



Environment and Natural Resources Trust Fund

2021 Request for Proposal

General Information

Proposal ID: 2021-211

Proposal Title: Reduction of Environmental Impacts with Road De-Icing Alternatives

Project Manager Information

Name: John Gulliver

Organization: U of MN, College of Science and Engineering

Office Telephone: (651) 636-4166

Email: gulli003@umn.edu

Project Basic Information

Project Summary: Provide innovative solutions to reduce the bond between ice/snow and pavement surface, improve ice/snow removal using designed chemicals, and investigate the environmental impact of chosen road salt alternative.

Funds Requested: \$666,000

Proposed Project Completion: 2024-06-30

LCCMR Funding Category: Water Resources (B)

Project Location

What is the best scale for describing where your work will take place?

Region(s): Metro

What is the best scale to describe the area impacted by your work?

Statewide

When will the work impact occur?

In the Future

Narrative

Describe the opportunity or problem your proposal seeks to address. Include any relevant background information.

Minnesota uses on average (past two years) a quarter million tons of road salt (sodium chloride), which ends up polluting our lakes, rivers and groundwater. The state has started to use alternative anti-icing chemicals, however, their application is limited by material cost and the environmental impact is not fully understood. It is of critical importance to identify solutions that could lead to a substantial reduction of alternative de-icing chemicals without affecting the safety of road users. We have investigated the environmental impact and anti-icing capability of known alternative chemicals in a current LCCMR project. The next step is to find an improved means of delivering these chemicals through the ice and to investigate the efficacy of new chemicals as road de-icing alternatives. Pretreatment of road surfaces (anti-icing) is known to substantially reduce required chemical, but often de-icing is required, where solid salt is distributed over the ice surface to melt the ice. The de-icing method currently used is salt-intensive. A better method to get liquid chemical through the ice to the road surface is needed to remove existing ice. In addition, the design of chemical mixtures that could function as road de-icing alternatives needs to be fully explored.

What is your proposed solution to the problem or opportunity discussed above? i.e. What are you seeking funding to do? You will be asked to expand on this in Activities and Milestones.

We will facilitate a paradigm shift from melting ice, requiring large quantities of chemicals, to weakening the ice-pavement bond with minimal melting, which is known to require substantially lower quantities of chemicals. To do this, we will engage in three activities:

- 1) Investigate the best means of delivering a de-icing liquid through the ice and packed snow to the road surface,
- 2) Investigate the chemistry of ice-pavement bonding and how to best reduce bonding strength and
- 3) Investigate the environmental impacts of all new chemical alternatives and method of delivery.

Preliminary laboratory results performed as part of a current LCCMR project have shown that smart use of certain chemicals can reduce the strength of the bond at the ice-pavement interface, which is the primary goal of anti-icing road salt alternatives. Such a reduction can substantially improve snow/ice removal. Innovations in snow/ice removal equipment are needed, however, that can provide additional improvement without additional use of chemicals. In addition, there are many industrially-produced chemicals that may be an improvement to current road salt alternatives due to a minimal environmental impact combined with an increase in ice removal effectiveness. These will be investigated under activities 2 and 3.

What are the specific project outcomes as they relate to the public purpose of protection, conservation, preservation, and enhancement of the state's natural resources?

The outcome of this project is to investigate and enhance strategies that improve water quality by evaluating road salt alternatives and snow removal innovations to reduce the chloride load from road runoff. The methods and tools developed during this project will inform state, municipal and private entities using chloride-based salt on roads and parking lots on the availability of new chemical alternatives and novel snow removal options. A feasibility matrix will be developed to summarize high-level economic, environmental, time frame, implementation & maintenance challenges and benefits of using the strategies proposed.

Activities and Milestones

Activity 1: Investigate Effectiveness of De-Icing Chemicals Alternatives for Reducing Bonding Strength at the Ice Pavement Interface

Activity Budget: \$318,386

Activity Description:

There exist a variety of industrially-produced chemicals that may be an improvement on current road salt alternatives, due to a minimal environmental impact combined with an increase in ice removal effectiveness. Hydrophobic (water repellent) liquids create an upward pressure on the ice after delivery to the pavement-ice interface, while hydrophilic (water loving) liquids quickly spread over the pavement-ice interface possibly resulting in a lower bond strength. There are many types of hydrophobic and hydrophilic liquids that are available and can be manufactured to result in desired properties. With the objective of determining the optimum surface tension, we will study of the effect of liquid surface tension and wetting behavior on ice surfaces. The penetration of the liquids into ice crevices may also be studied using visualization methods. The next stage will be to measure the bonding strength, determine the kinetics of the bond-weakening process as a function of the temperature of the de-icing chemical and of the pavement, and establish the link between bond strength reduction and the surface tension and the liquid ability to penetrate the interface. Finally, we will look for liquids that have the surface tension of interest and meet the cost and environmental requirements.

Activity Milestones:

Description	Completion Date
Synthesize past and current investigations of hydrophobic and hydrophilic liquids for ice removal	2021-12-31
Study of the kinetic of the bond weakening process	2023-07-31
Select liquids and perform bond strength experiments at different temperatures and application rates	2023-12-31

Activity 2: Reduce Required Mass of Chemical Alternatives through Innovations in Ice/Snow Removal Technologies

Activity Budget: \$173,495

Activity Description:

The proposed solution for ice removal from the road to reduce the environmental impact and to minimize the pavement deterioration is a three-pronged operation that combines mechanical and chemical intervention with the use of two plow trucks. The first step involves a modified icebreaker – a rotating drum lined with rows of spikes mounted on the front of the first plow truck to poke craters in the ice. In a second step, a heated de-icing chemical solution is sprayed into the crater to reach the pavement and weaken the ice-pavement bond. The final third step is executed by a second truck equipped with a front blade to remove the ice from the pavement. The research aims to optimize these operations. First, we will explore modifications to the icebreaker to reduce pavement damage. The proposed concept is to swap the spikes on the drum by replaceable cartridges containing a spring-loaded spike designed to ensure a uniform distribution of loads on the pavement. Second, we will optimize the delivery of the heated de-icing chemical to minimize the mass of liquids to be sprayed on the pavement. Finally the optimum time delay between the chemical spray and the ice scraping will be determined.

Activity Milestones:

Description	Completion Date
Design of the pick cartridge to minimize damage to the pavement	2022-06-30

Optimum delivery of the de-icing chemical (temperature and flow rate)	2022-12-31
Investigate optimum time delay between the chemical spray and the ice sremoval	2023-08-31

Activity 3: Environmental Impact of Chemical Alternatives and De-Icing Methods

Activity Budget: \$174,119

Activity Description:

All road salt alternatives have an environmental impact. Information gathered in Activity 1 will be synthesized through the use of computer models to evaluate potential water quality impacts of road salt alternatives in Minnesota. Many of the non-chloride-based alternatives are organic compounds, which have a biological oxygen demand when released into the environment. The quantity and kinetics of such alternatives required for anti-icing and de-icing will be estimated from literature values, and computer models will then be used to determine the water quality impacts of these quantities on common water resources in Minnesota. These will be compared to the environmental impact of chloride-based road salt. In addition, some environmental impacts will be positive, such as the reduced mass of chemical that will result from Activity 2.

Activity Milestones:

Description	Completion Date
Develop computer model of chemical dispersion with existing software	2022-06-30
Analyze impacts of various chosen chemical treatment methods on the environment	2024-03-31

Long-Term Implementation and Funding

Describe how the results will be implemented and how any ongoing effort will be funded. If not already addressed as part of the project, how will findings, results, and products developed be implemented after project completion? If additional work is needed, how will this be funded?

A better understanding of road salt alternatives and innovative snow removal methods, combined with knowledge of environmental impacts and application, will enable an improved decision-making process for public and private entities. Input and advice from several agencies, such as the Minnesota Pollution Control Agency and MnDOT's Office of Maintenance will be utilized to ensure that the goals of this research are met, and that the findings are useful to, and shared with, decision-makers in Minnesota, such as city, county, and state scientists and engineers.

Other ENRTF Appropriations Awarded in the Last Six Years

Name	Appropriation	Amount Awarded
Reduce Chlorides in Minnesota Waters by Evaluating Road-Salt Alternatives and Pavement Innovations	M.L. 2018, Chp. 214, Art. 4, Sec. 2, Subd. 04c	\$400,000
Understanding Impacts of Salt Usage on Minnesota Lakes, Rivers, and Groundwater	M.L. 2016, Chp. 186, Sec. 2, Subd. 04n	\$497,000

Project Manager and Organization Qualifications

Project Manager Name: John Gulliver

Job Title: Professor

Provide description of the project manager's qualifications to manage the proposed project.

John Gulliver is a professor of civil, environmental and geo- engineering, performing his research at the St. Anthony Falls Laboratory. Much of his research, in conjunction with other faculty, involves the development of new technology for stormwater treatment and assessment of field performance of stormwater treatment practices, including the SAFL Baffle, which converts any sump into an effective sediment settling device, the Iron-Enhanced Sand Filter, which removes dissolved, as well as particulate phosphorus, and the MPD Infiltrometer, which can measure infiltration into soil accurately and effectively with minimal volume of water. He has investigated the retention of metals by bioretention media, the infiltration rates of various stormwater treatment practices, the impact of various types of impervious areas on runoff, the transport of road salt into the groundwater table, the effectiveness and the environmental impact of road salt alternatives and the impact of climate change on stormwater infrastructure. He is a co-author of the book, *Optimizing Stormwater Treatment Practices: A Handbook of Assessment and Maintenance*, published by Springer. Gulliver has expanding his interdisciplinary research activities related to managing and treating urban runoff and publication of the practitioner-oriented newsletter, *Stormwater Updates*

Organization: U of MN - Twin Cities

Organization Description:

The Department of Civil, Environmental, and Geo- Engineering is located on the Minneapolis campus of the University of Minnesota. The department has outstanding facilities and a vigorous and diverse education and research program in several disciplines. The Pavement and Rock Mechanics Laboratories are equipped with state of the art testing equipment.

The St. Anthony Falls Laboratory (SAFL), an interdisciplinary fluids research and educational facility, is focused at the intersection of fluid dynamics with major societal challenges in energy, environment and health. SAFL serves as a

resource for departments across the Twin Cities campus, the statewide University system, and the broader research community.

The Coating Process and Visualization (CPV) Lab is a unique academic facility with equipment for coating and printing, visualization and characterization. The CPV Lab is the primary lab of the Coating Process Fundamentals Program, a research program of the Industrial Partnership for Research in Interfacial and Materials Engineering (IPRIME).

The connections and collaborations of the three facilities reach across the country and all over the world, and our laboratories partner with local, state and federal agencies, and other educational institutions to expand knowledge and solve problems.

Budget Summary

Category / Name	Subcategory or Type	Description	Purpose	Gen. Ineligible	% Benefits	# FTE	Classified Staff?	\$ Amount
Personnel								
John Gulliver		Professor, PI and Project Manager			36.5%	0.18		\$35,694
Mihai Marasteanu		Professor and co-PI, Supervisor of Pavement Laboratory			36.5%	0.18		\$29,491
Emmanuel Detournay		Professor and co-PI, Project support			36.5%	0.18		\$38,733
Jia-Liang Le		Associate Professor and co-PI, Research Support			36.5%	0.18		\$26,225
Mugur Turos		Pavement Lab Manager, Ice/pavement experiments			36.5%	0.75		\$72,636
Andrew Erickson		Research Associate, Environmental impact analysis			36.5%	1.2		\$128,425
Wieslaw Suszynski		Manager of Coating Process and Visualization Laboratory, Experiments and selection of chemicals			36.5%	0.9		\$111,496
Post-Doctoral Associate		Design and experiments on ice/pavement removal device			25.4%	3		\$201,551
							Sub Total	\$644,251
Contracts and Services								
							Sub Total	-
Equipment, Tools, and Supplies								
	Tools and Supplies	Laboratory supplies to run experiments	The Coating Process and Visualization Laboratory will require \$11,749 for supplies to facilitate experiments, and the pavement laboratory will require \$10,000 to facilitate experiments.					\$21,749
							Sub Total	\$21,749
Capital Expenditures								
							Sub Total	-

Acquisitions and Stewardship								
							Sub Total	-
Travel In Minnesota								
							Sub Total	-
Travel Outside Minnesota								
							Sub Total	-
Printing and Publication								
							Sub Total	-
Other Expenses								
							Sub Total	-
							Grand Total	\$666,000

Classified Staff or Generally Ineligible Expenses

Category/Name	Subcategory or Type	Description	Justification Ineligible Expense or Classified Staff Request
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Non ENRTF Funds

Category	Specific Source	Use	Status	Amount
State				
			State Sub Total	-
Non-State				
			Non State Sub Total	-
			Funds Total	-

Attachments

Required Attachments

Visual Component

File: [0e76c5f4-e44.pdf](#)

Alternate Text for Visual Component

Clockwise from upper left: A diagram of a roadway showing how current de-icing is an inefficient means of removing ice, a photo showing how different deicing chemicals can spread on the pavement, a sketch showing how stormwater ends up in receiving water bodies, and a conceptual diagram showing one means of improving de-icing technology.

Optional Attachments

Support Letter or Other

Title	File
U of M financial report, 2019	33f14b2b-ec4.pdf
Letter from Sponsored Projects Administration	b00daf21-c7c.pdf
Support letter from MnDOT	8591cb17-e36.pdf

Administrative Use

Does your project include restoration or acquisition of land rights?

No

Does your project have patent, royalties, or revenue potential?

Yes,

- Patent, Copyright, or Royalty Potential

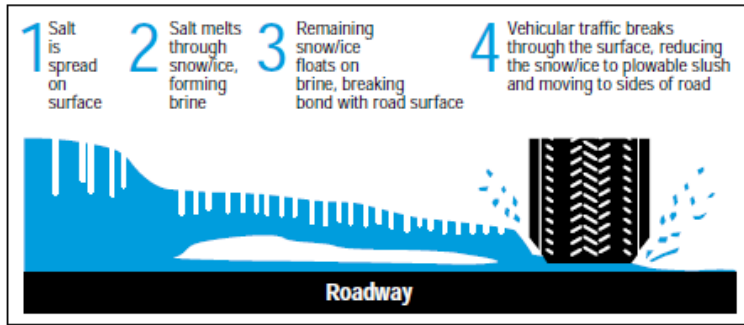
Does your project include research?

Yes

Does the organization have a fiscal agent for this project?

Yes, Sponsored Projects Administration

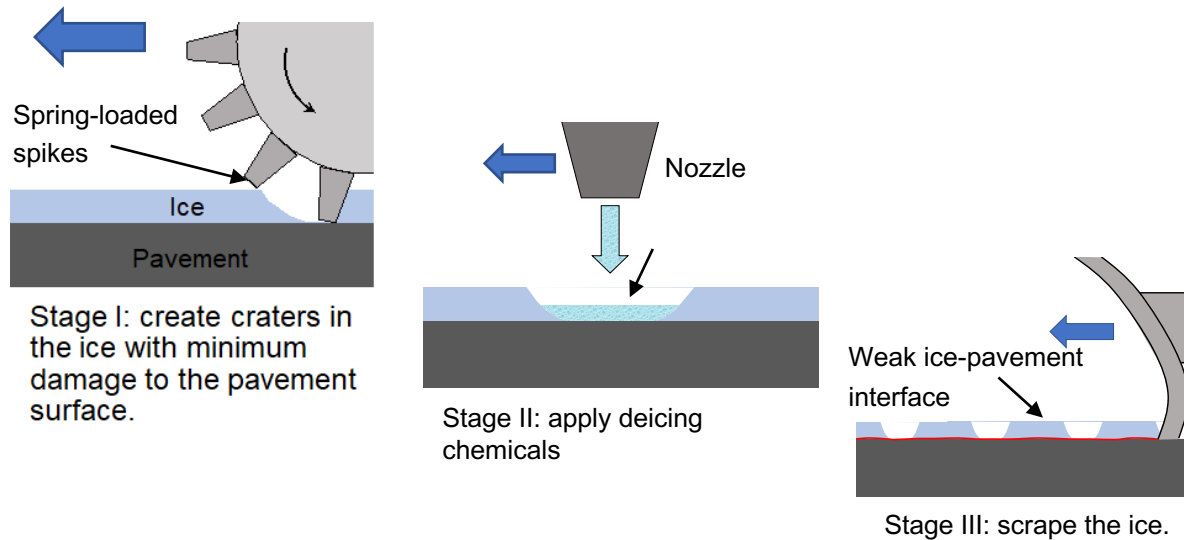
Project Title: Reduction of Environmental Impacts with Road De-icing Alternatives



Use new de-icing materials that weaken the ice-pavement bond

Replace inefficient spreading of salt (large quantities, slow reaction rate)

Use innovations in ice/snow removal technologies



Investigate Environmental Impacts

