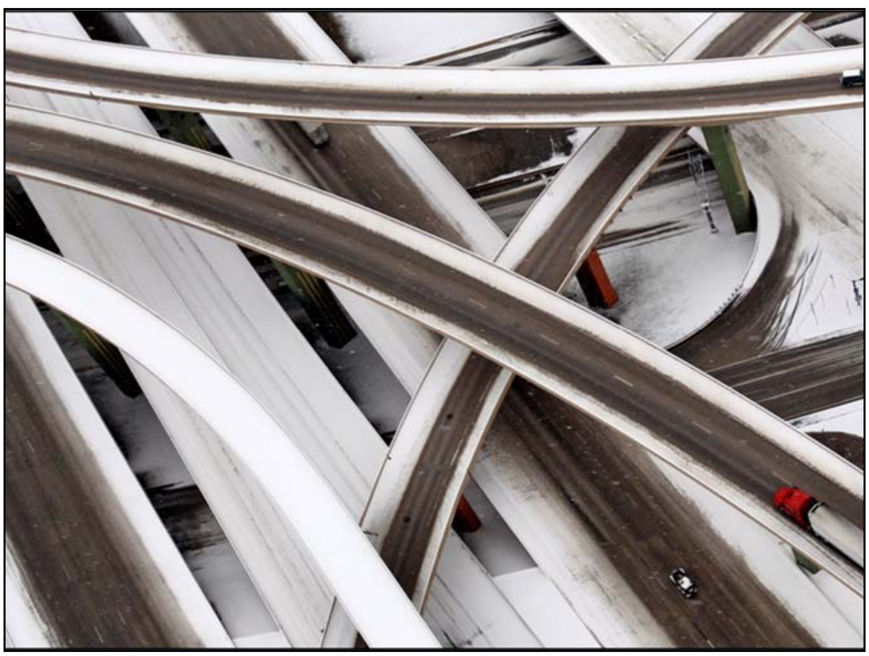
TEXAS DEPARTMENT OF TRANSPORTATION

GUIDELINE TO FACILITATE THE EVALUATION OF BRINES FOR WINTER ROADWAY MAINTENANCE OPERATIONS

RESEARCH PRODUCT 0-6793-P2

RESEARCH STUDY NO. 0-6793

Texas Department of Transportation



September 2017

Cover image: The 2011 Groundhog Day Blizzard, US75 at IH635 – the “High Five” intersection – Dallas District. Image Credit: LOUIS DELUCA, The Dallas Morning News, 07 Feb 2011. *Used with permission*

Guidelines to Facilitate the Evaluation of Brines for Winter Roadway Maintenance Operations

Research Product 0-6793-P2

study title
Snow and Ice Chemicals for Texas Roads
Research Study 0-6793-01

sponsored by
Texas Department of Transportation

in cooperation with
U.S. Department of Transportation
Federal Highway Administration

project manager
Kevin Pete

project advisory committee
Dennis Markwardt (lead advisor)
Darwin Lankford, Gilbert Jordan, Ted Moore, Wendy Simmons,
Lowell Choate, Lauren Garduno
Kevin Pruski, Paul Martinez, Mike Taylor, Billy Hester, Russell Luther

publication date
FINAL: September 19, 2017

authors
William D. Lawson, W. Andrew Jackson, Kenneth W. Rainwater,
Sanjaya Senadheera, Daan Liang

published by
TECHMRT: Multidisciplinary Research in Transportation
TEXAS TECH UNIVERSITY
Box 40123
Lubbock, TX 79409-1023

DISCLAIMER

PREFACE

This document presents guidelines to facilitate the evaluation of brines for winter weather roadway maintenance applications in Texas. The following topics are covered:

- An introduction to brines and to this winter weather research study
- Pre-approved brines including products on the PNS qualified products list, TxDOT pre-qualified products, pre-blended chemicals for anti-icing, other pre-blended brine products, and homemade salt brine
- Guidance on natural, manufactured, and oilfield brines
- Corrosion, corrosion inhibitors, environmental impacts
- Operational best practices

Expressed within the broader context of snow and ice operations, the guidance on brines presented herein is intended to help TxDOT maintenance professionals address the challenges of winter roadway maintenance in order to better provide safe and reliable transportation solutions for Texas.

TABLE OF CONTENTS

SECTION 1. INTRODUCTION

PURPOSE

This document presents guidelines to facilitate the evaluation of brines for winter weather roadway maintenance applications in Texas. Brines are used in anti-icing applications which typically consist of placing liquid snow and ice control chemicals onto the roadway surface prior to the storm event. These chemicals depress the freezing point and prevent snow and ice from forming a bond to the roadway surface. Anti-icing also helps by weakening the bonds that are formed and allowing for easier plowing of snow and ice. Because the chemical is applied prior to receiving snow and ice, anti-icing is termed a “proactive” winter weather maintenance strategy (Figure 1).

FIG 1. . Project 0-6793 evaluated the cost effectiveness of TxDOT’s typical snow and ice control chemicals as a function of intended use and location

RESEARCH STUDY 0-6793

In 2012, TxDOT sponsored a major winter weather research study, 0-6793, Snow and Ice Chemicals for Texas Roads. The objective of project 0-6793 was to quantify and qualify the relative merits of common snow and ice chemicals used in TxDOT maintenance operations (Figure 2). Project 0-6793 considered all aspects of TxDOT's typical snow and ice control chemicals including their effectiveness, availability, environmental concerns, environmental regulations, and impact on infrastructure durability (corrosion). Taking all of these considerations into account, the study further evaluated the cost effectiveness of each chemical as a function of intended use and location. Work tasks included a series of literature and best practice reviews supported by both lab testing and a field trial over three winter seasons. This guidance document is a research product based on the findings of project 0-6793.

FIG 2. Project 0-6793 considered all aspects of TxDOT's typical snow and ice control chemicals including their effectiveness, availability, environmental concerns, environmental regulations, and impact on infrastructure durability

ABOUT THIS DOCUMENT

This document presents guidelines to facilitate the evaluation of brines for winter weather roadway maintenance applications in Texas.

Section 1 provides an introduction to the usage of brines for snow and ice control and to research on this topic.

Section 2 presents a description of the different types of pre-approved brines which are available for TxDOT's winter weather roadway applications.

In Section 3, we provide guidance on natural brines, manufactured brines, and oilfield brines.

Section 4 discusses impacts of snow and ice chemicals relative to corrosion, the environment, and operational best practices.

Section 5 discusses operational best practices.

Section 6 presents conclusions from the research report.

SECTION 2. PRE-APPROVED BRINES

OVERVIEW

Brine is defined as any snow and ice chemical mixed with water to form a liquid solution. This solution is then sprayed onto the roadway (Figure 3). Brines can be made from several snow and ice control chemicals, and can be further classified as to the major chemical in the brine, such as a sodium chloride brine, magnesium chloride brine, etc. Natural brines and manufactured brines can possibly have a combination of chlorides. The eutectic point, the lowest temperature at the optimum solution concentration for a given chemical solution, is commonly used to determine the correct dry chemical to water ratio.

FIG 3. Anti-icing consists of placing liquid snow and ice control chemicals onto the roadway surface prior to the storm event

QUALIFIED SNOW AND ICE CONTROL CHEMICAL PRODUCTS

Snow and ice control chemicals, including brines, are available from multiple sources. The Pacific Northwest Snowfighters (PNS) is an association of transportation agencies dedicated to ensuring the safety of winter maintenance products through structured testing and evaluation. The PNS group has established procedures for testing deicing and anti-icing chemicals and maintains specifications that these products must meet to be considered for widespread use.

The PNS maintains a qualified product list of snow and ice control chemicals including corrosion-inhibited and non-corrosion inhibited solid sodium chloride (*e.g.*, road salt), corrosion inhibited solid sodium-magnesium chloride blends (*e.g.*, Meltdown 20), standard gradation brining salt (*e.g.*, for making salt brine), corrosion-inhibited liquid magnesium chloride (*e.g.*, Meldown Apex), and more.

TXDOT PRE-QUALIFIED PRODUCTS LIST FOR DMS-6400 "DE-ICER/ANTI-ICER"

TxDOT vendor information identifies three pre-approved producers of snow and ice control chemicals:

- Meltdown products (Meltdown 20 and Meltdown Apex) and Road Salt are offered through Envirotx, Fort Worth, TX which is a subsidiary of EnviroTech Svcs, Inc., Greeley, CO,
- Freezeguard products are offered through Scotwood Industries, Overland Park, KS
- Road Salt is offered through United Salt Corporation, Houston, TX

PRE-BLENDED LIQUID CHEMICAL FOR ANTI-ICING

MeltDown® Apex is one of the anti-icing chemicals TxDOT uses (Figure 4). Meltdown Apex is a magnesium chloride brine solution obtained by solarizing natural salt brine from the Great Salt Lake in Utah (Speer 2012). This liquid product is shipped from Utah to EnviroTech in Greeley, Colorado, where the proprietary blend is added. The final product is then distributed to TxDOT through Envirotx. MeltDown Apex contains 25-35 percent magnesium chloride, 65-75 percent water, and proprietary additives.

FIG 4. MeltDown® Apex is is a magnesium chloride brine solution obtained by solarizing natural salt brine from the Great Salt Lake in Utah

OTHER PRE-BLENDED BRINE PRODUCTS

Other snow and ice control materials exist but are used on a very limited basis in Texas. Alternative products include Calcium Magnesium Acetate (CMA) and Potassium Acetate (KA), which have lower corrosion potential when compared to chlorides. CMA was the result of a Federal Highway Administration (FHWA) effort to find a low corrosion biodegradable substitute for sodium chloride. CMA has low corrosion but it is also costly to produce and is mainly used as an additive to other chloride salts or placed on bridges as a low corrosion alternative (Levelton Consultants Ltd., 2006). Potassium Acetate is a non-chloride, high-performance product originally designed for use as a runway deicer. Due to its high cost, potassium acetate is usually used as an additive to other chloride salts or in automated bridge de-icing systems (Levelton Consultants Ltd., 2006).

HOMEMADE SALT BRINE

Salt brine (NaCl) is the liquid form of sodium chloride (NaCl). Salt brines may be manufactured for roadway applications in commercially-available brine production units.

In 2011, the TxDOT Childress District invested in a salt brine manufacturing system (Figure 5) where they now make their own salt brine at proper concentration for anti-icing applications (23 percent salt), in a dedicated mixing tank. The raw materials for salt brine are water and brining-quality road salt. Because the parent chemical – in this case, brining salt – is an approved product, the brine resulting from this salt is also approved.

FIG 5. The TxDOT Childress District invested in a salt brine manufacturing system to make their own homemade salt brine

SECTION 3. NATURAL, MANUFACTURED, AND OILFIELD BRINES

Site-manufactured (homemade) salt brine must be stored in tanks of adequate capacity, with proper-sized pumps and hoses for quick loading and recirculation capability. This is to maintain product consistency should settling of solids occur (Figure 4). Liquid chemical storage should include containment barriers sufficient to contain and recapture spills or the volume released from a tank rupture (Levelton Consultants Ltd., 2006).

OVERVIEW

Three types of "geologic" brines exist for consideration in snow and ice control, so-called because they source to underground geologic salt formations. The first type is natural brine that naturally exists either as surface water or in water-bearing formations *unrelated* to oil or gas plays. The second type is brine manufactured by circulating fresher water in naturally occurring below-ground NaCl deposits. The third type is produced water related to oilfield operations for oil and gas production.

These geologic brines are in addition to TxDOT's pre-approved, vendor-supplied, pre-blended brine products such as Meltdown Apex™ or FreezGard®, or other products identified on the Pacific Northwest Snowfighters qualified product list mentioned previously. Similarly, the three geologic brine types do not include homemade brine such as brine manufactured at the Memphis Maintenance Section (Childress District). The raw materials for homemade brine are water and brining-quality road salt blended in a salt brine manufacturing system with a dedicated mixing tank. Because the parent chemical – in this case, brining salt – is an approved product, the brine resulting from this salt is also approved by TxDOT.

NATURAL BRINES

Brine is simply salt dissolved in water. Natural brine can be found in surface water (*e.g.*, Dead Sea or the Great Salt Lake) or groundwater (*e.g.*, Kent County Brine). The use of natural brines is a relatively unexplored option for snow and ice control in Texas. Of the State Departments of Transportation contacted as part of research project 0-6793, none of these DOTs directly used natural brines.

In fact, only one type of natural brine, Kent County brine, has been identified as a potential candidate for snow and ice control in Texas. The nominal product is a "10-lb brine" with the weight corresponding to the percentage of dissolved solids. A 23 percent salt level – which is the ideal concentration of solids for salt brines – corresponds to 10.25-lb brine. The Kent County brine actually tests to be approximately an 11-lb brine, as a 31.7 percent solution, so this brine could be diluted to reach the 23 percent level if desired. Table 1 presents the water quality description for the brine from the Kent County site as provided by the owner.

Table 1. Kent County Natural Brine Quality from Ana-Lab Corp. Test Report

Analyte	Value	Units	Reporting Limit
Calcium	659	mg/L	12.5
Magnesium	1140	mg/L	12.5
Potassium	1180	mg/L	12.5
Sodium	104000	mg/L	500
Bromide	<1000	mg/L	1000
Chloride	212000	mg/L	3000
Fluoride	<1000	mg/L	1000
Nitrate	<1000	mg/L	1000
Ortho-phosphate as P	<300	mg/L	300
Sulfate	7200	mg/L	3000
Iodide	<300	mg/L	300
Alkalinity as $CaCO_3$	38.3	mg/L	1
Boron	<100	mg/L	100
Phosphorus	<200	mg/L	200
Aluminum	0.198	mg/L	0.1
Barium	<0.010	mg/L	0.01
Copper	0.91	mg/L	0.01
Total Iron	<0.209	mg/L	0.209
Strontium	23.4	mg/L	20
Zinc	<0.050	mg/L	0.05
Total Dissolved Solids	316000	mg/L	1000
Laboratory pH	6.8	s.u.	2
Specific Gravity	1.207		

As part of project 0-6793, the research team employed several procedures to analyze the concentrations of trace metals in the Kent County brine in addition to those identified in Table 1. Due to the high salt content in the brine, there are concerns about significant matrix interference and potential damage to the detection instruments. Methods to selectively extract the trace elements from the salt matrix are needed to achieve detection limits below the regulatory limits.

MANUFACTURED BRINES

Manufactured brines are made by mixing fresher water with deep salt formations to obtain a mixture that is free from hydrocarbon contamination and useful for multiple applications. A total of 20 manufactured brine sites were identified from the Texas Railroad Commission permit list (2011). The nominal product from these sites is 10-lb brine, with the dissolved solids made up primarily of sodium and chloride from the targeted salt beds. The vendors can also make denser brines up to 14-lb if requested by the customer. None of the brine vendors would provide tabulated laboratory water quality analyses.

The locations of the 20 manufactured brine sources plus the Kent County source are mapped in Figure 6. The sites are located in the Permian Basin or Southern High Plains of West Texas. Table 2 provides owner information about each site as well as their estimated unit cost per barrel (bbl or 42 gal) of brine. It should be noted that other similar brine sources may exist beyond this list, as based on our experience these vendors do not typically advertise their products through normal business media such as telephone listings or internet websites.

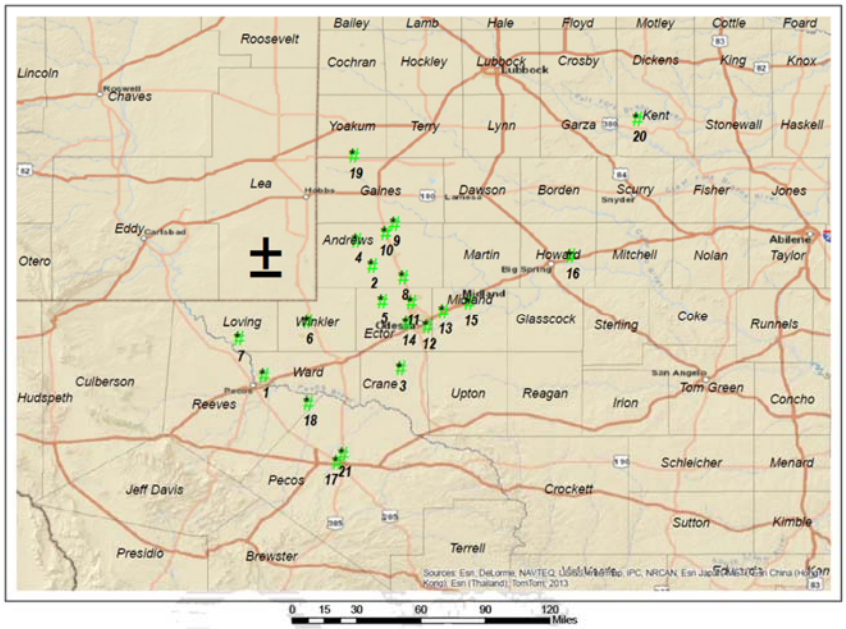


FIG 6. Locations of Available Manufactured Brines in Texas

Table 2. Identification and Locations for Manufactured Brine Sources in Texas

No.	Owner	County	Latitude	Longitude	Contact	Price ($/bbl)
1	Basic Energy Svcs	Reeves	31.480209	-103.408728	Barry Byrd	1.3 5
2	Basic Energy Svcs	Andrews	32.221942	-102.678469	Barry Byrd	1.3 5
3	Basic Energy Svcs	Crane	31.525979	-102.485082	Barry Byrd	1.3 5
4	Basic Energy Svcs	Andrews	32.393769	-102.784277	Barry Byrd	1.3 5
5	Basic Energy Svcs	Ector	31.982053	-102.610009	Barry Byrd	1.3 5
6	Basic Energy Svcs	Winkler	31.840287	-103.112848	Barry Byrd	1.3 5
7	Basic Energy Svcs	Loving	31.726853	-103.577321	Barry Byrd	1.3 5
8	Basic Energy Svcs	Andrews	32.141701	-102.469009	Barry Byrd	1.3 5
9	Basic Energy Svcs	Andrews	32.505455	-102.526731	Barry Byrd	1.3 5
10	Basic Energy Svcs	Andrews	32.443663	-102.587274	Barry Byrd	1.3 5
11	Basic Energy Svcs	Ector	31.972269	-102.413682	Barry Byrd	1.3 5
12	Basic Energy Svcs	Ector	31.808656	-102.306983	Barry Byrd	1.3 5
13	Basic Energy Svcs	Midland	31.912445	-102.197936	Barry Byrd	1.3 5
14	Basin Brine Sales	Ector	31.831250	-102.443804	Jason Hickerson	1.00-1.50

Table 2. (continued) Identification and Locations for Manufactured Brine Sources in Texas

No.	Owner	County	Latitude	Longitude	Contact	Price ($/bbl)
15	Chaparral Water Systems	Midland	31.967961	-102.024919	Darrel Franklin	1.10
16	Newpark Environmental Services	Howard	32.287024	-101.338792	Phillip Meyer	1.00
17	Newpark Environmental Services	Pecos	30.894289	-102.915341	Phillip Meyer	1.00
18	Enstor Waha Storage & Transport	Reeves	31.293007	-103.110195	Peter Sterzing	1.25
19	Salty Brine 1 LTD	Yoakum	32.964405	-102.802033	Josh Parker	1.10
20	Salt Fork Water Quality District	Kent	33.209608	-100.888428	Judge Jim White	0.50
21	Wilson Systems, Inc.	Pecos	30.948258	-102.876617	Sylvia Delgado	1.00

OILFIELD BRINES

Oilfield brines are a type of produced water related to oilfield operations for oil and gas production. The only readily available database for oilfield produced brines is published by the USGS (U.S. Geological Survey 2002) and discussed by Welch and Rychel (Welch, R. and Rychel, D., 2004). Figure 7 shows the distribution of produced oilfield brine qualities across the State using that database. The produced water total dissolved solids (TDS) concentrations ranged from a few thousand to almost 400,000 mg/L, with many samples reported from the northern half of the State.

Per the Texas Railroad Commission (RRC), oilfield brines can only be purchased from brine pit owners that hold specific permits from the RRC that allow them to sell the brine, whether the brine was produced from an oil or gas well or manufactured by mixing fresher water with a subsurface salt formation. Historically, the pit operators with actual produced water from oil and gas wells will not sell their brine for TxDOT's intended use, but rather use their produced water for secondary recovery or eventual disposal in deep wells.

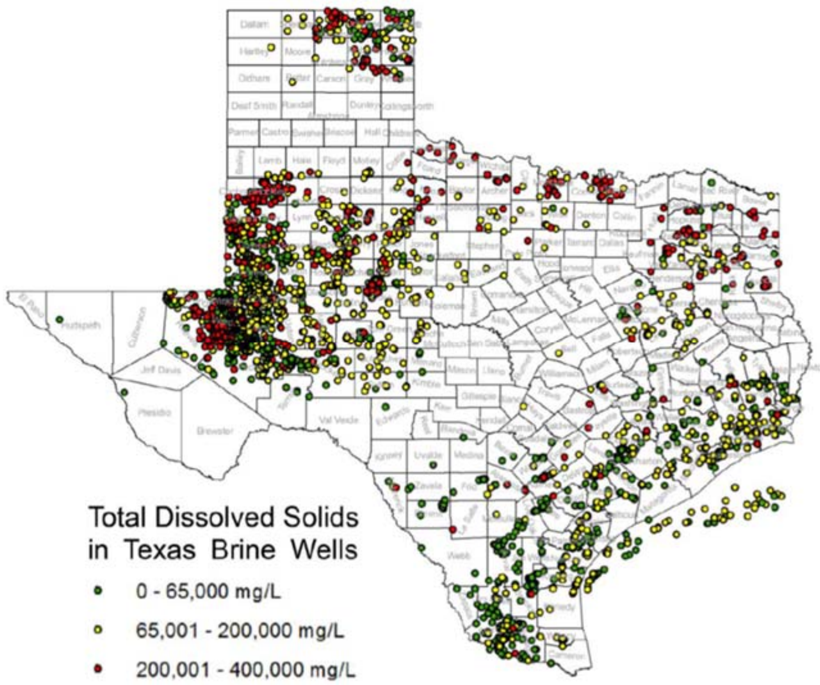


FIG. 7. Distribution of total dissolved solids concentrations in Texas oilfield brine samples included in the USGS database

Notwithstanding the fact that oilfield brines are normally not permitted for sale for non-oilfield applications, in 2014, the RRC voiced a more open perspective about TxDOT's desired usage of oilfield brine for snow and ice control. The RRC's willingness to consider oilfield brine came during a period of statewide drought exacerbated by a shortage of salt supply – conditions which were not considered "normal" at the time. The RRC's consideration of oilfield brine included requirements for analytical chemical testing for multiple parameters intended to "characterize the produced water so that TxDOT's risks would be known and minimized as the water is applied to the pavement." The discussion also recognized that produced water should not be required to meet drinking water standards.

Analytical results suggest that concentrations of trace metals could be highly variable among different brine sources. For this reason *any* geologic brine – natural, manufactured, or oilfield – should be tested and approved prior to widespread use. The PNS product specification and test protocols identified in the next section are appropriate for such evaluation.

SECTION 4. CORROSION, CORROSION INHIBITORS, ENVIRONMENTAL IMPACTS

CORROSION IMPACTS

Corrosion is a significant durability issue relative to the application and use of snow and ice control chemicals. Corrosion is inevitable regardless of the snow and ice control chemical used. Corrosion is a complex process that includes many factors making it site specific and hard to predict in the field environment. Studies that have tried to compare specific snow and ice control chemicals show a wide range of conclusions, and sometimes contradict one another (Levelton Consultants Limited, 2006).

Corrosion due to snow and ice materials varies between concentration of chemical, metal type, and metal alloy. Overall, chloride-based snow and ice control materials are the most corrosive. Studies attempting to rank the corrosiveness of chloride salts have not come up with definitive conclusions. The hygroscopic magnesium and calcium chlorides are generally considered the most aggressive due to the longer time of wetness, but for practical purposes all chloride salts can be considered *highly corrosive* (Levelton Consultants Limited, 2006).

The main corrosion concern to infrastructure is the corrosion of ferrous metals, specifically iron in wrought carbon steels (Figure 8). Atmospheric corrosion includes the corrosion of vehicles, roadside infrastructure, and steel bridges. Types of atmospheric corrosion include uniform (or general) corrosion, crevice, poultice, pitting, and galvanic corrosion, and filiform corrosion of aluminum and magnesium alloys (Levelton Consultants Limited, 2006).

FIG 8. The main corrosion concern to infrastructure is the corrosion of ferrous metals

Corrosion of concrete reinforcing steel and deterioration of concrete are also of concern. Chloride ions can diffuse through the concrete cover to the depth of the rebar and destroy the thin passive oxide film which protects the steel rebar from corrosion (American Society for Metals, 2005). Chloride ions break down the passive layer locally, so consequently, large cathodic areas of passive metal surround small anodes. If sufficient water and oxygen are available, corrosion will occur. When the steel corrodes the rust occupies a greater volume, creating expansion. The expansion causes tensile stresses in the concrete which lead to cracking, delamination, and spalling. This, in turn, allows more moisture to infiltrate and corrode the steel.

Sulfates are a concern for the deterioration of concrete. Sulfates can be introduced in snow and ice operations when natural brines are used. The sulfates react with hydrated compounds in the hardened cement. This results in pressure that disrupts the cement paste, causing a loss of cohesion and strength (American Society for Metals, 2005). Some pozzolans, such as fly ash meeting the requirements of ASTM C 618 Class F can increase the resistance to sulfates while other pozzolans, such as ASTM C 618 Class C fly ash can decrease sulfate resistance (American Society for Metals, 2005). Acids also cause deterioration of concrete.

Concrete scaling, flaking, peeling, or pitting of the concrete surface has been caused by snow and ice chemicals in concrete without sufficient strength or air entrainment. However, scaling has not been an issue on DOT system roads built and maintained under strict standards for design and construction.

CORROSION INHIBITORS

Multiple strategies exist to mitigate corrosion. Measures can be introduced directly to the infrastructure to protect against corrosion. Alternatively, corrosion inhibitors can be added to the snow and ice chemicals themselves. These different methods vary in effectiveness and depend on several factors. Of particular interest are corrosion inhibitors added to snow and ice chemicals.

When one considers that corrosion impacts directly relate to the quantity of chemical used, and the quantity of chemical is driven by climate severity, it can be observed that because Texas winters are relatively mild, most portions of the State see only a few winter storms per year, and some see no storms at all. Further, even the coldest and snowiest portions of Texas have less severe winters than northern states with active, chemical-based winter roadway maintenance programs. Figure 9 indicates that Texas' winter maintenance activities are an order of magnitude lower – one-tenth to one-fiftieth – compared to states such as Iowa, Ohio, and Massachusetts. Quantitatively, it is reasonable to infer that TxDOT winter maintenance operations apply an order of magnitude (or lower) of chemical to Texas bridges and roads. While this does not eliminate corrosion concerns associated with winter roadway maintenance in Texas, it does put these issues in perspective.

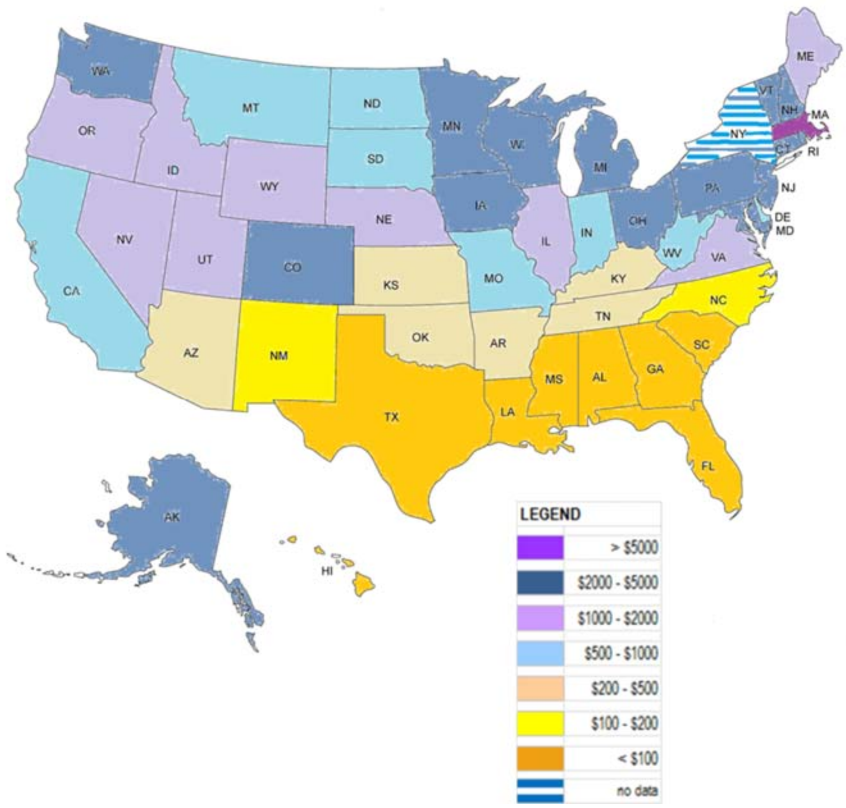


FIG 9. United States removal of snow and ice, annual average maintenance cost per lane mile.

Corrosion inhibitors are added to many of the manufactured blended, snow and ice control products. These corrosion inhibitors are almost always proprietary, so little is known about the chemical makeup. In the past, agricultural by-products have been popular additives. Though the corrosion inhibitors could have some corrosion inhibiting effect on vehicles, these agricultural products biodegrade, and are thought to have little long term effects for inhibiting corrosion for infrastructure. There are three basic types of corrosion inhibitors: anodic inhibitors, cathodic inhibitors and mixed inhibitors (Levelton Consultants Limited, 2006).

For practical purposes, all chloride salts are considered highly corrosive, with the main factor being time of wetness. Hygroscopic de-icing materials suggest that roadway infrastructure will stay wet longer, causing higher corrosion. Corrosion inhibited snow and ice control chemicals which are tested in the laboratory show reductions in corrosion rates of the metals being tested, but they may show little or no inhibiting effect on other metals (Levelton Consultants Limited, 2006). Also, corrosion inhibited snow and ice control chemicals can show significant reductions in corrosion rates in the laboratory, but under field conditions show much lower inhibiting effects.

ENVIRONMENTAL IMPACTS

Sodium chloride (NaCl), or road salt, is one of the most commonly used de-icing chemicals (NCHRP 2007). When used in excess, sodium chloride can be detrimental to the environment; however, a method known as *sensible salting* promotes using the appropriate amount of salt on roads to reduce negative impacts (Salt Institute 2004).

All of the State DOTs that were contacted use sodium chloride and none of them expressed environmental concerns involved with using road salt. The state of Washington collects annual soil samples from roadsides to assess if damage is being caused by their de-icing chemicals. The soil samples are tested for their chloride loading and heavy metal contamination. To date, no adverse results have been reported (Jay Wells 2012).

The Federal Highway Administration states that highway runoff is appreciably cleaner than other non point runoff sources such as agricultural and industrial sources (FHWA 1997). The United States Geologic Survey in Ohio reported that deicing chemicals, including road salt, did not affect the environment in the long term (Kunze and Sroka 2004). The Salt Institute encourages cities and municipalities to plant salt tolerant vegetation along roadways (Salt Institute 2004).

The use of natural brines is an unexplored option for snow and ice control. Of the State DOTs contacted as part of the research study, none directly used natural brines. A few bought brines from companies procuring it from the Great Salt Lake.

Because there is a lack of research on natural brines, assumptions about their impact must be made. As has been noted, oilfield brine is a waste product of drilling. The possibility exists that oilfield brines may contain heavy metals, hydrocarbons, or naturally occurring radioactive materials. The brine in question should be tested for constituents and toxicity and if it passes the criteria for a deicer the brine should be safe for use on highways.

When discussing the viability of using natural brines in Texas, concerns were raised by some other State Departments of Transportation. For example, oilfield brines cannot be used in Utah because of the regulations on the heavy metals and hydrocarbons the brine may contain (Lynn Bernhard 2012). The regulations in Utah require brines to be tested for potentially dangerous constituents.

SURVEY OF REGULATIONS AND TECHNICAL GUIDANCE

The Texas Commission on Environmental Quality (TCEQ) has no implicit rules about snow and ice control on their website or in the Texas Administrative Code.

The Iowa Institute of Hydraulic Research (IHR) released *Technical Report Number 420* as a guide to choosing a deicer. They take into account the environmental impacts of the deicer based on the performance results for several tests. Test parameters include heavy metal concentrations, toxicity, nitrogen levels, the BOD of the liquid and, the chemical oxygen demand (COD) of the liquid (Nixon and Williams 2001). The report instructs users to weight each category for their specific needs in order to differentiate and rank the deicers.

The Pacific Northwest Snowfighters group has established detailed procedures for testing deicing and anti-icing chemicals and maintains specifications that these products must meet to be considered for widespread use. The PNS "Snow and Ice Control Chemicals Products Specifications and Test Protocols" document provides guidance on preparing and submitting products for the testing and evaluation process required to be placed on the Qualified Products List. Table 3 summarizes the PNS required tests and methods.

Table 3: Test Methods for PNS Snow and Ice Chemical Product Evaluation (revised 12/2010)

No.	Test Description	Test Method (abridged)
1	Percent Concentration of Active Ingredient In The Liquid	Atomic Absorption or Inductively Coupled Plasma Spectrophotometry as described in "Standard Methods for the Examination of Water and Waste Water", APHA-AWWA-WPCF
2	Weight Per Gallon	Specific Gravity by ASTM D 1429 Test Method A
3	Corrosion Control Inhibitor Presence and Concentration	Test procedures provided by the manufacturer
4	pH	ASTM D 1293 as modified by PNS
5	Corrosion Rate	NACE Standard TM0169-95 (1995 Revision) as modified by PNS
6	Percent Total Settleable Solids and Percent Solids Passing a 10 Sieve	Test Method "C" in Appendix A of PNS Specifications
7	Total Phosphorus	Standard Methods for the examination of Water and Waste Water, APHA-AWWA-WPCF
8	Total Cyanide	Standard Methods for the examination of Water and Waste Water, APHA-AWWA-WPCF
9	Total Arsenic, Barium, Cadmium, Chromium, Copper, Lead, Selenium and Zinc	Atomic Absorption Spectrophotometry or Plasma Emission Spectroscopy as described in "Standard Methods for the examination of Water and Waste Water", APHA-AWWA-WPCF
10	Total Mercury	Cold Vapor Atomic Absorption Spectrophotometry as described in "Standard Methods for the examination of Water and Waste Water", APHA-AWWA-WPCF
11	Milliequivalents	Milligrams of acetic acid to neutralize 1 gram of unreacted base

Table 3: Test Methods for PNS Snow and Ice Chemical Product Evaluation (revised 12/2010)

No.	Test Description	Test Method (abridged)
12	Moisture Content Of Solid Chemical Prod-ucts	ASTM E 534
13	Gradation	ASTM D 632
14	Visual Inspection and Field Observations	As specified
15	Toxicity Test	"Short-Term Methods for Estimating the Chronic Toxicity of Effluent and Receiving Waters to Freshwater Organisms", Third Edition, EPA-600/4-91/002
16	Ammonia - Nitrogen	"Standard Methods for the examination of Water and Waste Water", APHA-AWWA-WPCF
17	Total Kjeldalh Nitrogen	"Standard Methods for the examination of Water and Waste Water", APHA-AWWA-WPCF
18	Nitrate and Nitrite as Nitrogen	"Standard Methods for the examination of Water and Waste Water", APHA-AWWA-WPCF
19	Biological Oxygen Demand	"Standard Methods for the examination of Water and Waste Water", APHA-AWWA-WPCF
20	Chemical Oxygen Demand	"Standard Methods for the examination of Water and Waste Water", APHA-AWWA-WPCF
21	Frictional Analysis	As specified
22	Insoluble Material	ASTM E534 "Standard Test Methods for Chemical Analysis of Sodium Chloride"
23	Chloride	"Standard Methods for the examination of Water and Waste Water", APHA-AWWA-WPCF

NCHRP Report 577, *Guidelines for the Selection of Snow and Ice Control Materials to Mitigate Environmental Impacts* (Figure 10) presents guidelines for the selection of snow and ice control materials through an evaluation of their cost, performance, and impacts on the environment and infrastructure. This report identifies aquatic systems as the primary environmental concern associated with snow and ice control materials.

Well brines are characterized as "blended chlorides" and these were evaluated through an analytical test program that included chemical analysis, aquatic toxicity, concrete corrosion, and atmospheric corrosion. From this work, NCHRP Report 577 generated a matrix of significant properties for consideration in evaluation of snow and ice control chemicals.

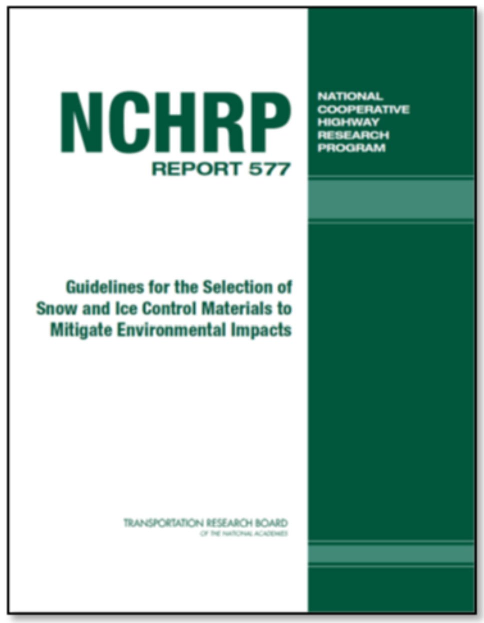


FIG 10. NCHRP Report 577. *Guidelines for the Selection of Snow and Ice Control Materials to Mitigate Environmental Impacts*

One of the outcomes of the NCHRP effort was a Decision Tool that agencies can use when selecting a snow and ice control material. Decision categories include cost, performance, potential to impair the natural environment, and potential to impair infrastructure. These balance economic value related to cost and performance with potential consequences of use related to environmental and corrosion impacts

Much of the environmental risk involved with putting a deicer on the roadway is negated by the amount of dilution when the deicer leaves the roadway. NCHRP Report 577 assumed that the concentrations of the applied materials are diluted 500 times at the point these materials leave the roadway.

In a manner similar to the discussion of corrosion impacts, even the coldest and snowiest portions of Texas have less severe winters than northern states with active, chemical-based winter roadway maintenance programs. The inference is that environmental impacts from Texas snow and ice control operations will therefore be less than those from winter maintenance operations in the northern states.

SECTION 5. OPERATIONAL BEST PRACTICES

USAGE OF BRINES

TxDOT has historically relied on pre-approved brine products such as MeltDown Apex™ and to a lesser extent, salt brine, for anti-icing operations associated with snow and ice control. Geologic brines such as natural brine (unrelated to oil or gas plays), manufactured brine (created by circulating fresher water in naturally-occurring below-ground salt deposits), and oilfield brine (produced water related to oilfield operations for oil and gas production) have been identified as potential alternative brines for winter roadway maintenance applications, especially during times when customary sources of brine are either unavailable or prohibitively expensive. Recommendations include the following.

1. One benefit of using pre-approved brines (and granular chemicals) is that these products have been tested and cleared for use by the Pacific Northwest Snowfighters (PNS) "Snow and Ice Control Chemicals Products Specifications and Test Protocols." Chemical constituents and impacts are known.
2. TxDOT has initiated steps to manufacture their own homemade salt brine on site (in the maintenance yard) using pre-approved brining quality salt. This approach can be very economical and makes sense for areas of the State where brine usage is significant.
3. Analytical results suggest that concentrations of trace metals and other constituents could be highly variable among different brine sources. Therefore, any geologic brine (natural, manufactured, or oilfield) should be tested and approved prior to widespread application on Texas roads. The PNS product specification and test protocols identified herein are appropriate for such evaluation.

USAGE OF INHIBITED AND NON-INHIBITED CHEMICALS

Typical snow and ice control chemicals used in Texas are chloride salts, and all chloride salts are highly corrosive. Historically TxDOT has used both inhibited chlorides (Meltdown Apex™, Meltdown 20®) and uninhibited chlorides (road salt, salt brine). Both laboratory test results and findings published in the literature on durability impacts are mixed. These recommendations are encouraged.

1. The use of inhibited chlorides provides some added protection against atmospheric corrosion.
   a. Approved snow and ice control chemicals containing corrosion inhibitors can be purchased directly.
   b. Approved corrosion inhibitors can be purchased and applied to homemade salt brine and other chemicals.
2. TxDOT should proceed with caution when using non-inhibited chemicals.
   a. Concrete infrastructure (both pavements and bridges) that is not designed for low permeability or with epoxy-coated reinforcing will be more susceptible to corrosion impacts.
   b. Metal infrastructure (bridges), especially with partially-coated or non-coated steel, will be more susceptible to corrosion impacts.
   c. Routine maintenance inspections of treated infrastructure should include observation, monitoring, and evaluation for any signs of increased corrosion impact.
3. The usage of any snow and ice control chemical – either inhibited or non-inhibited – should be done within the context of maintenance practices that minimize corrosion impacts.
   a. Roadway maintenance following the winter season should include cleaning of infrastructure to remove, dilute, or otherwise normalize the effects of chloride salts with special attention to expansion joints and other metal elements directly exposed to the chemical.
   b. Equipment maintenance should include cleaning of equipment to remove, dilute, or otherwise normalize the effects of chloride salts with special attention to electrical wiring, gears, and any other uncoated metal elements directly exposed to the chemicals.

ENVIRONMENTALLY-FRIENDLY WINTER MAINTENANCE PRACTICES

The Texas Commission on Environmental Quality (TCEQ) has no implicit rules about snow and ice control on their website or in the Texas Administrative Code. Overall, the literature suggests there is minimal added risk to the environment when using Na, Mg, Ca, and Cl salts for snow and ice control. Recommendations include the following.

1. TxDOT winter roadway maintenance should continue to employ best practices for snow and ice control operations with a view to minimizing environmental impacts.
   a. Annually calibrate both granular and liquid chemical application equipment.
   b. Train maintenance personnel in proper application of snow and ice control chemicals.
   c. Employ anti-icing strategies to minimize the amount of chemical needed for snow and ice operations.
   d. Use chemical application strategies such as pre-wetting to achieve less bounce and scatter (material loss) and more effective melting action.

2. Any snow and ice control chemical product should be tested and approved prior to widespread application on Texas roads.
   a. Pay particular attention to geologic brines that can be spatially and temporally variable.
   b. The PNS product specification and test protocols identified herein are appropriate for such evaluation.

3. Consider chemically-inert abrasives for areas of the State with particularly mild winters, especially the southern Districts.

MAINTENANCE PRACTICES AGAINST CORROSION

Snow and ice control chemicals are highly corrosive, and if improperly managed they can be harmful to equipment, infrastructure and the environment. Maintenance supervisors must therefore employ operational best practices so as to minimize impacts. Here are a few best practices:

- Safety first. Maintenance section personnel must be trained to safely perform all aspects of snow and ice control operations.
- Tailor the snow and ice control material strategy to your particular district with due consideration to the winter weather maintenance zone for your area.
- Properly store and safely handle all snow and ice chemicals.
- Use anti-icing where appropriate to minimize the amount of chemical needed for snow and ice control.
- Calibrate liquid spray application rig so that the amount of brine applied corresponds to the target application rate.
- Thoroughly and completely power wash your snow and ice application equipment after storm events, and in particular, following the winter storm season.
- Protect equipment using chloride neutralizers where appropriate. Paint or treat any bare metal parts. Clean, apply silicon, and cover electrical connections.

In addition, maintenance section personnel should be trained in operational aspects of snow and ice control including application of the correct amount of snow and ice control chemical and proper clean-up when the job is done.

SECTION 6. CONCLUSIONS FROM THE RESEARCH REPORT

Project 0-6793 considered all major aspects of TxDOT's typical snow and ice control materials including their effectiveness, availability, impact on infrastructure durability (corrosion), environmental concerns and regulations, field performance, and cost. The reader is directed to the individual report chapters for details. The following statements are the key conclusions from this study, presented by research task.

<u>Task 1</u>. Review of technical literature on snow and ice control materials used in the United States and in Texas, including the effectiveness of these materials in relation to type of application, shows the following:

1.1 Texas snow and ice control material historical usage has relied heavily on Meltdown® products (51% granular, 8% liquid), but national usage focuses even more strongly on road salt and road salt brine.

1.2 A widespread belief exists among TxDOT personnel that MeltDown® products are comprised of magnesium chloride. Liquid MeltDown Apex™ is truly $MgCl_2$ in water, but granular MeltDown 20® is almost pure <u>sodium</u> chloride. *Manufacturer's* data for MeltDown 20® shows this product consists of 90 to 98% NaCl (road salt) and 0.06 to 0.2% $MgCl_2$ plus other elements and a proprietary corrosion inhibitor.

1.3 Texas ranks 30th nationally in terms of snow and ice control expenditures, and 42nd nationally in terms of percent maintenance effort *and* cost of treatment per lane mile.

1.4 Texas winter weather is very challenging for snow and ice control in that it is unpredictable (varying number and frequency of storms), diverse (both snow *and* ice), and presents with a wide range of severity (from climate normals to extreme winter storm events).

1.5 Weather directly influences winter roadway maintenance strategy and operational issues including the type, application, quantity, and effectiveness of snow and ice control materials, as well as equipment selection and personnel training.

Task 2. Review of technical literature and other data on the usability of brines for snow and ice control shows the following findings.

2.1 Texas historical usage of brines includes Meltdown Apex™ and more recently, homemade salt brine in the Childress District.

2.2 Many pre-approved brine products with known properties are available for purchase.

2.3 Three types of “geologic” brines are available for consideration in snow and ice control: natural brine, manufactured brine, and oilfield brine (produced water).

2.4 All of the geologic brines should be tested and approved prior to widespread use; concentrations of trace metals could be highly variable.

Task 3. Review of technical literature and a limited experimental program on durability impacts of snow and ice chemicals on infrastructure show the following facts.

3.1 TxDOT’s historical usage of chemicals includes both inhibited chlorides (Meltdown Apex™, Meltdown 20®) and uninhibited chlorides (road salt, salt brine).

3.2 These are all chloride salts and all chloride salts are highly corrosive.

3.3 Atmospheric corrosion tests indicate

- No difference in corrosion rate observed between sodium chloride products, and
- Inhibited chlorides are 36% to 55% less corrosive than uninhibited road salt.

3.4 Chloride diffusion tests indicate

- Magnesium chloride achieves the highest chloride concentrations during diffusion, and
- No chemicals diffused beyond Level 2 (0.75” to 1.25”).

3.5 The literature demonstrates that studies that have tried to compare specific snow and ice control chemicals show a wide range of conclusions, and sometimes contradict one another.

3.6 Laboratory corrosion results often differ from observed field impacts.

3.7 Texas' annual chemical applications are generally an order of magnitude lower than applications in northern states.

Task 4. Review of literature on environmental impacts and regulations associated with application of snow and ice chemicals, nationally and in Texas, shows the following results.

4.1 Overall, the literature suggests there is minimal added risk to the environment when using Na, Mg, Ca, and Cl salts for snow and ice control.

4.2 Any product (solids or brines) should be tested for constituents and toxicity prior to use, with particular attention to geologic brines that can be spatially and temporally variable.

4.3 De-icing chemicals commonly used in Texas include road salt (both liquid and granular), liquid MeltDown Apex™, and granular MeltDown 20®, all of which are approved products on the PNS Qualified Products List.

4.4 Dilution by snowmelt greatly decreases potential impacts (~500X).

4.5 The coldest and snowiest portions of Texas have less severe winters than northern states with more active, chemical-based winter roadway maintenance programs.

Task 5 (field trials). The field trials performed in Winter 2012/13, Winter 2013/14, and Winter 2014/15 showed the following findings.

5.1 Photo and video datasets for anti-icing applications typically showed

- No statistically-significant difference in the amount of visible bare pavement for sections treated with Salt Brine vs. sections treated with MeltDown Apex™, and
- No statistically-significant difference in the amount of visible bare pavement for sections treated with Salt Brine or MeltDown Apex™ compared to untreated control sections.

5.2 Decelerometer tests for anti-icing applications indicated

- MeltDown Apex™ -treated sections could be 10 to 20 percent slicker (lower deceleration) than the Salt Brine-treated sections, and
- MeltDown Apex™ -treated test sections could be slicker (lower deceleration) than untreated sections.

5.3 Photo and video datasets for de-icing applications typically showed

- A statistically-significant improvement in the amount of visible bare pavement for sections treated with road salt (at the TxDOT rate of 300 lb/lane mile) vs. sections treated with MeltDown 20® (at the TxDOT rate of 150 lb/lane mile), and
- No statistically-significant difference in the amount of visible bare pavement for sections treated with road salt or MeltDown 20® de-icing chemical compared to untreated control sections.

5.4 Decelerometer tests for de-icing applications indicated

- No statistically-significant difference in pavement friction between sections treated with road salt vs. sections treated with MeltDown 20®, and
- Both MeltDown 20®-treated test sections and road salt -treated sections were less slippery (better deceleration) than untreated sections.

<u>Task 5 (laboratory testing)</u>. The laboratory testing program shows the following:

5.5 With respect to ice melting and undercutting

- MeltDown 20® and Salt Brine de-icing solutions are comparable with regard to their ability to melt ice or undercut ice under laboratory conditions at temperatures above 15°F,
- Neither Salt Brine nor MeltDown 20® was particularly effective at 0°F (which is near the freezing temperature of a 23% salt mixture),
- MeltDown Apex™ was substantially more effective at ice melting, even at 0° F, and was generally more effective at undercutting although this effect was much more variable, and
- The melting process rapidly dilutes the salt solutions, reducing their effectiveness.

5.6 With respect to surface friction

- MeltDown Apex™ was much “slicker” than either MeltDown 20® or Salt Brine, and
- Friction data for MeltDown 20® and Salt Brine were similar to distilled water.

Task 6. Detailed cost analyses established the baseline of TxDOT's snow and ice control expenditures and show the following results.

6.1 Opportunities to improve efficiency in snow and ice material procurement include

- Standardize selection of materials,
- Develop a uniform standard for selecting snow and ice control materials, and
- Leverage TxDOT's purchasing power to lower prices.

6.2 Opportunities to improve efficiency of winter maintenance operations include

- Reduce Operation to Material (O-M) ratios,
- Capture data on cleanup and anti-icing maintenance functions, and
- Manage risk for low-frequency, high-impact events.

6.3 Opportunities to improve efficiency of winter maintenance policy include

- Apply performance-based models for snow and ice control,
- The current cost analysis focuses on input factors, and
- A significant question remains unanswered, namely: "Is the current level of winter maintenance spending adequate in maintaining snow and ice free roadways in Texas?"

sponsored by the

Texas Department of Transportation

in cooperation with

U.S. Department of Transportation
Federal Highway Administration

September 2017

TEXAS TECH UNIVERSITY

Texas department of transportation

TECHMRT

TEXAS TECH UNIVERSITY
Box 41023

Phone: 806.742.3505
Fax: 806.742.4168
Web: http://www.techmrt.ttu.edu/