CMA (On-site liquefaction)

RESULTS: Good results on light morning ices and freezing fog at 25-30 GPLM. Worked well on open-grade ("F") mixes as well as on structures.

PROBLEMS: Equipment lacks accurate control of application rates. Weather forecasting lacks accuracy needed to properly manage the process.

SAVINGS: Money: None identified
Labor: Some

COMMENT: Will continue and expand the use of chemicals. There will be savings when compared to sand.

DISTRICT 8 - ASHLAND/SISKIYOU PASS

CHEMICAL: Magnesium Chloride ($MgCl_2$) and Calcium Magnesium Acetate (CMA)

STRATEGY: Liquid $MgCl_2$

RESULTS: Good results on morning ices at 20-30 GPLM. Application prior to heavy storms enhances pack breakup. Recommend use before all storms. Greatly reduced use of sand and subsequent clean up.

PROBLEMS: Equipment lacks accurate control of application rates. Weather forecasting lacks accuracy needed to properly manage the process. Corrosive to equipment. Some problems with crystallization of $MgCl_2$.

SAVINGS: Money: Roughly 10:1 b/c ratio on light icing.
Labor: Some

STRATEGY: Liquid $MgCl_2$ mixed with sand

RESULTS: Works well as a tool to accelerate the breakup of pack snow.

PROBLEMS: Corrosive to equipment.

SAVINGS: Money: None identified
Labor: None identified

STRATEGY: Dry CMA mixed with sand

RESULTS: Works well as a tool to accelerate the breakup of pack snow.

PROBLEMS: None.

SAVINGS: Money: None identified
Labor: None identified

COMMENT: Works well and will expand operations as equipment and funding allow. Use of CMA requires dry storage.

DISTRICT 8 - CENTRAL POINT

CHEMICAL: Calcium Magnesium Acetate (CMA)

STRATEGY: Liquid CMA(On-site liquefaction)

RESULTS: Good results on both bridges and AC at 30-50 GPLM. Good results with open-graded mixes.

PROBLEMS: Equipment lacks accurate control of application rates. Weather forecasting lacks accuracy needed to properly manage the process.

SAVINGS: Money: Some
Labor: Some

COMMENT: Will continue to use chemicals.

DISTRICT 8 - GRANTS PASS

CHEMICAL: Magnesium Chloride ($MgCl_2$)

STRATEGY: Liquid $MgCl_2$

RESULTS: Good results on all types of pavement at 30-50 GPLM.

PROBLEMS: Equipment lacks accurate control of application rates. Weather forecasting lacks accuracy needed to properly manage the process. Corrosive to equipment.

SAVINGS: Money: Some
Labor: Some

COMMENT: Will continue to expand program. It is the way to go.

DISTRICT 8 - PROSPECT

CHEMICAL: Calcium Magnesium Acetate (CMA)

STRATEGY: Liquid CMA

RESULTS: Good results on all types of pavement at 30-50 GPLM.

PROBLEMS: Equipment lacks accurate control of application rates. Weather forecasting lacks accuracy needed to properly manage the process.

SAVINGS: Money: None identified due to limited use.
Labor: Some.

COMMENT: Will expand the program given the right equipment.

DISTRICT 9 - ARLINGTON

CHEMICAL: Magnesium Chloride ($MgCl_2$)

STRATEGY: Liquid $MgCl_2$

RESULTS: Fair on pack snow. Good on light icing. Excellent retention on open-graded mixes.

PROBLEMS: Storage and equipment delivery. Equipment corrosion. Weather forecasting lacks accuracy needed to properly manage the process. Corrosive to equipment.

SAVINGS: Money: B/C Ratio = about 10:1
Labor: Some

COMMENT: Works well, crew needs to better understand the scope of operations. Will definitely expand operations, budget permitting.

DISTRICT 11 - KLAMATH FALLS

CHEMICAL: Magnesium Chloride ($MgCl_2$)

STRATEGY: Liquid $MgCl_2$

RESULTS: Good on light icing. Limited with snow.

PROBLEMS: Refreezing after application. Equipment lacks accurate control of application rates. Weather forecasting lacks accuracy needed to properly manage the process. Corrosive to equipment. Some problems with crystallization of $MgCl_2$.

SAVINGS: Money: None
Labor: Requires someone to operate the equipment.

STRATEGY: Liquid $MgCl_2$ mixed with sand

RESULTS: Good in accelerating the breakup of packed snow.

PROBLEMS: Was unprepared for rapid melting.

SAVINGS: Money: None identified
Labor: None

COMMENT: The process works. Budget limitations will control future usage.

DISTRICT 12 - MILTON FREEWATER

CHEMICAL: Magnesium Chloride ($MgCl_2$)

STRATEGY: Liquid $MgCl_2$

RESULTS: Worked well with 36 GPLM at 20° on 1/2" pack snow after plowing.

PROBLEMS: Length of haul. Equipment lacks accurate control of application rates. Weather forecasting lacks accuracy needed to properly manage the process. Corrosive to equipment.

SAVINGS: Money: Some - replaced sand
Labor: Some

COMMENT: Would like to expand the program, budget permitting.

DISTRICT 12 - MEACHAM

CHEMICAL: Magnesium Chloride ($MgCl_2$)

STRATEGY: Liquid $MgCl_2$

RESULTS: Cut 2" snow pack with 80 GPLM (two passes) at 20° in about two hours.

PROBLEMS: Equipment lacks accurate control of application rates. Weather forecasting lacks accuracy needed to properly manage the process. Corrosive to equipment.

SAVINGS: Money: Some due to sanding reduction
Labor: None identified

STRATEGY: Sand pre-wet with Liquid $MgCl_2$

RESULTS: Excellent - removed 2" pack in about two hours; rate unknown.

PROBLEMS: Equipment lacks accurate control of application rates. Weather forecasting lacks accuracy needed to properly manage the process. Corrosive to equipment.

SAVINGS: Money: Some - sanding reduction
Labor: Some

COMMENT: Will expand the program given budget and equipment. Need to adjust storage points.

APPENDIX C

ENVIRONMENTAL STUDY COMMITTEE RECOMMENDATIONS

as of June 1996

MAINTAINING WATER QUALITY IN SNOW AND ICE OPERATIONS

GENERAL CONCERNS FOR ALL CHEMICALS AND SAND

APPLICATION: Snow and ice control chemicals and sand should be applied at the lowest application rate consistent with environmental, meteorological, traffic conditions, and customer needs. ***All personnel should be well trained in the use of chemicals and sand and their environmental effects.***

STORAGE: Sand and chemicals should be stored in such a manner as to minimize any contamination of surface or ground water. Care should be taken to prevent runoff from chemical tanks or chemical-treated stockpiles. Covered storage for dry chemicals is required.

CONTAMINANTS: Chemicals and sanding materials should have minimal levels of contaminants known to cause water quality problems. These include:

Arsenic	Barium	Cadmium	Chromium
Fluoride	Lead	Mercury	Nitrate
Selenium	CopperZinc	Phosphates	

INVENTORY: Inventory of all known runoff receptors should be taken using the criteria in the attached form to identify possible problems.

RECORDS: Careful records of chemical and sand applications are necessary to determine both short and long-range effects. The use of sand and chemicals should be continuously and accurately recorded including total amounts applied, application rates, materials used and location.

CRITICAL AREAS: Receptors that have any of the following attributes should be reviewed by ODOT environmental staff in consultation with appropriate natural resource agencies:

1. Spawning streams and those inhabited by protected aquatic species, especially salmon and trout;

2. Those receiving direct runoff from treated roads and highways where there would be less that 100:1 dilution;

3. Those where a large volume of highway runoff can directly reach small, poorly flushed, ponds, lakes and wetlands;

4. Those where the receiving water temperatures have warmed by the time highway runoff arrives;

5. Those areas where shallow ground water is overlain by very coarse and permeable soils; and,

Drywells, french drains or similar facilities which allow surface water access to underground aquifers.

MAINTAINING WATER QUALITY IN SNOW AND ICE OPERATIONS

SPECIFIC USAGE GUIDELINES:

SAND: The use of sanding materials or abrasives has a negative environmental impact. In addition to areas listed in the general notes, the following are some areas where careful review of the use of sand is needed:

1. Those with PM_{10}(dust)-related air quality problems;

2. Those near spawning streams, shallow lakes or ponds where siltation may occur;

3. Those which have sensitive or rare plants near the roadside; and,

4. Those where sand is considered to have a negative impact on esthetics.

CMA: The use of calcium magnesium acetate (CMA) and potassium acetate (KA) in the following areas should occur only after careful review which indicates that it is appropriate:

1. Those where receiving waters will not provide at least 100:1 dilution, or if the runoff occurs late in the season when the receiving waters may have warmed and protect aquatic species are present;

2. Those where a larger highway runoff volume can directly reach a small, shallow pond, lake or wetland, particularly if the receptor is ice-covered;

3. Those where there is no vegetation buffer between the road and the receiving waters, and the waters should be protected from oxygen depletion. Present ODOT standards for vegetation buffers is adequate;

4. Those known to have heavy metal concentrations, coarse soils overlying sensitive aquifers, or percolation devices such as french drains and drywells.

When CMA or KA is used in any of the above situations due to overriding concerns for highway safety, water quality should be carefully monitored for possible problems.

$MgCl_2$: The use of magnesium chloride ($MgCl_2$) in Oregon is presently limited to experimental use only.

ROADSIDE RECEPTOR INVENTORY

REGION __ DISTRICT ____ SECTION ______________________________ HIGHWAY # _____

SURVEYOR _________________________ Date _____________

MILE POINT		L or R	NOTES (SEE BACK OF FORM) NAME of Waterway, IF ANY	1 TYPE	2 DEPTH	3 FLOW	4 ICE y/n	5 BUFFER	6 COVER	7 SPECIES	COMMENT

NOTES and CODES

1. TYPE	2. DEPTH	3. FLOW	4. ICE	5. BUFFER	6. COVER	7. SPECIES
R=River **C**=Creek **S**=slough **L**=lake **P**=pond **D**=drywell **O**=other explain in comments	Depth, in feet (estimate)	**Winter flow:** **F=f**ast **M=m**edium **S=s**low **N=n**one	Does it ice over in winter? **Y** = yes **N** = no	How far from the edge of pavement to the water edge?	Type of ground cover between the pavement and receptor **B**=brush **T**=trees **G**=grass **M**=mixed **N**=none	**M**=migratory - cold water (salmon, steelhead & cutthroat) **N**= non-migratory-cold water (rainbow, cutthroat, brook, brown, lake, bull, dolly varden) **W**=warm water (bass, bluegill, crappy, catfish, perch) **O=other** (frogs, salamanders, toads, etc.)

COMMENTS: should include:

1. list known species present, include fish, reptiles, amphibians, and birds.
2. spawning stream?
3. any other plants or wildlife that may be affected by chemical use.
4. any other items of interest.

CRITICAL AREAS:

Receptors that have any of the following attributes should be reviewed by ODOT environmental staff in consultation with appropriate natural resource agencies:

1. spawning streams and those inhabited by protected aquatic species, especially salmon and trout ;
2. those receiving direct runoff from treated roads and highways where there would be less than 100:1 dilution;
3. those where a large volume of highway runoff can directly reach small, poorly flushed, ponds, lakes and wetlands;
4. those where the receiving water temperatures have warmed by the time highway runoff arrives;
5. those areas where shallow ground water is overlain by very coarse and permeable soils; and
6. drywells, french drains or similar facilities that allow surface water access to underground aquifers.