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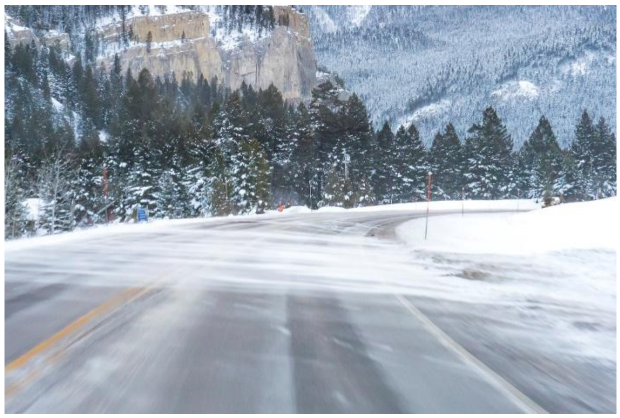

South Dakota Blowing Snow Mitigation Strategies, Prioritization, and Implementation

Study SD2023-06

Final Report

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16. Abstract

Blowing and drifting snow on the roadway can cause major challenges for safety and mobility, as well as increased maintenance needs. This challenge can be particularly problematic in more rural locations where the distance for a snowplow to travel to treat an impacted roadway can be longer. In addition, if a road were to shut down due to weather impacts, there may be fewer alternative routes available for the traveling public, resulting in decreased access to potentially critical services. The 2021-2022 winter in South Dakota resulted in record-breaking snowfall, and with it, significant costs for winter maintenance operations. As a result, the South Dakota Department of Transportation (SDDOT) is seeking to reduce the need for mechanical snow removal by controlling the blowing snow before it impacts roadways. To do so, literature on the topic of blowing snow mitigation was reviewed, interviews with surrounding states were conducted to gain insight on snow fence implementation and challenges, interviews with SDDOT maintenance staff were conducted where blowing snow problem areas were identified, blowing snow problem areas on South Dakota rural highways were mapped, the top 100 problem areas were prioritized utilizing a data-driven approach, and finally, a guidance document was developed to assist users with planning-level mitigation measures that could be applied to the identified areas.

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TABLE OF ACRONYMS

Acronym	Definition
AADT	Average Annual Daily Traffic
BSHARP	Blowing Snow Hazard Assessment and Risk Prediction
BSSI	Blowing snow susceptibility index
C	Carbon
CO_2	Carbon Dioxide
CFD	Computational Fluid Dynamics
CRP	Conservation Reserve Program
DOT	Department of Transportation
FFA	Future Farmers of America
FHWA	Federal Highway Administration
FLMA	Federal Land Management Agencies
ft	Feet
GPS	Global Positioning System
HSIP	Highway Safety Improvement Program
Hwy	highway
INCA	Integrated Nowcasting Model
IRB	Institutional Review Board
kW	Kilowatt
kWh	Kilowatt Hour
lbs	Pounds
L/H	Length-to-Height
LSF	Living Snow Fence
MDSS	Maintenance Decision Support System

Acronym	Definition
MDT	Montana Department of Transportation
Mg C	Mega grams of carbon
MnDOT	Minnesota Department of Transportation
mph	miles per hour
MRMs	Mileage Reference Markers
MSU	Montana State University
NCHRP	National Cooperative Highway Research Program
NDDOT	North Dakota Department of Transportation
NDSU	North Dakota State University
NW	Northwest
PAD-US	Protected Areas Database of the United States
PBSM	Prairie Blowing Snow Model
PROTECT	Promoting Resilient Operations for Transformative, Efficient, and Cost-saving Transportation Program
PSA	Public Service Announcement
REBS	Roadway Environment Blowing Snow
ROW	Right-of-Way
RWIS	Road Weather Information System
SAS	Snow Accumulation Season
SDDOT	South Dakota Department of Transportation
TLN	Transportation Learning Network
USDA	United States Department of Agriculture
USFS	United State Forest Service
WHYM	Wintertime Hydrologic Model

Acronym	Definition
WisDOT	Wisconsin Department of Transportation
WRF	Weather Research and Forecasting Model
WVC	Wildlife-Vehicle Collision
WYDOT	Wyoming Department of Transportation

1.0 EXECUTIVE SUMMARY

This report summarizes the research project, *South Dakota Blowing Snow Mitigation Strategies, Prioritization, and Implementation*. The following sections discuss the findings from a literature review of blowing snow mitigation strategies, findings from interviews with surrounding states, input obtained through interviews with SDDOT maintenance staff, a summary of the blowing snow locations identified on South Dakota rural highways, the prioritization process to identify the Top 100 blowing snow locations, and a summary of the guidance document. Then after, the conclusions and recommendations generated as a result of the research are described.

1.1 Literature Review of Blowing Snow Mitigation Strategies

An extensive literature review was conducted as part of the research. Research on the following topics were sought out for review and inclusion: 1) how snow fences work, 2) types of snow fences, 3) design considerations of snow fences, 4) blowing snow models and forecasts, 5) carbon sequestration potential and emission reduction, 6) impacts to wildlife, 7) safety impacts of snow fences, 8) cost and benefits of snow fences, 9) communication strategies, and 10) compensation strategies. Ronald D. Tabler was involved in much of the foundational research associated with the topic of snow transport and ultimately the design of snow fences. Today, while significantly fewer research studies are being conducted, tweaks or contemporary approaches to design, like the use of solar panels, are being experimented with. Furthermore, since much of the foundational research was conducted in the Mountain West, other northern states, with different climatic conditions, are making practical modifications.

1.2 Interview Surrounding States

Interviews were conducted with the six state departments of transportation (Iowa, Minnesota, Montana, Nebraska, North Dakota, and Wyoming) that surround South Dakota, as well as the Wisconsin Department of Transportation, to gain an understanding of blowing snow mitigation strategy implementation efforts, best practices, lessons learned, and funding mechanisms utilized. Limited funding available for the installation of snow fences was identified as a common barrier. Project and operating funds were the most typical funding sources used for their implementation. A few creative ways for funding snow fences, both at the federal (e.g., PROJECT) and state (e.g., Environmental and Natural Resources Trust Fund) level, were identified.

1.3 Obtain SDDOT Input

Interviews were conducted with all 12 SDDOT maintenance areas to identify locations where blowing and drifting snow are occurring on rural highways, as well as potential challenges to the implementation of blowing snow strategies. A notable quote from the interviews is as follows: “Putting up a snow fence on a secondary route is like having an extra plow to do work.” The experience of the maintenance areas varied, from limited interest in snow fences to innovative approaches, like a wooden board fence. The need for blowing snow mitigation measures seems to vary across the state, with west river (those areas west of the Missouri River) generally seeming to have fewer needs, while east river (those areas east of the Missouri River) has more. Yet, the value of land east river is reported to have resulted in limited cooperation by landowners to work with SDDOT maintenance staff to address blowing snow challenges. Two aspects highlighted as challenges when considering the use of standing corn rows as snow fences are: 1) the every-other-year rotation between soybeans and corn to ensure sufficient nutrients remain in the soil which can cause blowing and drifting snow one year and provide for a potential snow fence the opposite year, and 2) the orientation of some corn rows was reportedly not desirable for the standing corn rows to be used as snow fences (e.g., not perpendicular to the prevailing wind).

1.4 Identify Blowing Snow Locations

SDDOT maintenance areas identified and prioritized blowing snow problem locations within their area. The total number of blowing snow problem areas differed across the maintenance areas, with as few as two blowing snow problem areas (Winner Area) and as many as fifty-three (Aberdeen Area). The total length of blowing snow problem areas by maintenance area ranged from a low of 2.49 total miles (Mobridge Area) to as long as 122.32 total miles (Custer Area).

1.4.1 Top 100 Blowing Snow Problem Areas on South Dakota State Rural Roadways

The identified blowing snow problem areas on rural, non-interstate South Dakota highways were prioritized utilizing a data-driven scoring methodology. Variables used for prioritization include: maintenance area feedback, crash and incident data, roadway functional classification, distance from maintenance shop, and prevailing wind direction. Other variables were considered for inclusion into the prioritization process, but challenges with them led to their removal.

Maintenance area feedback was considered the most important variable; its maximum prioritization score was 40. Crash and incident data consisted of blowing snow crashes; winter weather crashes; fatal and injury winter weather crashes; winter road condition crashes; fatal and injury winter road condition crashes; and slide-ins. Thirty total points were assigned for prioritization based on the crash and incident data, distributed as follows: blowing snow crash rate (5 points); winter road crash rate (10 points); fatal and injury winter road crash rate (2 points); winter weather crash rate (10 points); fatal and injury winter weather crash rate (2 points) and; slide-ins (1 point). The greatest number of blowing snow problem areas occurred on roadways with the functional classification, "Rural – Minor Arterials." The maximum prioritization score of 5 was assigned to "Principal Arterial (Urban)/Freeway (Urban)." Distance from the maintenance shop was a representation of the cost to treat the blowing snow problem areas; the maximum points assigned for prioritization were 10. An analysis of ten years of winter wind data (2014-2024) suggests that when the probability of blowing snow conditions was present (wind speeds are greater than or equal to fifteen miles per hour), the wind typically comes from the northwest. This data-driven result correlated with feedback from SDDOT maintenance staff who reported prevailing winds predominantly from the northwest. While South Dakota has an extensive Road Weather Information System (RWIS) network across the state, not all blowing snow problem areas have an RWIS station within a reasonable distance for wind data to be applied. RWIS stations east river show the greatest propensity for blowing snow conditions. RWIS within the Custer and Rapid City Maintenance Areas have a lower percentage time during which blowing snow conditions are present. Consequently, Custer and Rapid City each received 2 points for wind, and all other maintenance areas received 5 points.

The Mitchell Area had the greatest number of blowing snow problem areas (n=15) in the Top 100 list; the Winner Area had the fewest (n=2). The Custer Area had the greatest length of blowing snow problem areas in the Top 100 list (122.02 miles), and the Mobridge Area had the shortest length (2.21 miles).

1.5 Develop a Guidance Document

A Guidance document was developed that provides information on blowing snow treatment strategies, including structural snow fences, temporary snow fences, living snow fences, earthwork grading, snow berming, and non-traditional options. To aid SDDOT in determining which blowing snow treatment may work at each of the top 100 sites identified, summary tables are provided with critical information for each site that includes site location, length, adjacent land ownership, feasibility of structural, living, or temporary snow fence placement, and feedback from the maintenance districts on their preference of blowing snow treatment. To support SDDOT in selecting a blowing snow treatment for each of the 100 locations identified, additional guidance is provided on adjacent land and working with landowners, maintenance effort, site-specific considerations, and funding for implementation of these strategies. An overview of key basic design considerations like soils, geology, terrain, context sensitivity and land use planning, and wildlife is discussed, but any design effort should be based on Tabler (2003) (1). Additional resources to support this effort are provided.

The guidance document provides historical information on costs and benefits of various blowing snow treatment strategies, resources for conducting a cost-benefit analysis, and presents a lifecycle framework tool to compare costs to build and maintain a blowing snow treatment strategy versus the life span.

1.6 Recommendations

Nine recommendations are presented for SDDOT's consideration.

1.6.1 In-Depth Crash Analysis to Determine Additional Blowing Snow Areas

An in-depth crash analysis should be conducted to determine if additional blowing snow areas should be considered for blowing snow mitigation strategies. In addition, there are several other opportunities for micro-level crash analyses that South Dakota could consider.

The analysis of crashes and slide-in data are centered on the blowing snow problem locations which were identified by SDDOT Maintenance Areas. A review of the crash and slide-in data suggests that crash and slide-in clusters exist outside of the locations identified by SDDOT Maintenance Areas. These additional locations could be where solutions like grading and snow fences are already programmed in by projects. The locations could also be undetected by SDDOT Maintenance Areas (an analysis could identify why) or they may reflect lower priorities for SDDOT Maintenance Areas.

While the above is a macro-level crash analysis, additional opportunities could be identified to mitigate blowing snow crashes by conducting a micro-level crash analysis. This analysis would review the narrative, types, conditions present, roadway geometry, and potential presence of wildlife specific to crashes identified as "blowing snow" crashes in the data. Such an analysis could also instead consider several randomly selected rural South Dakota corridors and review how crashes specifically identified as "blowing snow" differed from those associated with other winter crashes to understand if there is a bias in the data or those specific to "blowing snow" tend to more precisely relate to the impacts of blowing snow. Finally, a more detailed crash analysis could include collaborating with South Dakota Highway Patrol to better determine the location of the first harmful event of the crash as compared with the end resting place of a vehicle, to determine if there are gaps regarding crash location identified and the cause behind the crash.

1.6.2 Collaborate with DTN to Improve Their Blowing Snow Model for South Dakota

SDDOT should consider working with DTN (their MDSS provider), to define at a higher resolution, sheltered, semi-sheltered, and unsheltered routes which will help to improve the MDSS blowing snow model.

In MDSS, a blowing snow model has been developed which allows for each route to be defined as sheltered, semi-sheltered and unsheltered. Yet, the length of some of the routes does not well capture the variation that can be experienced along the route regarding blowing snow impacts. Therefore, SDDOT should consider coordinating with DTN regarding opportunities to provide a more disaggregated understanding of the blowing snow impacts experienced along the route.

1.6.3 Improve Cost Estimates by Incorporating Snowplow Routes

SDDOT can improve cost estimates by incorporating snowplow routes to determine the distance from the maintenance garage to each blowing snow problem area.

SDDOT should work with each maintenance garage to map out snowplow routes to better determine specific costs of treating the identified blowing snow problem areas to allow for better cost-benefit analysis. As described in Distance from Maintenance Shop, the analysis presented herein used estimates.

1.6.4 Develop Communication Guidance for Adjacent Landowners About Blowing Snow Challenges and Treatment Options

SDDOT should develop guidance to improve communication with landowners about the snow fence program and the benefits of participation.

SDDOT should develop communication guidance that includes efforts to improve communication with landowners, participation in community meetings, providing training, and leveraging support from conservation districts, farm bureaus and co-ops, and State Forestry to help encourage buy-in from landowners. One document that can assist with the development of communication guidance is MnDOT's *Promoting the Adoption of Snow Fences through Landowner Engagement* (https://mdl.mndot.gov/index.php/items/202214) (2). Early and often communication is suggested to support SDDOT in creating working relationships and maintaining these partnerships. Landowner involvement is critical to the success of these programs.

A part of this effort may include the development of communication materials which include information on safety, cost, benefits, reimbursement rates, and landowner expectations (e.g., access for snow fence installation and maintenance), and testimonials. It is recommended that the existing knowledge of maintenance crews be integrated into materials, as they will know the land, the road, the weather, and most likely the landowners.

A tool that could be used to communicate this information is a short pamphlet that can be shared. The South Dakota Department of Agriculture and Natural Resources created, *The Living Snow Fence Program in South Dakota*, (https://danr.sd.gov/Conservation/docs/InfoPubs/LSF-Brochure.pdf) (3) in 2010. This document could be updated to more recent times using information gathered from this effort.

These efforts could include increasing public awareness of why snow fences are important. SDDOT could develop a Public Service Announcement (PSA) about snow fences to aid in buy-in. SDDOT communication folks could work with local news organizations to help disseminate the benefits of snow fences, like this example from Minnesota: https://www.keyc.com/video/2023/01/09/mndot-farmers-join-forces-combat-snow-fences/. The video highlights the landowner and maintenance supervisor and provides overarching benefits of snow fences. Photos could be captured by SDDOT central office staff or by maintenance staff.

1.6.5 Set Snow Fence Program Metrics – Collect Data

When implementing blowing snow mitigation strategies, SDDOT should collect program data to better understand the benefits and costs.

SDDOT should prioritize addressing a select number of blowing snow problems annually, collecting data that will help SDDOT to understand the challenges and benefits. Over time, SDDOT will better understand how locations that might be deemed as “tricky,” could be addressed with an appropriate treatment. To support programmatic decisions and to show the effectiveness of installations, collecting data on all aspects of blowing snow treatments is recommended. Recommended data fields include but are not limited to the following: the reasoning for the selection of a blowing snow treatment; the installation date; all costs to design, build, and maintain; and detailing communication efforts with landowners. This will help develop a detailed cost-benefit analysis of the treatments applied. Furthermore, SDDOT should ensure that a group of staff members are trained on the process and results, to ensure that as staffing changes over time, the institutional knowledge is retained.

1.6.6 Add Blowing Snow Strategies as a Topic at SDDOT’s Annual Maintenance Meeting

SDDOT should consider conducting peer exchanges on blowing snow mitigation strategies so maintenance crews can learn from each other and their peers.

SDDOT should consider including snow fencing and other blowing snow strategies as a topic at the Annual SDDOT Maintenance Meeting. This could include having maintenance staff present on successful implementation of snow fences and potential pitfalls to avoid. This could also include potentially bringing in people from other states to present on their snow fence implementations. The presentations should represent potential solutions and examples from both east and west river.

1.6.7 Disseminate the Findings of the Project

SDDOT should consider sharing the findings of this project with others within SDDOT and with peer organizations at conferences, trainings, and workshops.

As mentioned in the literature review section, there are few recent research efforts occurring related to snow fences. Disseminating the results of this research effort could help other state DOTs as they look to implement snow fences. Generally, snow fences were popular around the time of research conducted by Tabler. However, in more recent years, with a focus on cost savings, efficiencies in practices (e.g., using less salt), there is a need to reconsider solutions like snow fences and grading.

1.6.8 Develop a Memorandum of Understanding for Critical Routes

SDDOT should consider developing or revising an MOU for landowners, schools, and emergency services to prioritize critical routes.

SDDOT should consider developing memorandums of understanding (MOUs) for critical routes. As landownership changes may result in the new owner not understanding existing agreements regarding snow fences, developing a written MOU ensures the transferability of agreements. In rural areas, highways are critical routes for residents to obtain medical care and access and receive goods and services. Routes closed as a result of drifting snow can prevent access for school buses to pick up and drop off students and impair the travel of emergency vehicles. While it can be impractical to keep all local routes open, specific routes should be identified that emergency vehicles can depend on to remain open in case of an emergency. MOUs should address what SDDOT is prepared to do to keep critical routes open during severe winter weather. These actions can be as commonplace as plowing school bus routes before the beginning and ending of the school day.

1.6.9 Review Existing LSFs for Present Day Functionality

SDDOT should review the present day functionality of existing LSFs.

SDDOT provided information to the researchers about existing snow fences, including LSFs. Early LSF designs included tree species that grew too large over their more than 20-year life span, such that they no longer trap snow as intended. Adding or replacing trees with other species, like juniper, will allow the LSF to continue to function as originally intended. Therefore, the researchers recommend that SDDOT review LSFs identified in the file shared to confirm that they are functioning as intended.

2.0 PROBLEM DESCRIPTION

South Dakota Department of Transportation's (SDDOT's) strategic plan includes a short-term goal of reducing winter-related crashes (4). Grading can and has been used by SDDOT to address winter-related crashes caused by blowing snow. Another strategy that can be employed to support this goal is the installation of snow fences. Snow fences are designed to disrupt the wind flow carrying snow particles, causing them to drop from the wind stream and deposit the snow at the fence instead of on the roadway (5). Snow will start to blow when winds reach about fifteen miles per hour (1). Blowing snow can have significant impacts, considering that the amount blown onto the roadway can be one hundred times that which falls directly onto the road (5). Blowing snow can reduce a driver's visibility and cause snow drifts on roadways. In rural areas, where detection and subsequent response times can be delayed due to distances between emergency medical services and where crashes may occur, the consequences can be fatal. Furthermore, where snow drifts occur, additional effort is required to treat and maintain passable roadways.

A permanent snow fence can be created in three ways: a structural snow fence, a living snow fence (LSF), and a solid snow fence (6). Structural, porous snow fences are often built using horizontal or vertical slatted fencing, which can function as a wind break, allowing snow to settle rather than blow across a roadway. LSFs consist of trees, shrubs, grasses, or rows of a crop, like corn, left in place ((5), (7)). Earthwork grading can be used to create storage areas for blowing snow and for plowed snow. Snow berms, sometimes called ridging, also act as a solid snow fence that can be created outside the right-of-way, although they need to be maintained throughout the winter and as such, require significant maintenance. They are short-term solutions. Snow berms retain water, which some landowners may welcome, whereas others may find to be a nuisance because it can cause muddy fields.

Snow fences offer many benefits, including maintaining open roadways, reducing crashes, reducing winter maintenance needs (Figure 1), storing water, serving as habitat for certain wildlife species, providing shelter for livestock, and sequestering carbon ((5), (7)). Research in neighboring states has suggested an average benefit-to-cost ratio as a result of the provision of snow fences to be 17:1 ((3), (8)).

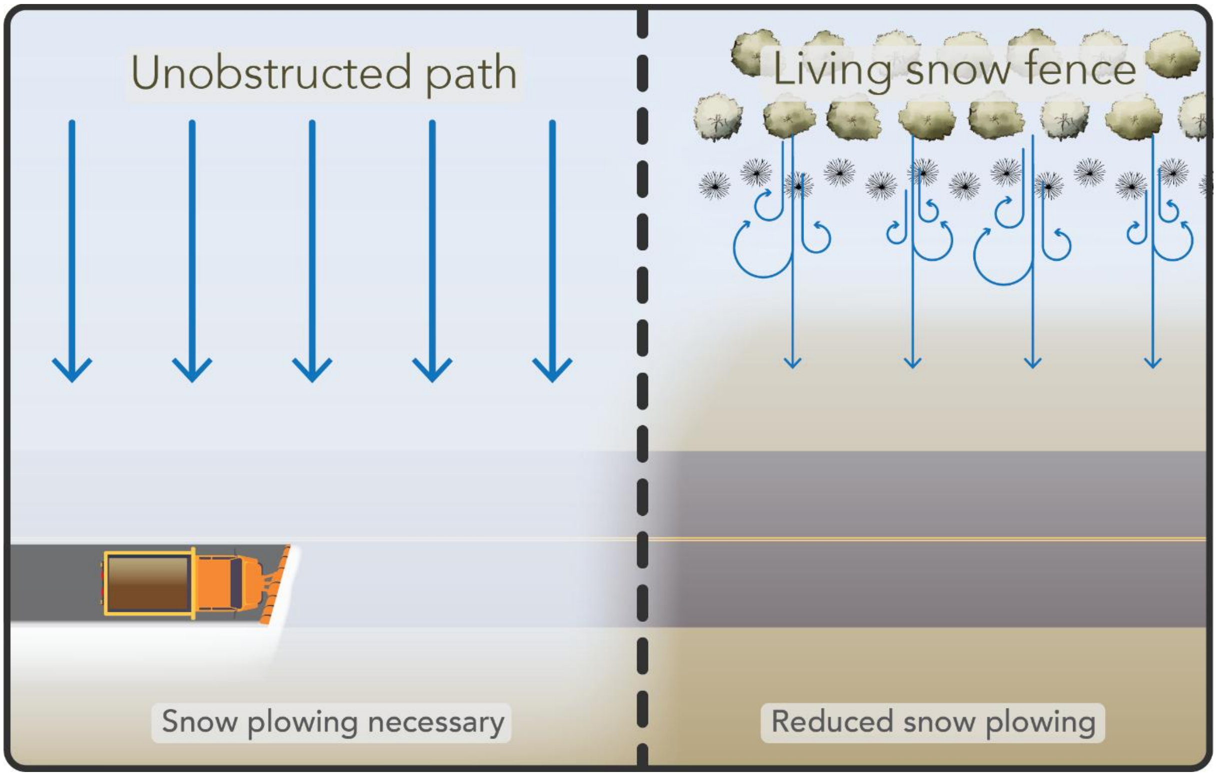

Figure 1: Visual representation of how a living snow fence can improve roadway conditions during blowing snow events.

3.0 RESEARCH OBJECTIVES

3.1 Evaluate commonly used blowing snow mitigation strategies and designs and give the benefits, challenges, and suitability for each.

Snow mitigation strategies and designs will be identified through the literature review, from speaking with other state DOTs, and drawing on the expertise of the team. In addition, information collected by speaking with SDDOT regional employees and the South Dakota Highway Patrol will be used to obtain information about ongoing snow mitigation efforts in South Dakota. Comprehensively, the information gathered will help to inform strategies utilized, funding leveraged, identify best practices, and determine lessons learned.

The researchers conducted an extensive literature review and drew from resources our Subject Matter Expert had utilized. A survey was developed, reviewed, and approved by SDDOT and MSU's Institutional Review Board (IRB) and distributed to the Iowa, Minnesota, Montana, Nebraska, North Dakota, Wisconsin, and Wyoming Departments of Transportation for input. Interviews were conducted with all SDDOT Areas using a survey tool developed and approved by SDDOT and MSU's IRB. The researchers also obtained slide-in incident data from the South Dakota Highway Patrol. An evaluation of snow mitigation strategies available, best candidates, and considerations for the identified top 100 blowing snow problem areas has been completed, as well as cost-benefit framework.

3.2 Identify the potential impacts of snow fences on wildlife migration, habitat fragmentation, and carbon sequestration and emissions to ensure environmentally responsible implementation.

The WTI Team includes an expert in road ecology who can help to inform, through both practical experience and a review of relevant literature, the potential impact of snow fences on wildlife migration and habitat fragmentation. Carbon sequestration and emission reduction will be estimated by better understanding how frequently SDDOT staff currently conduct maintenance to address blowing snow impacts, and the anticipated impact of these should a snow fence be implemented. In addition, one could consider whether or not to introduce the emissions from motorists stranded by blowing snow blocking the roadway. Carbon can be sequestered both through the application of an LSF and by reducing the maintenance needs.

The researchers conducted an extensive literature review, as well as drew from resources our Subject Matter Expert had utilized. A survey was developed, reviewed and approved by SDDOT and MSU's IRB, and distributed to the Iowa, Minnesota, Montana, Nebraska, North

Dakota, Wisconsin, and Wyoming Departments of Transportation for input. Interviews were conducted with all SDDOT Areas, using a survey tool developed and approved by SDDOT and MSU's IRB. Wildlife species and their positive and negative interaction with the various snow mitigation strategies have been explored. A cost-benefit framework provides carbon sequestration and emission values that can apply.

3.3 Develop a prioritized list of non-interstate routes, of blowing snow mitigation locations based on the benefit-cost analysis of the preferred strategies, provide a preliminary cost estimate, and identify potential funding types.

Findings from the literature review and interviews with SDDOT regional employees will be used in coordination with data in order to identify potential locations for snow fences. Costs and benefits that can be incorporated into the analysis include crash history, winter maintenance costs, winter weather severity, and potential carbon sequestration and emission reductions. It is anticipated that the comprehensive literature review as a part of this effort may identify other criteria for incorporation.

Potential funding types will be identified by speaking with other state DOTs as well as with SDDOT. In addition, the researchers are aware of other funding sources that may be considered. For example, depending upon a state's objectives, highway safety improvement program (HSIP) funds could be consulted to determine if the reduction in crashes would warrant the use of funds from this program. As the reduction of winter crashes was specifically called out in SDDOT's strategic plan, it seems that there is the opportunity for such a use. Other funding programs that could be assessed are the Conservation Reserve Program (CRP), Environmental Quality Incentive Program (EQIP), and State Transportation Innovation Councils (STIC).

SDDOT Maintenance Areas provided information on their blowing snow problem areas. These areas were prioritized to the top 100 rural blowing snow locations using several data variables. These included: 1) SDDOT Maintenance Area priority; 2) crash and incident data (slide-in incidents, blowing snow crashes, winter weather crashes, and winter road condition crashes) within 250 feet of a blowing snow problem area, 3) roadway functional classification (used as a proxy for route priority and annual average daily traffic (AADT)), 4) distance from maintenance shop (used to examine potential costs to treat a blowing snow problem area), and 5) prevailing wind speeds within 250 feet, 1 mile, and 5 miles of a blowing snow problem area where RWIS sites are present.

A high-level cost-benefit framework has been developed that allows SDDOT to compare various blowing snow treatments for each of the top 100 rural blowing snow locations. This includes an examination of the cost to treat a blowing snow problem area as well as a high-level look at surrounding land use which may lead to one blowing snow mitigation strategy over another (e.g., LSFs along areas with cultivated crops). Additionally, the framework considers feedback from the SDDOT Maintenance Areas on blowing snow mitigation strategies which will or will not be implemented based on previous experience.

Potential funding options were identified during the literature review and discussions with neighboring state DOTs and include: USDA funding through the Farm Bill and Farm Service Agency, USDA CP17A Living Snow Fence program, Trunk Highway Funds, district-level funding, Highway Safety Improvement Funds (HSIP), and a state's lottery.

3.4 Develop a guidance document to implement a blowing snow mitigation program in South Dakota.

The researchers will develop a guidance document based on the knowledge acquired throughout the research project for SDDOT. The researchers will draw on their experience creating guidance documents to create an easy-to-read resource.

The researchers developed a guidance document based on the knowledge acquired throughout the research project. Blowing snow mitigation options, including structural (temporary and permanent), living snow fence, and grading (earthwork, snow ridging), are presented. Guidance is also provided related to SDDOT Maintenance Area feedback, existing blowing snow treatment options used, maintenance effort and cost, site-specific considerations, and collaborating with adjacent landowners.

4.0 TASK DESCRIPTIONS

This section describes all twelve tasks for the project:

1) kick-off,
2) literature review of blowing snow mitigation strategies,
3) interview surrounding states,
4) obtain SDDOT input,
5) develop and present, technical memorandum for Phase I,
6) identify blowing snow locations,
7) top 100 blowing snow locations on South Dakota roadways,
8) develop and present, technical memorandum for Phase II
9) develop a guidance document,
10) present guidance document to technical panel,
11) develop final report,
12) present guidance document to SDDOT research review board.

4.1 Kick-Off

Meet with the project's technical panel to review the project scope and work plan.

The project kick-off meeting was held on April 11, 2024.

4.2 Literature Review of Blowing Snow Mitigation Strategies

Perform an extensive literature review relevant to all commonly used blowing snow mitigation strategies, including types of snow fence and grading improvements. Describe the benefits and challenges of each, their suitability, and potential impacts on wildlife migration, habitat fragmentation, and carbon sequestration and emissions.

Snow fences were said to have been first used in 1852 to address blowing snow impacts on railroad lines (5). However, it was not until the growing popularity of automobiles and their cross-country travel, starting around the 1930's, that snow fences began to be used more frequently. In fact, in the United States, Wyoming is suggested as one of the earliest adopters, with a reported sixty-three miles of snow fence in 1927 (5). Figure 2 highlights some key points regarding the use of snow fences over time.

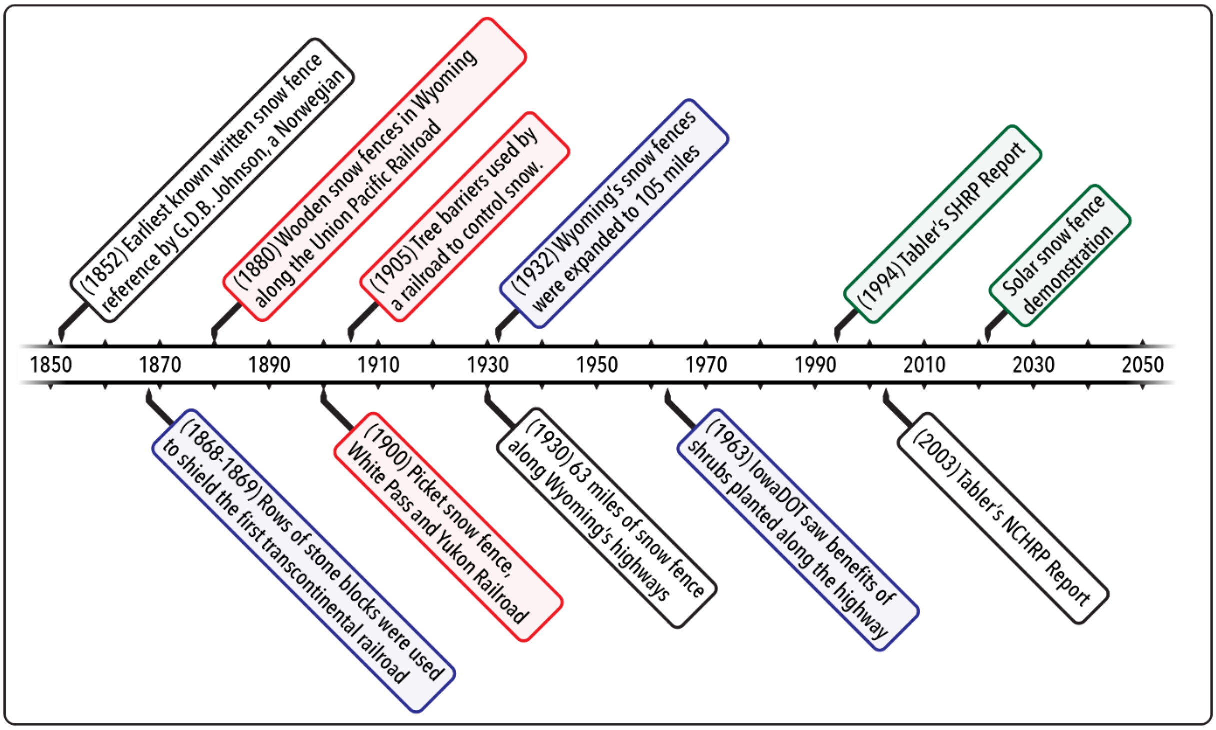

Figure 2: Timeline of snow fence use.

Much of the research and design recommendations on snow fences come from Ronald D. Tabler, with a 2003 guide noting that it was an updated resource that included research and technology advances that occurred in the ten years between its publication and the publication of *Design Guidelines for the Control of Blowing and Drifting Snow* (9) in 1994. Since a new, comprehensive guide has not been published in twenty years, the following sections present the root knowledge related to categories of interest, layered with the most recent knowledge on the topic, organized by the following:

1. How Snow Fences Work
2. Types of Snow Fences
3. Design Considerations for Snow Fences
4. Blowing Snow Models & Forecasts
5. Carbon Sequestration Potential & Emission Rates for Various Strategies
6. Benefits & Impacts of Wildlife
7. Comprehensive Safety Impacts of Snow Fences
8. Cost/Benefits
9. Communication Strategies with the Public
10. Compensation Strategies for Private Landowners.

4.2.1 How Snow Fences Work

A snow fence is essentially intended to modify wind flow to cause airborne snow to be deposited in a desired location (10). Figure 3 shows a schematic of how a structural snow fence traps blowing snow (11) where the following elements are identified: upwind drift, downwind drift, recirculation zone, cornice, and slip face (12).

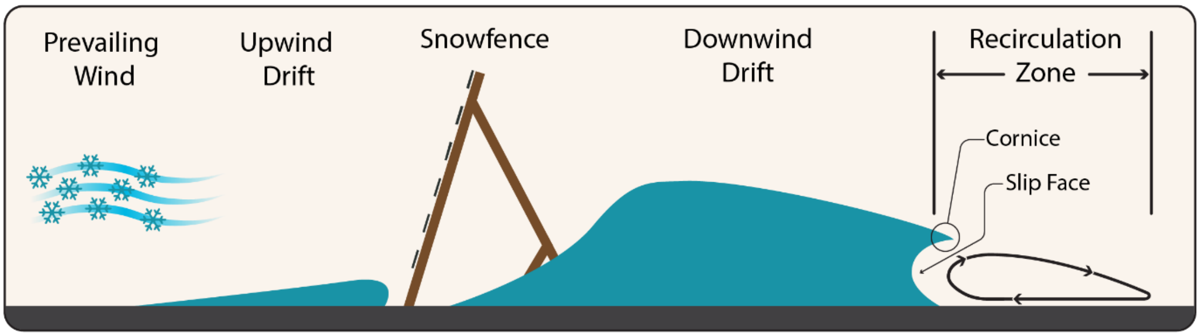

Figure 3: Schematic of how a structural snow fence traps blowing snow & features.

Long, open, level areas result in a significant amount of snow being transported (10). The duration and intensity of storms also impact a barrier's design (10).

Creep (large snow crystals), saltation (medium snow crystals), and turbulent diffusion (small snow crystals) all contribute to the relocation of snow on the ground by the wind (13). In the simplest sense, snow fences serve as obstructions that help to reduce the wind speed and consequently the movement of snow. By doing so, there is a need to allow storage space for the impacted snow moving through the air, which consequently impacts how close a snow fence can be to a roadway based on its height and porosity (e.g., the ability of the snow to travel through the snow fence). Equilibrium drift is the maximum capacity of the snow fence.

Reducing the wind speed by 50% with the use of snow fences is equated to an approximately 94% reduction in snow transport.

In *Trapping Efficiency of Snow Fences and Implications for System Design*, Tabler and Jairell (11) discussed the history and science behind how snow fences work. Basic concepts of snow fence design are introduced, as well as transportation and porosity, and how snow drifts are formed. Snow fences work by disturbing the wind flow, which allows snow particles to drop out of the wind stream. These particles freeze together on contact, which is how snow drifts are started. Bottom gap, porosity, terrain, fence height, and length all impact snow drift formation and location. For a 50% porosity Wyoming fence, 85% of the snow is deposited on

Doubling the speed of wind results in an almost 14 times increase in the movement of snow.

the downwind side of the fence. This translates into a rule of thumb that 30H to 35H (H being the height of the snow fence) of downwind storage is needed. For a 12-foot-high snow fence, 420 feet of downwind storage is necessary for the fence to fill and not impact the road. If the bottom gap is too low, the drift will form within the structure of the fence, potentially crushing the structure. If the porosity is less than 50%, the upwind drift will form upwind before downwind. For some locations, that may be an ideal design, but less snow is stored and the fence will fill faster. For porosities greater than 50%, the snow drift will form further away from the snow fence, potentially creating a situation where the drift will impact the roadway. High porosity fences typically hold less snow overall and will need additional storage area to hold the snow. The rule of thumb of 35H for downwind snow storage will not apply for high porosity fences. For example, reducing the wind speed by 50% with the use of snow fences results in about a 94% reduction in snow transport. Doubling the speed of wind results in an almost 14 times increase in the movement of snow.

4.2.2 Types of Snow Fences

Generally speaking, two types of snow fences are most commonly identified: structural and living snow fences ((5), (6)). However, earthwork or snow berms can be used to create what may be termed “solid” snow fences.

4.2.2.1 Structural Snow Fences

Structural snow fences can be porous or non-porous (6). Non-porous snow fences have less snow storage capacity (6). Non-porous snow fences are almost completely solid, with a porosity of ten percent or less that essentially only allows some wind through (6). They have been applied to protect a railway line in Spain (6). If the goal of the snow fence is to collect as much snow as possible, non-porous snow fences are not the optimal solution; they are good solutions, however, where space is limited (6). In addition, non-porous snow fences may be visually unappealing because they are a solid vertical wall blocking views (6).

Ordered from most common to least common, wood, metal, plastic, and concrete have all been used to create porous snow fences (6). Wood snow fences are commonly used in Wyoming (6). Porous snow fences are designed to impact the wind profile, thereby changing how snow accumulates based on the design of the snow fence (6). The porosity percentage, height, length, and bottom gap of porous snow fences will impact their storage capacity ((5), (6)). Fifty percent porosity was reported as the most effective ((5), (6)). The greater the height, the greater the number of particles captured and stored. Typically, Wyoming structural barriers are less than 3.75 meters (12.3 ft) (10). Canadian structural snow fences are typically 1.2 meters (3.9 ft) in height (10).

Assuming other factors remain constant, doubling the height of a snow fence is said to quadruple the storage capacity ((5), (6)). Some recommendations identify ten to fifteen percent of the total snow fence height as the desirable bottom gap for snow fences with a fifty percent porosity, although recently, Wyoming has seen effectiveness with a much lower bottom gap ((5), (6)). Another important variable that influences the effectiveness of structural snow fences is the angle between the snow fence and the wind direction, with a perpendicular orientation preferred (5).

Recently, applying solar panels to a structural snow fence was demonstrated and evaluated in Wyoming (12). The concept is intended to provide year-round benefits from a structural snow fence by producing solar power which can either power an intelligent transportation system component, like a dynamic message sign, or benefit a landowner whose land hosts a snow fence by providing them with the generated power. To obtain the benefits from the solar snow fence, there needs to be the ability to transfer its generated power.

4.2.2.2 Living Snow Fences

Railroad companies were some of the first to use tree barriers to control snow, with the first reported such installation in 1905 in North Dakota by the Great Northern Railway Company (10). The Wyoming State Highway Department (predecessor to WYDOT) initiated a living snow fence (LSF) program in 1927 but discontinued it in the 1930s when drought caused significant mortality. In 1963, the Iowa Department of Transportation (DOT) planted shrubs along an interstate highway and noted that they provided some benefits (5). LSFs are formed by growing one or more rows of trees, bushes, and other plantings to control snow ((5), (6), (7)). The density of vegetation directly influences its effectiveness, meaning that the effectiveness of LSFs vary over time, with full effectiveness delayed until the vegetation has matured ((3), (5), (14), (6)). In North Dakota, vegetation reportedly did not reach a sufficient height until ten years after installation (5). Soil type, soil pH, drought, and species competition all influence LSF configuration (5). WYDOT has used temporary structural snow fences to help protect LSFs as they mature (15). A significant challenge associated with LSFs is ensuring the survivability of the plants (14).

LSFs have several benefits: stabilize soil, store carbon, provide wildlife habitat, provide protection for winter livestock, provide protection for spring calving, are more aesthetically pleasing, and enhance crop yields ((10), (5)). The Iowa DOT reported that the retention of moisture by the snow fence mitigated the drying effects of the wind, consequently increasing crop yield (5). In addition, there is a potential that some of the material can be used as a source of “wood biomass,” such as the case where willows were cut during the maintenance of LSFs in Minnesota.

LSFs in North Dakota took 10 years after planting until sufficient height and density was reached to effectively trap snow (13). In Colorado, after twenty years, Rocky Mountain juniper reached an average height of 6 meters (19.7 ft), eastern red cedar reached a height of 6.25 meters (20.5 ft), and ponderosa pine reached a height of 7 meters (23 ft) (10). Rocky Mountain juniper and easter red cedar are the preferred species for the "Great Plains" (10).

"Snow forests," which are very wide LSFs, are used in Japan to enable the placement of plantings "immediately adjacent to highways" (10).

The species of plants that are chosen for LSF applications should be defined by the amount and seasonal distribution of precipitation, temperature (minimums, maximums, duration), and winter storm characteristics (frequency, intensity, duration) (10).

South Dakota has a history of implementing LSFs, with 72,000 feet of highways protected as a result of LSF installations between 1985 and 1999 and another 192,170 feet of South Dakota roads protected from additional LSF implementations since 1999 (3). An LSF along I-90 near Rapid City is considered to be one of South Dakota's most effective installations (4).

Ogdahl et al. (16) compared the growth and establishment of four shrub willow cultivars and one native shrub willow species to two shrub species for LSFs. After two years of growth, all species had survival rates of more than 77%. Additionally, growth in the willows significantly exceeded the growth of the traditional LSF species by up to 4.8 times. Native willow species had comparable growth to the tallest and greatest stem-producing willows. This work showed willows, including native species, may establish faster than traditional LSF species, and that planting timing for willow LSF depends on species.

Field data collected from 18 LSF sites in New York looked at height and optical porosity, snow storage capacity, average annual snow transport, and downwind snow drift length (17). The height of LSFs increased over time and porosity decreased. Within three years of planting, substantial snow trapping occurred. Four to eleven years after planting, snow storage capacity was significantly greater than transport potential, and within five years of planting, snow drifts were estimated at 10 m (32.8 ft).

Additional drawbacks that Wyoming has found when considering LSFs include wildfires, drought, and insects. If a wildfire passes where an LSF is installed, it can remove fifteen plus years of growth in a day (5). Established trees and shrubs can be killed during a drought and from insects preying on the trees and shrubs ((5), (14)). Furthermore, the type of plant that constitutes an LSF needs to be carefully considered, as WYDOT has found that some ponderosa pines ended up causing unwanted snow drifting once they reached a certain height. Site conditions, like soil pH, can also make the establishment and viability of LSFs challenging (18).

South Dakota has reported the following benefits of LSFs as compared with "slatted" snow fences (a type of structural snow fence): greater snow storage capacity, longer life span, winter livestock protection, wildlife habitat, soil erosion control, carbon sequestration, more aesthetically pleasing, almost maintenance free (once established), cheaper to install and maintain (about a tenth), and reduced costs for snow removal (3). Three drawbacks include a larger space requirement, a delay in its effectiveness as the plants become established, and a need for protection from livestock and wildlife ((3), (18), (5)).

4.2.2.3 Solid Snow Fences

Embankments formed by moving the earth or grading can create solid fences (6). They have been used by railroads in Colorado to ensure that snow does not accumulate on the tracks (6). When constructed concurrently with the creation of a roadway, solid snow fences are relatively inexpensive since the earthmoving machinery is already being used to grade the roadway to specifications. Temporary snow berms (Figure 4), made up of graded snow, can also be used as a solution to control blowing snow. However, they can also negatively impact stopping sight distance, potentially impacting safety. Structural snow fences are easier to construct than solid snow fences, which require earthwork machinery (6). Furthermore, they are easier to adjust for porosity, length, height, and bottom gap.

Figure 4: Snow ridging or berming as a blowing snow treatment (K. Ahlenius).

4.2.3 Design Considerations for Snow Fences

The location of snow fences in relationship to the asset that they are trying to protect significantly influences their effectiveness – too close to the roadway and the snow drifts will form on the roadway; too far from the roadway and they will be ineffective (15). Snow quantity, wind speed and direction, and topography can also influence the design of snow fence and its effectiveness.

The following are important design considerations for LSFs:

1. Distance from the road
2. Effective length
3. Tree and shrub species selection (specific to shrub/tree installations)
4. Number of rows of corn or shrubs
5. Spacing in and between rows (typically related to installations of shrubs and trees)

6. Wildlife considerations.

Tabler's 1982 snow fence design guide provides the following recommendations (19):

- Install a snow fence at a minimum of thirty times the height of the fence from the right-of-way (ROW).
- Barriers: the minimum length of snow fence should be 30H to avoid the "end effect;" early work by Shaw (10) more simply said barriers should extend beyond the areas to be protected, as a rounding or "end effect" results in the loss of storage capacity at the end of a barrier.
- The length of a snow fence should be extended 10H beyond the length of roadway to be protected.
- For structural snow fence, one row of 3.78-meter (12.4 ft) fence was found to be sufficient. However, should multiple rows be needed, a spacing of 35-40H is recommended.
- Snow fence should be located "at the upwind edge of depressions to increase storage capacity."
- Snow fence should be orientated perpendicular (90 degrees) to the "prevailing wind."

Snow fences in Wyoming for I-80 were identified using aerial photographs of snowdrifts (19).

Blanken identified a process for designing LSFs in Rocky Mountain National Park (13) (Figure 5):

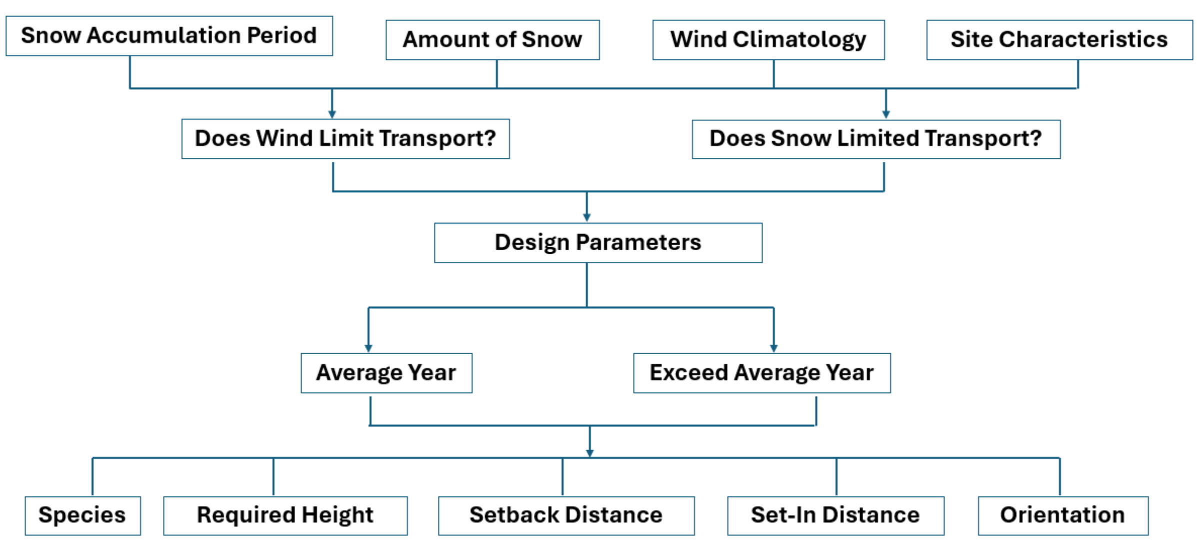

Figure 5: Flowchart for Designing LSF in Rocky Mountain National Park

Wind tunnel modeling found that the 2D fractal fence design, vertical columns like tree trunks with a cross grid, shows a clear favorable shelter effect, extending the sheltered area of 1.5–4 times the fence height with the shelter parameter of 0.4, about 70% longer than that of the non-fractal fence provides (20). Multi-scale fractal fences may potentially be adopted to transform the porous fence design by allowing tuning of the arrangement of struts, an additional set of parameters besides fence height, length and porosity.

Thiis and Ferriera (21) investigated the feasibility of windbreaks composed by three-dimensional arrays of pillars, in four and six-row arrangements as sculptural representation of a Saami (indigenous people of northern Scandinavia) labyrinth for snow fencing. Modeling showed that, when using the vertical pillars, wind and snow deposition are not very sensitive to wind speed. The four-row arrangement produced longer snow drifts with maximum height located further downwind than a common 50% porous snow fence. The results show that there is a large variation of the friction velocity within the labyrinth, and that the vertical pillar arrangement can be considered as an alternative for landscape architects aiming to shelter a specific area. Optimization studies are recommended to address the size, orientation, and shape of the pillars at each local.

Using a wind tunnel, snow fence effectiveness was analyzed based on wind velocity and tilt angle of the fencing (22). They found snow fences are most effective when perpendicular to wind direction, and that snow fencing not angled in line with perpendicular can actually increase blowing snow.

Brugnot's research focused on the use of snow fences in flat regions where there are obstacles such as road cuts and vegetation (23). Brugnot found that the bottom gap effects offset the snow fence height effect. This study had problems with synthetic snow fences used due to low porosity, causing clogging. Ideal fence lattice openings were determined to be 100mm (~4 inches).

4.2.4 Blowing Snow Models & Forecasts

The following is a review of the literature on the topic of blowing snow models and forecasts.

Data used by Osborne (24) included visibility and particle detection, air temperature, wind speed and direction, and moisture. The most important variables identified were wind speed and temperature.

Orientation of the roadway to the wind direction is a key factor for blowing snow, as well as snow mass present, and surface roughness (25). Grabow and Osborne looked at roadside vegetation roughness and its influence on blowing snow across roads, from minor vegetation (grasses and cattails) to larger vegetation (trees, shrubs, etc.).

Modeling simulated storm event effects on blowing snow across roads and the influence of highway design and maintenance practices to aid in prioritizing changes to drift-prone locations (26).

This method combined numerical simulation and field observation to study the influence that characteristics, like porosity, have at different times around snow fences (27). They found increased snow fence porosity gradually decreased speeds in the low-speed zone and vortex range on the leeward side of the snow fence, leading to slower snow accumulation velocity. With the first 5-9 hours, the first stacking position of snow on the leeward of the snow fence is filled for different porosities and gradually extends to both sides. The bottom gap of the snow fence accelerates air flow at the bottom of the snow fence reducing snow particle deposition, prolonging the time it takes to bury the snow fence. In the 2.5 – 18-hour time range, snow particles accumulate on both sides of the snow fence, but accumulation rates decrease as snow storage is increased.

Models were used to determine the snow accumulation season (SAS) and to quantify windblown snow for the purpose of snowdrift control for locations in Minnesota (28). The models require mean monthly temperature, snowfall, density of snow, and wind frequency distribution statistics. Analysis showed temperature-based methods lead to geographic variability (latitude and elevation) in the start and end dates of the season. Mean snowfall was affected by topography and lake locations. Mean snow density was impacted by elevation. Wind frequencies had two prevailing directions, northwest and southeast. Higher wind frequencies were noted in western and south-central parts of the state, above the 7m/s (15.7 mph) threshold, for potential snow transport of up to 40 to 90%.

While a more historical piece of literature, Katado and Yano (29) modeled one through three rows of snow fencing. Katado and Yano found that three rows are more effective than two, which is more effective than a single snow fence row. Petrie et al. (30) conducted more contemporary research on the topic of snow fence rows. Wind tunnel modeling was used to validate results for porous snow fences using computation fluid dynamic modeling. Simulations found that when two rows of LSF row spacing is small, they behave as a single row.

Wakes (31) used Computational Fluid Dynamics (CFD) to effectively design snow fencing (31). The turbulence model used was found to greatly influence results; the physics at each unique location should be considered in the model.

Wind tunnels scale models of 11 different snow fence types (Japanese collector and blower types, Chinese vertical and inclined types, USA Wyoming, Russian, French, Swedish, Norwegian, Canadian, and concrete) were tested for catch efficiency, drift volume, dimensionless drift area, rate of collection, and shape of the drift both on the leeward and windward sides (32). The

Norwegian snow fence had the highest catch efficiency, and the Russian snow fence had the lowest. When all performance parameters were considered, normalized depth was the best indicator of snow fence performance for this model. Leeward side drift was a 1 to 26 Length-to-Height (L/H) ratio for all models. The model found vertical slats had leeward side drifts further down and more homogenous snow distribution moving farther away from the snow fence.

Wind tunnel modeling showed that for flat areas, moderate winds can cause snow drifting (33). Furthermore, porous snow fences (50%) are most effective; the bottom gap increases the effectiveness of dense snow fences. For steeper slopes, dense snow fences are more effective.

Ohara's (34) research significantly increased the amount of wind field and snow precipitation data (1980 to 2014) from the original Tabler dataset. With this new data set, Ohara found the number of blowing snow events in Wyoming to increase, despite increasing air temperatures because Wyoming winters are sufficiently cold. Ohara's efforts validated the idea that the existing snow fence system is effective under prevailing winds; however, Ohara found simulated wind patterns during blowing snow events can be quite different than average prevailing winds. There was the implication that historical wind statistics indicated large deviations in wind direction along I-80.

Prokop and Procter's (35) work focused on steep alpine terrain prone to avalanches. Relevant to this effort is the regional and local wind data analysis that compared current data with historical data. They found a shift in prevailing wind direction and reported typical wind speeds of 5 – 7.5m/s (~11 – 17 mph). Using this information, they modeled using wind speeds of 7.5, 10, and 15 m/s (~17, 22, 33.5 mph).

While Sturm and Stuefer's (36) work is focused on Alaska arctic winters, they identified a range of wind speeds of 12 – 18 m/s (~27 – 40 mph) as relevant to wind flux rates for snow fence modeling.

Saltation – the movement of hard particles such as sand over an uneven surface in a turbulent flow of air or water, is the most important mass-transport process in snow drifting for wind speeds below 15 m/s (33.5 mph) (37).

Gover et al.'s (38) research used a 3D snow transport model to mitigate snow drift issues on highways in Ontario, Canada. The model can simulate the impact of snow ditches and snow drifts associated with embankments to aid in design. The results of the model were found to be more cost-effective snow fencing options than using rule-of-thumb approaches.

Advanced modeling looked at eight case studies from 2018 to 2023 and found past models overpredicted visibility reductions when full driftability of snow was assumed (39). Corrie recommends refinement by considering wind 12 hours after the event, skin wet-bulb temperatures, and precipitation. These refinements provided minor improvement to driftability of snow in the models.

4.2.4.1 Identified Models that have been used for Blowing Snow

The following models were identified for further consideration:

- BSSI – Blowing snow susceptibility index
  - A model developed and tested in the MDSS application to identify blowing snow locations and intensity of these conditions using wind data, snow mass, and surface roughness.
- REBS – Roadway environment blowing snow
  - Developed in North Dakota, this model uses snowpack information and road and atmospheric data to estimate temporal and spatial sublimation of snow in the road environment.
- PBSM – Prairie blowing snow model (40)
  - Describes snow transport on fields in a Canadian Prarie environment.
- WRF – Weather research and forecasting model ((41) and others)
  - A large-scale weather prediction model for both atmospheric and operation forecasting.
- CFD – computational fluid dynamics (42)
  - A modeling method used to analyze the behavior of liquid and gases and has been in snow drfit modeling.
- Turbulent-Flow Model coupled with Saltation Model (43)
  - A model that combines turbulent flow dynamics with specific particle movement, saltation, to simulate jumping and bouncing of snow or ice particles on a surface driven by wind.
- SNOWPACK (avalanche model modified to consider blowing snow) ((44); (45); and many others)
  - A snowpack and ground surface model based on meteorological data used to model snow structure and layering.
- SnowTran-3D ((46); (47))

    - A model of wind related snow distribution based on topographic and climatic conditions.
- Snow protection model (aerodynamic effects, standing air wave) (48)
    - A model used to study how wind interacts with snow to support design of structures to minimize snowdrift accumulation.
- SnowMan (used by the New York Department of Transportation) (49)
    - A software application that uses snow transport and deposition model, road and meteorological weather data, road design and orientation to design snow fence and earth work solutions to blowing snow locations.
- WHY – Wintertime Hydrologic Model (50)
    - A model focused on snow accumulation, melt, and hydrologic impacts for water resource managment in areas with significant snowfall.
- MAR (v3) Regional Climate Model (51)
    - A regional climate model focused on one-dimensional surface-atmosphere energy and mass transfer, which can be used to moel snow drifting.
- INCA – Integrated Nowcasting Model (52)
    - A high resolution model that uses weather models, meteorological data, topographical data to provide flood and avalanche forecasting.
- BSHARP – Blowing Snow Hazard Assessment and Risk Prediction (53)
    - A smaller scale model that assess snow surface erodability and the probablity of blowing snow.
- HiCAPS (used in MDSS)
    - This model incorporates all aspects of the road and weather data to support MDSS. Wind data is used and blowing snow is forecasted by the model. SDDOT currently is a part of the MDSS Pooled Fund and uses its applications.

4.2.4.2 Summary of Blowing Snow Models & Forecasts

In reviewing more than 90 pieces of literature on the topic of modeling and forecasting snow drifting and snow fences, all models appear to work well at predicting snow drift formation from various snow fence types and scenarios. Wind speeds used in the models typically varied from

7.5 to 15 m/s (about 17 to 34 mph), with the exception of maximum gusts. When modeling, the following wind speed ranges were used, ranging from very low to high:

- <4 m/s, 4-8 m/s, and >8 m/s (about 9-18 mph)
- 5-8 m/s as light, 7-11 m/s as moderate (about 11-25 mph)
- <15 m/s, 15-25 m/s, and >25 m/s (about 34-56 mph).

4.2.5 Carbon Sequestration Potential & Emission Rates for Various Strategies

Snow fences have been suggested as reducing the need for additional passes by snowplows, reducing personnel and vehicle time on the road and the use of chloride deicers, whose application has environmental considerations ((54) (Fay et al., 2013)).

The ability for snow fences or other blowing snow mitigation measures to contribute to carbon sequestration is largely associated with LSFs being able to absorb emitted gases and fewer snowplow trips and the use of other tools because blowing snow does not build up on the roadway, best described as follows:

- “Trees in agricultural or forested landscapes sequester carbon dioxide in the atmosphere, a primary greenhouse gas, and store it as carbon in their biomass” (7).
- “…the reduction in road maintenance activities linked to controlling blowing and drifting snow also result in a reduction of fuel use (and therefore carbon and other greenhouse gases emitted) for the trucks and other equipment used to deal with blowing and drifting snow” (7).

Wyatt et al. (7) provided some estimates of the fuel usage of various tools to assist with removing snow drifts from the roadway, as found in Table 1.

Table 1: Equipment fuel usage.

Class	Description	Fuel Usage	Unit
330	Single Axel	4.79	mpg
344	V-Plow	2.17	gal/hour
350	Tandem Axle	4.25	Mpg
428	Tractor	0.39	gal/hour
620	Motor Grader	3.77	gal/hour
710	Small Dozer	2.00	gal/hour
760	Loader	2.20	gal/hour
880	SnoGo Blower	1.14	Mpg

4.2.6 Benefits & Impacts to Wildlife

To the authors' knowledge, no research has been conducted that specifically looks at how snow fences installed along roadways impact wildlife habitat, migration routes, and wildlife-vehicle collision (WVC) rates. Snow fences along the sides of roadways may provide benefits or drawbacks, depending on the target species. There is at least one study that looks at the impact of snow fence on contributing to deeper snow and its impact on arctic lemmings; however, these fences were not installed in relationship to a roadway (55). Through other project work, the Western Transportation Institute at Montana State University is aware that while snow fences may provide habitat for deer and elk, they may reduce habitat for animals like pronghorn. There are many reasons snow fences may deter pronghorns. They rely heavily on their vision to detect predators from a distance. They commonly avoid wooded areas and prefer habitats with less vegetation and cover. They are highly vigilant animals and tend to avoid areas with perceived threats or disturbances.

Early research on LSFs makes some recommendations to increase the benefits for livestock and wildlife. Adequate spacing is needed between parallel rows of trees in order to provide space for food and cover for wildlife in the winter (10). If the rows are too close together, they may be covered by the snow drift and not able to be used for shelter. It is recommended to plant tall wheatgrass, alfalfa, and grain sorghum around the LSFs to assist with the catching and storage of snow as well as to support wildlife (10). Livestock and wildlife may shelter behind structural fences, and the additional moisture can help with early spring forage for livestock. A 1985 study suggested that roadside plantings did not contribute to greater incidences of roadkill and consequently driving hazards (10).

In the "Great Plains," pheasants prefer wide plains to narrow plantings (10). Pheasants are adaptable animals that are found in grassland, farmland and open forests, but prefer areas that provide cover and access to food. LSFs may be beneficial to pheasants regardless of the distance between the rows of trees or shrubs.

During the installation of a solar snow fence in Wyoming, the performance of the system was monitored by a camera (12). While not a focus of the research itself, the researchers suggested that "The operation of the solar snow fence did not seem to deter these animals [rabbits and prairie dogs] from foraging in and around the solar snow fence area" (12). As the focus of the research was not on wildlife, there is no understanding regarding how this new type of snow fence may or may not have impacted large mammals.

4.2.7 Safety Impacts of Snow Fences

In 1970, Interstate 80, between Laramie and Walcott Junction, was opened to motorists (19). Unfortunately, during the first winter, the roadway experienced large snow drifts on the highway. As a result, over the course of several years, WYDOT installed snow fences to address the issue. Snow fences installed ranged in height from 1.83 meters to 3.78 meters (6 to 12.4 ft). The journal article details the impacts to safety. With snow falling in Wyoming from mid-September through mid-May, the crash history was reviewed from September through May, although Tabler and Furnish found that 0.8% of “ground blizzard accidents” occurred in the outlying months of September and May. Therefore, they focused on their crash analysis from October through April. Most snow drifting was identified to occur from November through March. Their analysis suggested that using crash data from 1970-1981, snow crashes and “other” crashes were found to be independent of the degree of snow fence protection. “Ground blizzard accidents,” on the other hand, were found to be significantly reduced (70%).

Literature on snow fences report a reduction in crashes as a result of snow fences, by as much as seventy percent when comparing roads with and without snow fences ((14), (5)). A reduction of forty percent was reported when considering horizontal curves ((54), (56)).

Because snow transport exponentially increases with the speed of wind in the first 16 feet above the ground, truck drivers, who sit at a greater height above the ground than passenger vehicles, have better visibility until greater wind speeds occur (1).

4.2.8 Cost/Benefits

Early efforts (1989) by Brugnot (23) determined efficiency (cost-effectiveness) of each snow fence type by looking at cost and the maximum snow volume it can collect and maintenance required, with wooden and fixed snow fences being the most cost-effective due in part to reduced seasonal maintenance (set up and take down).

Daigneault and Betters considered various measures of cost benefit analysis to compare how the Wyoming board snow fence (Wyoming board), double-row slatted snow fence (double-row), and LSF performed. All snow fences were found to provide more benefits than costs (14). The following are Daigneault and Betters’ findings for Total Net Benefits, Present Net Value, Benefit-Cost Ratio, and Annual Breakeven Benefits:

- Total Net Benefits: LSF > Wyoming board & double row
- Present Net Value: Wyoming board is slightly better than double row; both > LSF
- Benefit-Cost Ratio: LSF > Wyoming board & double-row
- Annual Breakeven Benefits: Double row > LSF & Wyoming board

These results only consider snow and ice removal cost savings, crash reduction, establishment, maintenance, and an estimated useful life of each type of snow fence. These results do not consider more contemporary costs and benefits, like carbon sequestration, improved wildlife habitat and negative impacts to wildlife migration.

The Wyoming Department of Transportation (WYDOT) has employed a unique approach to minimize the costs of maintaining their snow fences made of wood. They have an agreement in place with a private company that harvests the wood from Wyoming snow fences after they have been weathered for a few years and replaces the face boards with new ones. The weathered wood is used in the home construction industry. WYDOT has found benefits and drawbacks with this process. For example, one group of thieves took down a Wyoming snow fence to harvest the wood and sell it to a company in Colorado (57).

LSF was identified as having the lowest installation and maintenance costs in Minnesota at $37mi/yr/row ($23/km/year/row), with Wyoming having the greatest at $470/mi/year/row ($292/km/year/row) (10). Canadian structural fence was identified as costing the least in South Dakota at $328/mi/year ($204/km/year) and the most in Minnesota at $3719/mi/year ($2310/km/year) (10). The cost of Wyoming structural barrier design was only provided by Wyoming at $4951/mi/year ($3075/km/year) (10).

Another source reported the installation and maintenance costs by "station" as $800 to $4,000 for the Wisconsin Department of Transportation and the Wisconsin Bureau of Highway Maintenance as well as a range of $15 to $30 per linear foot for the Minnesota Department of Transportation and WYDOT (5).

LSFs in El Paso and Elbert Counties in Colorado have been planted by private landowners, 4-H groups, Boy Scouts, local tree companies, conservation districts, and the Colorado DOT (58); hence, there are creative ways in which some of the installation costs can be mitigated.

Daigneault and Betters reported a benefit as a result of the reduction in crashes to be $8,256 per mile annually (14).

Snow fences are said to bring service benefits because road closures from blowing and drifting snow are mitigated or eliminated; Wyoming reported a reduction of eight days per year in road closures as a result of the installation of snow fences ((5), (14)). Daigneault and Betters provided an estimated cost savings of $14,497 miles per year (14). The use of snow fences has been identified as a best practice in winter maintenance operations to reduce personnel and equipment hours managing drifting snow (59). A benefit-to-cost ratio of 50 to 100:1 was identified related to a reduction in snow removal costs (5). Blowing and drifting snow can disrupt winter operations such that these patches of roadway often should not have deicers applied because it can cause blowing snow to stick to the roadway. Additionally, isolated, and rural locations, where drifting occurs on the roadway can require plows to travel long distances to manage trouble spots. Snow fences can also assist with extending the lifespan of a roadway by reducing the erosion caused by blizzards (5).

At 12 feet in height and with a 50% porosity, a 100 linear foot snow fence is estimated to cost $20,000 to $50,000, or $200 to $250 per linear foot (12). Using solar irradiance values for Wyoming and Colorado, an 8 kilowatt (kW) solar array can produce approximately 15,500 kilowatt hours (kWh) annually (12). The retail energy price is estimated as $0.085 per kWh (12).

Tabler and Jairell (11) found that using the "average winter" as the design year reduces the snow removal costs by 80%; doubling the capacity only reduces costs by an additional 11%. Even a storage capacity of half the average annual snow transportation reduces costs by 50%, leading Tabler and Jairell to conclude that snow fences "provide considerable benefits even in years in which snow transport exceeds the design storage capacity." A snow fence designed with a capacity to accommodate mean annual snow transport was recommended for economic optimization.

A snow fence designed with a capacity to accommodate mean annual snow transport is recommended for economic optimization.

4.2.8.1 Summary of Benefits and Costs

Benefits reported in the literature include crash reduction and a reduction in the frequency of road closures. More recently, researchers have been experimenting with applying solar panels to snow fences, with the idea that energy generated from the solar panels could be provided in the future as a benefit. In large part, the costs have been quantified as the ongoing installation and maintenance of the snow fences. Benefits and costs identified in the literature are provided in varying measures, which makes the ability to compare some of the cost and benefit information challenging. Compiling the installation and annual maintenance costs from one source (Cir. 2000) for two types of structural snow fences ("Wyoming snow fence" and the "double-row slatted" snow fence) and for LSFs can be found in Table 2 (14) along with life cycle estimates from that source as well as others ((10), (13)).

Table 2: Estimated costs for Wyoming and double-row slatted snow fence ((10), (13), (14)).

Type of Snow Fence	Name	Installation Costs	Annual Maintenance Costs	Life Cycle
Structural	Wyoming snow fence	$87,067/mile	$2,640/mile	20-25 years
	Double-row slatted snow fence	$16,336/mile	$8,672/mile	5-8 years
LSF	-	$20,434/mile	$1,000/mile for 3 years	50-75 years

4.2.9 Communication Strategies with the Public

Current et al. (2022) worked to promote the Minnesota Department of Transportation (MnDOT) snow fence program through landowner and public engagement (2). To accomplish this, Current et al. developed thirty case studies of landowners who had implemented a snow fence on their property and developed a public-facing platform where one could read these case studies and learn more about existing snow fences. A previous study conducted by Current et al. in 2019 found landowner constraints related to the adoption of snow fences included a lack of knowledge and real and perceived challenges of implementing and maintaining a snow fence. Case studies were conducted in late 2020, covering 30 landowners across the state of Minnesota. Case studies aimed to document landowners' experiences with implementing different types of snow fences and make these experiences available to other landowners who are considering implementation of snow fences.

Seventy percent of case study participants reported that their introduction to the MnDOT snow fence program was from an MnDOT employee. The most common primary motivation for implementing a snow fence was a concern for public safety/transportation including a desire to improve traffic conditions, reduce crashes, and a sense of civic duty. The second most common motivation was financial compensation. Conservation was not a common motivator for implementing snow fences.

Case study participants were asked to identify the impacts of the snow fence on their farming operations. Thirty percent of respondents reported a reduction in crop yield. Nineteen percent noted an impact on equipment; these were mostly attributed to the need for farming around the snow fence. Nearly thirty percent of participants reported a slight increase in labor (1-5 hours per year), and thirty percent reported a larger increase in labor (over 5 hours per year). Increased labor generally was related to the need to farm around the snow fence. For LSFs, additional labor included mowing and pest management.

Another impact that was noted by half of the case study participants included an increase in soil moisture in the area near the snow fence. This increase in soil moisture was noted as the reason for the need to delay the start of the farming season by fifteen percent of respondents.

Eighty percent of participants felt that their compensation was adequate. This compensation ranged from annual payments from a contract, which ranged from one to fifteen years to a lump sum payment for a permanent easement. Most wished for higher compensation but agreed that the compensation provided was adequate as an alternative land use.

Case study participants were asked to provide suggestions to improve the MnDOT snow fence program. Recommendations included: providing opportunities to sell or rent the snow cache area to MnDOT, noting that easements should not be taxed as productive farmlands; having consistent MnDOT staff on the snow fence program; and providing more certainty for annual contracts. Additional suggestions included providing information on the vegetation used and why it was chosen, and on how effective the snow fence is for cost savings, snow captured, or reduced salt applied to the roadway.

The results of these case studies were uploaded to a public facing platform, FarmMaps (https://farmmaps.umn.edu/#), which is an interactive map that allows users to see where snow fences have been implemented, and when a user clicks on a snow fence it displays the case study information. FarmMaps was designed for landowners to gain information from other landowners on their experiences with snow fence adoption and allow landowner to landowner networking. Case study details include information about the size and type of snow fence installed, reasons for the snow fence implementation challenges that the landowner faced, and advice that the landowner would give to others considering adopting a snow fence on their property.

4.2.10 Compensation Strategies for Private Landowners

Compensation strategies for private landowner adoption of snow fences varied from state-to-state and by snow fence type. Common barriers to snow fence adoption included a lack of knowledge of snow fence programs and what snow fences do, poor relationships with the snow fence program/agency, lack of appropriate compensation, and intimidation or lack of certainty with contracts (60; 2; 61).

Baral et al. (2022) utilized a survey of Illinois landowners to identify factors that affect landowner participation in snow fence programs, types of snow fences that are preferred, and appropriate funding for participation (60). This survey was distributed to landowners with assistance from the Illinois Department of Transportation (IDOT) and the Illinois Farm Bureau and was announced in Farm Week, an online publication. In addition, a survey of transportation agencies aims to gather feedback from Midwest departments of transportation on existing snow fence programs and compensation to landowners.

The agency survey noted that the Department of Transportation will generally site a snow fence within an existing right-of-way (ROW) or will compensate landowners based on the market value of their crop. LSFs were seen as less favorable due to their maintenance needs. Nearly fifty percent of agency respondents noted that they always or regularly compensate landowners for their participation in their snow fence program, compensation which included easements or purchased land.

The landowner survey received 141 completed responses covering 46 counties in Illinois. Landowners were asked to rank the intrusiveness of the different snow fence types. Structural snow fences and standing corn rows were seen as the least intrusive, and LSFs consisting of trees were seen as the most intrusive. Respondents were asked to discuss concerns about entering into a contract with IDOT for implementation of a snow fence. Common concerns included proper compensation, timing of installation, and timing of removal. For payment structure, respondents noted that acres used and average crop yield per acre were important.

A study conducted by Current et al. for MnDOT examined existing snow control programs across the United States; examined MnDOT staff knowledge of snow control programs; and developed promotional materials and staff training to promote the growth of snow-control measures on private lands (61). This study identified several compensation programs for various snow fence types.

For LSFs, it was common for programs to provide payments to the landowner for maintenance and/or the use of their property (61). Generally, landowners were required to maintain the snow fence when it was established. Contracts for an LSF ranged from ten years to thirty years.

For standing corn row snow fences, landowners are generally under a seasonal contract. Minnesota pays landowners on a per acre basis using the University of Minnesota's cost-benefit tool to determine the payment (averaging $1,000 per acre) (61). Wisconsin paid landowners $0.50 more per bushel than market price and Iowa paid a flat rate of $5.00 per bushel. Additionally, the corn harvested from standing rows can be used as a tax write-off.

For permanent (structural) snow fences, compensation structures varied widely. Maine did not offer compensation to install permanent fencing. Montana generally prefers to purchase the land for the permanent snow fence via easements. Montana will also do an annual lease and pay the landowner the rental value of the land. Iowa pays landowners $1.00 per linear foot and uses a five-year contract. These snow fences are generally maintained by the Department of Transportation.

Current et al. also examined engagement with landowners to encourage implementation of snow fences on private lands. Outreach programs are usually targeted to focus on areas with drifting snow challenges. Iowa has a broad outreach program where they publicize information on snow fences on their website, brochures, radio ads, and social media (61). It was suggested that a broader outreach to the public could help improve knowledge of snow fences and increase adoption by landowners.

Another challenge identified included fears related to contracting. This included a fear of liability if someone was injured as a result of the snow fence or if the snow fence is damaged. Additionally, there were challenges getting landowners to participate if the contract was long and inflexible (61). WYDOT has a thirty-year contract for LSFs and has experienced challenges with property ownership changing over the course of that thirty-year period (61).

4.2.10.1 Current State Information on Living Snow Fence Compensation

MnDOT provides a Living Snow Fence Partnership Program Payment Structure brochure (62). This brochure described the cost share assistance that is provided to landowners who plant an LSF. Compensation includes:

- Up to $1.00 per linear foot of geotextile fabric weed barrier installed.
- Costs of planting trees and shrubs.
- Costs of planting a pollinator seed mixture in the snow catch area.
- Annual payment for 10 to 15 years to landowners for snow storage and maintenance of the LSF, which is based on a 150-foot-wide snow catch area. This annual payment can be adjusted based on performance of the Farm Product Price Index; however, it will never decrease less than the amount agreed upon when the snow fence was installed (62).
- Snow maintenance payment set at $155 per acre of LSF.

Landowners are reimbursed for any costs experienced as a result of the LSF; they can also receive payments to compensate them for easements associated with the LSF (3).

4.3 Interview Surrounding States

Interview surrounding state transportation departments, as approved by the technical panel, to identify blowing snow mitigation planning/implementation efforts, best practice processes, lessons learned, and funding sources used.

The following seven state departments of transportation were interviewed between July and August of 2024 to identify blowing snow mitigation planning/implementation efforts, best practice processes, lessons learned and funding sources used: Iowa, Minnesota, Montana, Nebraska, North Dakota, Wisconsin, and Wyoming (Figure 6).

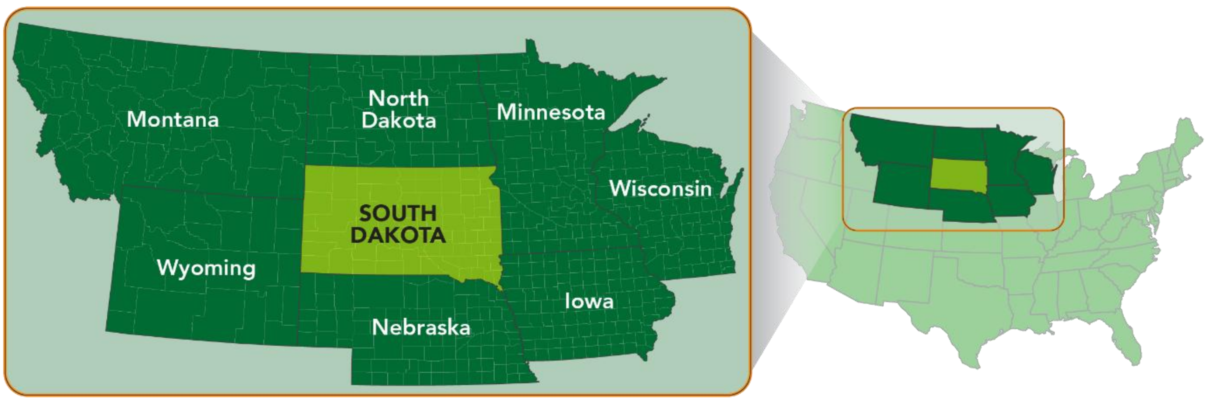

Figure 6: States surrounding South Dakota and Wisconsin.

A consistent set of questions was asked of each group of interviewees and can be found in Appendix A: Neighboring State Interviews. Hereafter are some main points highlighted for each state.

4.3.1 Iowa DOT

- Utilizes standing corn rows (minimum of 8 corn rows constitutes standing corn rows, with 12 preferred), standing round bales, and temporary fence
- Discussions for next year's agreement occur when finalizing the current agreement with a farmer in the fall
- Snow fences readily accepted by the landowner are selected
- Provide informal opportunities, like meeting for coffee, to provide farmers with information about their standing corn program
- Hosts an annual day-and-a-half-long conference to review the Standing Corn Snow Fence Program and answer any questions
- Designs rights-of-way (ROWs) for an errant vehicle rather than snow storage
- Facilitates the growth of native grasses off the immediate shoulders of ROWs to aid in blowing snow retention
- Re-grades cross-sections to make roadways passable, but it does not eliminate the blowing snow problem

- Has not established a correlation between crash occurrence and the presence of living snow fences (LSFs), although social media posts by the public suggest a link
- Utilizes $415,00 annually from their operation budget to support agreements with farmers to leave standing rows of corn and hay bales
- Funds LSFs through project budgets
- Offered to provide a peer-to-peer connection between Iowa DOT's and SDDOT's maintenance staff

4.3.2 Minnesota DOT

- Reporting more wind events with speeds in excess of 15 mph, suggesting an increasing need for snow fences
- Wind rows snow using motor graders, dozers and big plows, although these treatments need to be maintained throughout the winter as they fill up
- Raising the profile of the road, widening the ditches, and making the backslope steeper can be used to prevent drifting snow
- Views the use of seasonal snow fences as proof-of-concept with a desire to install more permanent snow fences later
- Used several funding sources to install snow fences over the years
    - Trunk Highway Fund
    - Promoting Resilient Operations for Transformative, Efficient, and Cost-saving Transportation Program (PROTECT)
    - The United States Department of Agriculture's CP17A Living Snow Fence
    - Highway Safety Improvement Program (HSIP)
    - The Environmental and Natural Resources Trust Fund
    - The Conservation Reserve Program (CRP) can provide additional financial incentive for farmers to participate
- Currently developing a vulnerability index
- Views their snow fence installations from a corridor perspective
- Studying whether there is a link between LSFs and crash occurrence
- Planning to use Agile Assets, a Transportation Asset Management System, to track their snow fence assets
- Created "Shared services" for regional designers to support the local areas
- Recommends using galvanized sleeves in the ground for structural snow fences

4.3.3 Montana DOT

- Primarily uses structural snow fences
- LSFs are not believed to work particularly well, in part because of the limited rainfall
- Uses snow traps to capture blowing snow

- No longer uses snow slopes of 11:1, as it required a substantial amount of grading and back slopes on private property
- Repurposed concrete barriers as snow fence, although effectiveness is unclear
- “Zig zag logs” have been used as snow fence
- The choice of guardrail can impact the retention of blowing snow
- Sees a link between wildlife crashes and LSFs due to the lack of habitat for wildlife in areas surrounding snow fences
- Project budgets fund the installation of snow fences as applicable
- Operational budget funds the maintenance of snow fences

4.3.4 Nebraska DOT

- Uses structural snow fences, a “roll fence” and guardrail fences; it does not use LSFs
- Slope and grading modifications are done during reconstruction of 3R (resurfacing, restoration, and rehabilitation) projects based on district-level request
- Does not use written agreements with landowners for the installation of snow fence on private property

4.3.5 North Dakota DOT

- Increased the distance between centerline highways from 84 feet to 105 feet to accommodate snow storage
- Reduced back slopes where blowing snow is a problem
- Uses LSFs, structural snow fences, mechanical windrows and temporary fences
- Experimented with standing corn rows but have not been tried since
- Reports no impacts to wildlife migration from snow fences
- Previously used hazard mitigation and transportation enhancement funds to install snow fences; currently, only operating and project budgets can be used for the installation of snow fences

4.3.6 Wisconsin DOT

- Uses steeper slopes when a guardrail is used, as they have found blowing snow to be collected by guardrails
- Implements LSFs, manufactured snow fences, standing corn rows and temporary snow fences, although LSFs are their preference
    - Shrubs are preferred to evergreens, as shrubs grow faster and are preferred by pollinators
- Overhauling their standing corn row program
- Charges businesses, like utility companies that remove vegetation from WisDOT’s ROW, which can be used for snow fences

- Utilizes HSIP funds for snow fences, typically structural
- Experienced preliminary success with a snow fence installed within 18 feet of the ROW
- Ties into existing tree lines, viewing blowing and drifting snow problems from a corridor perspective
- Conducted an internal analysis which found LSFs to reduce “winter-related” crashes by 84% at 8-years and 69% at 12-years
- Snow fence storage capacity is never full like that reported from Wyoming

4.3.7 Wyoming DOT

- Uses a state-of-the-art vehicle to collect data to use when designing snow fences
- Works with the Wyoming State Forestry Division to implement $100,000 worth of LSFs annually
- Prefers using structural snow fences
- Reclaims the weathered wood from structural snow fences through a “NetZero” agreement with a contractor
- Experienced no impact to wildlife migrations using snow fences short in length
- Utilizes the Transportation Learning Network (TLN) for snow fence training
- Success in working with landowners by developing relationships built on trust and integrity
    - Land is taken care of during access and egress
    - Transparency with plans and timelines
    - Primary line of contact is maintenance foreman who lives in the area

4.3.8 Summary of Surrounding State Interviews

States surrounding South Dakota were interviewed to learn more about their practices for planning and implementing snow mitigation efforts, best practices for processes, lessons learned, and funding sources used.

SDDOT was interested in learning about other practices besides installing snow fences that might mitigate or eliminate blowing snow challenges. Iowa DOT indicated that they facilitate the growth of native grasses off the immediate shoulders of their ROW to aid in blowing snow retention. The Iowa DOT also reported that grading can make roadways passable, but it does not eliminate the blowing snow problem. Several state DOTs reported “wind rowing snow,” using “snow traps,” and “mechanical windrows.” NDDOT reported expanding the distances between roadway centerlines from 84’ to 105’ to accommodate snow storage.

Most often, funding for snow fences was from operational or project budgets, although there were some innovative sources as well. Iowa DOT reported using $415,000 annually from their operation budget to support agreements with farmers to leave standing rows of corn and hay bales. For Iowa DOT, LSFs were funded through project budgets. MDT also reported integrating the cost of snow fences into a project's cost. NDDOT reported that while previously hazard mitigation and transportation enhancement funds were used, currently only operating and project budgets fund the implementation of snow fences. While MnDOT noted that their Trunk Highway Fund had historically paid for many of the snow fences found in the state, they also identified other sources leveraged.

MnDOT invited SDDOT to participate in their PROTECT grant application; SDDOT may want to consider if the objectives of future applications led by MnDOT would be relevant. MnDOT also reported leveraging funding focused on environmental improvement due to the benefits that snow fences can have in reducing the use of chloride deicers. MnDOT also reported that the USDA's CP17A Living Snow Fence program can be used to implement snow fences. CRP was also identified to provide more financial incentive for farmers to participate. MnDOT and WisDOT reported leveraging HSIP funds, although projects funded with this source seemed to prefer structural snow fences over LSFs as they saw more immediate returns. WisDOT reports that when businesses, typically utilities, remove vegetation from the ROW, a fee is administered, which is used to fund the implementation of snow fences. WisDOT reports that it is hard to replace LSFs that were lost and the crash occurrence after the removal of the LSFs is telling.

Maintenance supervisors should expect to invest time in enrolling farmers into a standing corn row (and hay bale) program. This may include maintenance staff hosting a coffee and snacks event to inform farmers about the snow fence program and leveraging local contacts. For farmers already in the program, when the agreement is finalized in the fall, discussions about next year's agreement are recommended. From a central office perspective, interviewees recommended that flexibility be provided to maintenance supervisors working with the locals. MnDOT suggested that some of these short-term programs could be used as a "proof of concept," where there is a potential to discuss longer-term snow fence solutions.

The Iowa DOT offered to connect its maintenance staff to SDDOT's. As many of the SDDOT interviewees reported finding it challenging to engage farmers, there could be an opportunity to virtually engage SDDOT maintenance staff with Iowa DOT maintenance staff so that they can ask questions about how they can best engage farmers.

There seems to be divergence or lingering questions regarding the influence of LSFs on crash occurrence involving wildlife. Iowa DOT reported that they found no correlation but suggested that social media posts by the public insinuated it to be an issue. MnDOT reported that they are currently studying the issue. MDT reported believing that it was an issue, noting that the lack of habitat in areas surrounding the snow fences made them appealing habitat for some wildlife.

MnDOT was unique in reporting an effort to include snow fences in its asset management tool. Incorporating snow fences into an asset management tool could assist the state DOT in better understanding the maintenance needs, costs, and life cycle of snow fences, making it a recommended best practice.

Both MnDOT and WisDOT reported viewing snow fence installations as corridor treatments rather than spot treatments. WisDOT indicated that previously, if they had treated a "problem spot" one year, the next year that "problem spot" seemed to move along the corridor.

MDT and WisDOT interviewees highlighted the negative impacts that guardrail selection can have on collecting blowing snow. WisDOT has taken to creating steeper slopes to address this issue. However, this would seem to conflict with Iowa DOT's reported preference to design for errant vehicles instead of blowing snow.

Iowa DOT seems satisfied with its standing corn row program, whereas WisDOT indicates it has a similar program that is being "overhauled." The primary challenge reported related to the current program is determining the going bushel rate of corn.

A trend seen by reported use of snow fence types by surrounding states seem to suggest a preference for structural snow fences west of the Missouri River and LSFs or standing corn rows east of the Missouri River (Figure 7).

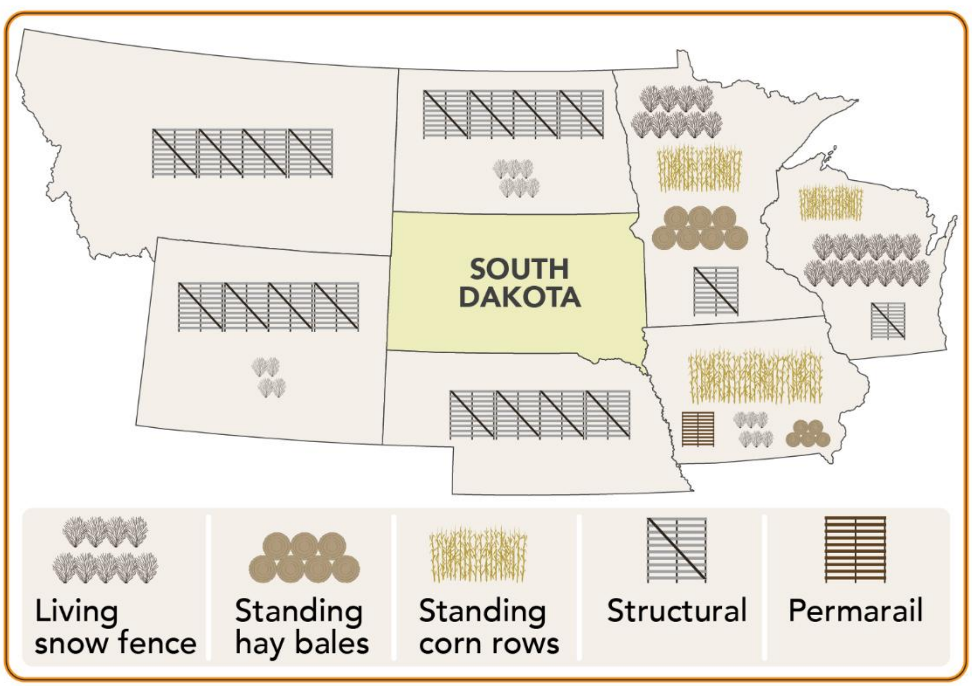

Figure 7: Surrounding state reported snow fence practices.

Several best practices were identified through interviews with the surrounding states:

- A minimum of 8 corn rows constitutes standing corn rows, with 12 preferred (Iowa DOT)
- Raising the profile of the road, widening the ditches, and making the backslope steeper can be used to prevent snow drift (MnDOT)
- For structural snow fences, galvanized sleeves in the ground (MnDOT)
- Shrubs are preferred to evergreens, as shrubs grow faster and are preferred by pollinators (WisDOT)
- Tie into an existing tree line if it's present, as the issue is similar to fluid, where if you plug up one spot and leave another open, the fluid will find the opening. This is why looking at blowing and drifting snow problems from a corridor perspective is preferred (WisDOT)

4.4 Obtain SDDOT Input

Obtain winter road condition crash data for non-interstate rural highways on the state system from the SDDOT. Conduct virtual meetings with SDDOT Region staff to identify snow-drifting locations and potential roadblocks to implementation. Interview SDDOT personnel to identify funding sources available.

From July through August of 2024, two researchers interviewed SDDOT's twelve areas. Ten questions were asked of each area and can be found in the Appendix. Some interviewees shared more detailed information, whereas others provided brief responses. The following are key takeaways from each area.

Belle Fourche Area (Rapid City Region)

- 10 blowing snow sites were identified
- The "generational" winter snow season in 1996 resulted in the implementation of Wyoming snow fences within the Area, which, while helpful, have presented challenges
  - They are viewed as requiring more maintenance, particularly one near Enning, SD
  - The height of at least one was reduced from 15 feet to about 8-10 feet so that it remained effective but would not get blown over by the wind
  - Maintenance Area staff believe that the lack of posts in the ground has resulted in them getting blown over
  - Cattle rub on the bottom boards, pulling them off all the way up the Wyoming snow fence, resulting in it being "completely destroyed;" when this happens, repairs can take weeks; maintenance staff have addressed this by adding a board to the bottom
- Prefer LSFs (if they can be grown) or "posts in [the] ground with boards" (a vertical snow fence that takes up less space and is well anchored)

    - The Area's preference for LSFs reflects the staff's experience with LSFs historically working better as well as landowners preferring them to support calving
- Prevailing winds are from the north or northwest; the Area has issues when the wind is blowing from the east
- Snow forecasts are reportedly poor whereas wind estimates are on par
- Challenges with landowner cooperation, in at least one case because of a lack of trust in the government; however, the Area has found some success in providing information about the safety benefits from snow fences
- Area discussed the implication of new state legislation enabling Areas to close roadways
    - Not used during the 2023-2024 winter
    - Previously, non-interstate routes could only be identified as "road blocked," "impassable," or "no travel advised," which did not restrict people from using the roads; as a result, navigation tools would re-route travelers onto these lower functional class roadways, stranding motorists
- Bridges are one of the biggest problems with blowing and drifting snow
    - The guardrails act like a snow fence
    - Red Elm Bridge is one of the worst bridges
    - Snow fences have been attempted to address the issue without success

Rapid City Area (Rapid City Region)

- 18 blowing snow sites were identified
- Experienced success with a 2-foot-tall by 12-foot-long wooden board fence, which they hope to use more often in the future (Figure 8)
- Typically, the Area prefers a wood lathe snow fence, which, while technically a temporary snow fence, the Area leaves in place until it rots out
- Experimented with steel post snow fences with poor results
- Experimented with hay bales, but they caused issues with elk, as hay is an appealing food source as winter progresses and natural forage becomes scarce
- Uses snow ridging to control blowing snow
    - The Area's ability to conduct snow ridging is limited once the snow starts to fall
    - Sometimes landowners conduct snow ridging, like on Hwy 14A
- Experiences blowing snow issues when the winds, equal to or greater than 15 mph, are from the north or northwest; they do not have blowing snow issues when winds come from the south
- The installation of a snow fence was desired, but was not installed because:
    - A landowner would not allow it

    - Of limited right-of-way due to topography where there is a high point in the road with a cliff on one side
- Have leveraged peer-to-peer knowledge transfer, working with WYDOT; they know they can reach out to ask questions about snow fences

Figure 8: Wooden board snow fence.

Custer Area (Rapid City Region)

- 11 blowing snow sites were identified
- Conducts snow ridging
- Winds are typically from the northwest; they must be above 20 mph to warrant blowing snow concerns by the Area
- They would like to see a mix of Wyoming snow fence and LSFs to address blowing snow issues
    - Minimal maintenance, if any, is conducted on existing Wyoming snow fences
- Establishing LSFs can take a while
- Typically occurring at night, the area experiences "thaw drift stick" cycle, where blowing snow sticks to thawing snow; motorists traveling at normal speed on roads that are otherwise clear encounter a thaw drift stick patch
- Challenges with landowner cooperation
    - In some cases, the landowner perceives there is a problem

    - It is unclear if landowners clearly understand the potential benefits – the ability of snow fences to retain moisture may be of interest to some landowners
    - The Area Engineer had created a proposal to install snow fences shared with select landowners; the landowners were not interested
    - Discussions that could occur while cattle branding was taking place was identified as a potential avenue to connect with landowners
- National Grasslands require additional considerations regarding potential snow fence solutions
- Mowing is done from the fence line to the shoulder to mitigate snow build up
- Participate in the Transportation Learning Network (TLN) programming on snow fences and the mitigation of blowing snow annually

Mobridge Area (Pierre Region)

- 6 blowing snow sites were identified (see Appendix B: SDDOT Interviews for detailed drawings of blowing snow problems shared by the Area)
- Prefers manufactured snow fences for the instant results; no maintenance was reported as being conducted on existing snow fences
- The county conservation district is working to revitalize an LSF
    - The implementation of an LSF was delayed by 2 years because of the existing herbicides and pesticides
- Coordinating with the Cheyenne River Sioux Tribe Reservation to implement a snow fence to address a location that restricts travel for more than 50 miles creating "misery"
- Area discussed the implication of new state legislation enabling Areas to close roadways
    - Previously, truck terminals would send drivers on roadways labeled as "blocked" and the trucks would get stuck because "For all intents and purposes, they [the roads] were closed."
- The every-other-year rotation between corn and soybeans presents a challenge
- Half of the Area uses ridging, but only where there is pastureland or winter wheat; where soybeans are more common is it challenge to ridge as the land is flat

Pierre Area (Pierre Region)

- 14 blowing snow sites were identified
- "Putting up a snow fence on a secondary route is like having an extra plow to do work."
- Buttes have resulted in snow build-up on Hwy 1806 near MRM 138.46 to 139.5
- Prefers LSFs, if they can be grown; a secondary preference would be Wyoming snow fences
    - Hwy 1806 has very alkaline soils; nothing grows

    - Wind has been known to push a Wyoming snow fence down, so the Area had to re-right it
- Northwest winds are most problematic for the Area
- Challenges coordinating with out-of-state landowners; permission had been given to retain corn for a standing corn row snow fence, but by the time permission was granted, the corn had already been harvested
- "Slide-ins," where the South Dakota State Highway Patrol pull vehicles out of the ditch, are known to occur, and are not believed to be represented in crash data
- South Dakota State Highway Patrol coordinates with the Area, notifying them of trouble spots on the roads
- Limited success coordinating data sharing between the Area and the Reservation that would justify the installation of a snow fence has delayed the installation of a snow fence; as a result of the lack of data, local funds are to be used
- National Grasslands require additional considerations, like a National Environmental Policy Act (NEPA) review, regarding potential snow fence solutions
    - A planned LSF is to be planted by the county conservation entity and maintained by the state DOT; maintenance staff are concerned that their requirement to support the growth of the LSF would reduce the time that they can dedicate to maintaining the roads
- The every-other-year rotation between corn and soybeans presents a challenge
    - Areas with soybeans, like Hwy 212, MRM 227-229, experience issues with blowing snow
- The Area expressed interest in SDDOT developing a Winter Operations Snow Coordinator position, which would support forming agreements with landowners
- Interested in hay bales but it is challenging to be "Johnny on the spot," strategically aware as to when the farmer is stacking bales; they do not want to ask the farmer to go out of his way to move hay bales to a preferred location
- Conducts snow ridging
    - Obtained permission from landowners
    - Permits obtained to conduct this maintenance work
- Challenges with cattle rubbing on boards, pushing them up and often off the snow fence
    - A perimeter fence installed around one snow fence to restrict cattle was pushed down by the snow which allowed the cattle access to the snow fence boards in the spring
    - A contractor had used nails instead of screws to install the boards, making it easier for the cattle to knock the boards off when they rubbed them

- Emergency vehicles cannot access roadways that are closed from snow drifts on the road (as an example, see Figure 9)
- Temporary orange snow fence has been used, but they prefer not to
    - Concerns about removing the fence in the spring in a timely fashion
    - Concerns with “mucking up” the soil and causing water issues in farmer’s fields
    - Most lengths range from 500 to 1,500 feet, making installation and removal a “major undertaking” that requires many man hours annually
- Current systems, like truck mobile data collectors and phones with MDSS, do not enable blower use to be tracked
- Area requested better coordination between maintenance staff and engineers
    - Acknowledged that maintenance staff need to be more open to technology
    - Suggested that engineers need to listen to the challenges that maintenance staff are reporting, even if data does not always demonstrate the need
- Area discussed the implication of new state legislation enabling Areas to close roadways
    - Previously, Google directions would tell people to take US 14, a roadway that was labeled as “impassable” or “blocked” because they were not identified as “closed”; to try to dissuade motorists from continue on the “impassable” roadways, the Area put out dynamic message signs stating, “stranded motorists ahead” at hub; the problem was significant enough that the sheriff and state highway patrol would assist with stopping people

Figure 9: Example of a snow drift (Photos Credit: SDDOT).

Winner Area (Pierre Region)

- 2 blowing snow sites were identified, but they were long (25 miles total)
- Previous and on-going efforts were identified
    - South Dakota DOT 2020 Decennial Interstate Corridor Study: Blowing Snow Analysis report
    - Study of crashes on I-90
    - Analysis of snow fences in relationship to safety data
- Backslopes on Hwy 248 are steep and are believed to be contributing to blowing snow
- Several locations known to experience issues when blowing snow occurs are scheduled to be re-graded in the next couple of years to mitigate the issue
- Large billboards were capturing snow in an undesired location
- Prefer Wyoming snow fences because of their immediate results
- Soils limit the viability of LSFs; SDDOT is required to maintain for 10 years
    - LSFs installed in the 1990's or early 2000's reportedly help tremendously
    - Cedar and rocky mountain junipers have successfully grown
- Limited success in coordinating with farmers to leave standing corn rows
- Tried ridging with limited success; filled in after one storm
- Experience with using orange snow fence
    - Functioned well
    - Farmers were displeased with the water retained by the orange snow fence, resulting in muddy conditions, restricting the farmers from accessing their fields in the spring; Area stopped using because of this experience
- Data currently collected does not necessarily allow the Area to specifically tie maintenance efforts with blowing snow roadway maintenance
- Have used cameras to identify snow drifting on the roads; the public also calls in trouble areas; if a location is a repeated issue, the areas requests a camera to allow the Area to proactively monitor it
- Area discussed the implication of new state legislation enabling Areas to close roadways
    - Previously, identifying roads as impassable or blocked would not dissuade drivers from trying to travel on them; navigation systems (e.g., Google Maps) would still re-route travelers onto roads classified as such when the interstate was classified as "closed"
    - Roads can now be identified as closed in "SD511" (https://www.sd511.org/)

Aberdeen Area (Aberdeen Region)

- 277 blowing snow sites were identified via a KMZ file

    - Every location where blowing snow had drifted over the roadway had been surveyed and the data used to create the file
    - Two priority sites, Hwy 12 and Hwy 10, were identified because they restricted travel
    - US 12, US 212, and US 281 also experienced issues, particularly because the traffic volumes are greater
- Interested in Wyoming snow fences
- Extensively use the forecast provided by MDSS; have worked with the vendor to improve the prediction model, particularly those early in the winter season
- Farmers have expressed limited interest in leaving standing corn rows or hay bales, in part because there is "too much money to be made off of row crops"
    - Hay bales have been placed by farmers in locations that cause problems (Hwy 10, W of 281) and requested compensation by SDDOT
    - Standing corn rows are viewed by farmers as leaving too much water in the field
- The every-other-year rotation between corn and soybeans presents a challenge
- Prevailing winds are from the north or northwest
    - Blowing snow occurs when wind speeds are above 12 mph
    - When winds are 35 mph or greater and there is a crust on the snow, it will break and contribute to the blowing snow
- A camera in Lake City is used by the public to identify roadway conditions
- Ditches
    - The Area mows their ditches to ensure there is sufficient snow capacity, reportedly a different practice than other SDDOT Areas
    - Storage for future storms is created by blowing snow out of ditches
    - An on-going project is working to widen or flatten out the approaches to increase snow storage capacity within the ditches
    - A previous project that widened/flattened out ditches is believed to have brought benefits, but mild winters have limited the Area's ability to assess its effectiveness
- Temporary snow fence has not been used in a long time
    - Previously, temporary snow fence had been used at an intersection in Brookings County
- Snow ridging has been used, but is not well supported by landowners
    - A lot of snow ridging is conducted in Faulk County

Huron Area (Aberdeen Region)

- 17 blowing snow sites were identified

- Lack of familiarity with snow fences
    - The Area indicate that they are aware information about snow fences can be found in the maintenance manual, but it is not used
    - Unfamiliar with the program that would allow farmers to be compensated for leaving standing corn rows
- Area questioned if snow fences could be used cost-effectively to address their long stretches, described as a half mile, of blowing snow problem areas
- "Plastic snow fencing" has been used
- The rotation of crops results in issues with blowing snow moving; wherever soybeans are planted, blowing snow can be expected to be an issue
- Limited success collaborating with landowners to date; in places where they have problems, farmers do not want to participate; in places where there are not problems, farmers are willing to participate
    - One farmer had already put in the fertilizer and did not want to disturb the soil
    - A farmer would not allow Area staff to conduct snow ridging
    - Farmers do not want to have water from snowmelt on their fields
    - One farmer left standing corn rows on both sides of Hwy 45, South of Miller, causing snow to build up in an undesirable location
- Prevailing wind does not seem to be a good predictor of whether blowing snow is an issue
- Interested in a "snow drift cost tracking option" to assist them with better understanding the costs to address blowing snow
- Did not seem to be aware of the new state legislation allowing them to identify non-interstate roadways as closed rather than impassable or blocked

Watertown Area (Aberdeen Region)

- 8 blowing snow sites were identified
- Winds out of the southwest present problems for the Watertown Area; winds come through like a funnel
- Wind predictions do not seem accurate
    - Wind predicted at 14 mph is more like 24 mph
    - Suggested that the segments may be too long
- Concerns regarding why one road receives a recommendation for a deicer treatment while a parallel road has no treatment recommendation
- Cameras reflect true conditions
    - National Weather Service does not seem to be using the data from the station or cameras

    - MDSS system does not seem to be using the data from the station or cameras
- Prefers Wyoming snow fences but believe there are ranchers who may be interested in LSFs to provide shade for the cows
- Standing corn rows
    - Alternation of soybeans and corn is a challenge
    - Orientation of the corn rows reportedly would not help to capture blowing snow
    - Some farmers have been known to gives others a hard time about not clearing their field
- Previous temporary snow fence installations, like orange mesh snow fence, have only lasted a few days
- Limited success with snow ridging due to rocks in the ground
- Utilized North Dakota State University's TLN for online snow fence training; the information provided regarding which direction to install the temporary snow fence was useful

Mitchell Area (Mitchell Region)

- 31 blowing snow sites were identified
- Locations reported by the Area as a part of the South Dakota DOT 2020 Decennial Interstate Corridor Study: Blowing Snow Analysis have not all been addressed
- Predominant wind direction is northwest; wind speeds over 10 mph are the threshold at which blowing snow occurs, although it is dependent upon the type of snow
- Chemicals are not applied when the winds are strong
- Made use of the new law allowing them to close Hwy 44 which runs parallel to the interstate during the 2023-2024 winter season
- Hwy 44 has six bridges along a 50-mile route that have snow drifting problems; a snowplow is regularly sent out to address the snow drifting problems at the bridges
- Temporary snow fence
    - Challenges with quick removal in the spring when the ground can be muddy
    - Installation is currently done with a handshake deal with the landowner; the Area would like to be able to pay farmers for allowing temporary snow fence to be installed
- Used extra w-beam guardrail, 25 feet long, as a snow fence; this idea was obtained from the Sioux Falls Area (Figure 10)
- Limited interest by farmers to leave standing corn rows
    - They must be planted in the desired direction
    - The crops that are planted alternate

- Farmers are required to fill out W-9 forms for compensation; they have not always been filled out correctly
- Land is valuable
    - Farmers want to farm every inch
    - Landowners are not supportive of LSFs
- They have shared the SDDOT flyer about snow fences; they would light to see temporary snow fence options identified in a flyer

Figure 10: W-Beam Guardrail as a snow fence (Photos Credit: SDDOT).

Yankton Area (Mitchell Region)

- 10 blowing snow sites were identified, drawing from a 10-year-old document
- The Area is the "banana belt" of South Dakota, typically experiencing warmer and wetter weather
- In a typical winter, the Area receives 20-40 inches of snow; during the 2022-2023 winter, the Area received more than 60 inches of snow prompting them to hire a private contractor with a "big wing" to assist; the contractor was paid $160-$170 per hour
- Prefers LSFs
    - After a change in ownership, SDDOT is paying $1,000 annually to the new landowner on Hwy 50, east of Vermillion to keep the LSF in place

- Landowners where other LSFs in the Area can be found are not receiving compensation
    - An LSFs planted about 4-5 years ago, with willows 4-5 feet tall, were reported as most recently providing noticeable benefits during the 2023-2024 winter
        - The Area believes that willows work best but that landowners are less supportive of this plant type
- The Area is not interested in Wyoming snow fences because of the maintenance required
- Land is valuable in the Area, selling for $15,000 to $30,000 an acre
- Farmers have expressed limited interest in standing corn rows and hay bales
    - Current compensation is about $1,000 to $2,000, which cannot compete with the yield returns that farmers receive from farming
    - The every-other-year rotation between soybeans and corn can make obtaining agreements with farmers challenging
    - Farmers have been questioned as to why corn remains after the harvest
    - A participant did not like having to wait to get paid until the end of the winter season (April 15); they called the Area maintenance staff throughout the winter
    - One farmer, without coordination with SDDOT, had left hay bales along Hwy 11, about MRM 44.5 to 46, which really made a difference
- One winter, a railroad company parked crude oil railroad cars near Hwy 50, east of Tabor, and it served as a snow fence
- Temporary snow fences are not used
- Ridging is conducted on I-29 toward Vermillion and Hwy 81 near MRM 45
- North and northwest winds cause the most blowing snow issues; there is no threshold at which blowing snow is known to occur

Sioux Falls Area (Mitchell Region)

- 6 blowing snow sites were identified
- Issues where the ditches and hills are higher than the roadway (Figure 11)
- Conducts about 50 miles of snow ridging annually, typically on secondary routes
- Installed a portable snow fence made of old w-beam guardrail 25 feet long, costing about $60 per panel; they learned of this solution from WYDOT
- Cable guardrail found in the Area does not collect snow
- Landowners have expressed limited interest in leaving standing corn rows, hay bales or LSFs
    - Flyers have been sent out explaining the snow fence program with no interest

- A farmer tried it; SDDOT pays the market price plus $3; the farmer reported being displeased with the hassle of having to remove the remaining corn in the spring
  - The farmland in the Sioux Falls Area is “very lucrative,” which leaves farmers little incentive to participate
  - The Area is interested in using fast-growing willows along a fence line, something they have seen in Minnesota, but they do not think that the landowners would support it
- Temporary orange snow fence has been installed, but it only lasts for about 3 years
- Winter of 2022-2023
  - Area contracted out work for $50,000
  - Contractors used road graders with wings and widened the shoulders; this was valuable to the Area, as they do not have a blade with a wing
  - It took two weeks to clear the snow
  - Assistance was needed because the Area had no space to plow the snow off the road

Figure 11: Ditches and hills higher than Hwy 38 (63).

4.4.1 Summary of SDDOT Input

A total of 416.00 miles (Table 3) of blowing snow problem areas across 134 locations (Figure 12) were identified for all of SDDOT’s areas, excluding the Aberdeen Area.

Table 3: Total estimated distance of blowing snow problem areas.

Region	Area	Estimated Length (miles)
Rapid City	Belle Fourche	49.89
	Rapid City	20.86
	Custer	122.34
Pierre	Mobridge	2.6
	Pierre	24.07
	Winner	25.0
Aberdeen	Aberdeen	-
	Huron	30.47
	Watertown	67.4
Mitchell	Mitchell	11.7
	Yankton	19.06
	Sioux Falls	42.6
TOTAL		416.00

One of the objectives of this task was to obtain winter road condition crash data for non-interstate rural highways on the state system from SDDOT. SDDOT provided the crash data to the researchers early in the research project. Several exchanges were made between SDDOT and the researchers to ensure that the data contained descriptive information that allowed for the identification of crashes occurring because of winter conditions. This data was integrated into maps provided to SDDOT staff prior to the interviews. The researchers will dig deeper into this data in future tasks.

Another objective of this task was to interview SDDOT personnel to identify available funding sources. Overall, SDDOT staff identified project funding as well as ongoing maintenance funding as largely supporting the installation or maintenance of existing or future snow fences.

This task also conducted virtual meetings with SDDOT region staff to identify snow-drifting locations and potential roadblocks to implementation. Twelve virtual meetings were held. Every SDDOT area identified at least one location that presented problems to the area regarding blowing snow. The greatest number of blowing and drifting snow issues in the maintenance areas just east of the Missouri River (Figure 12).

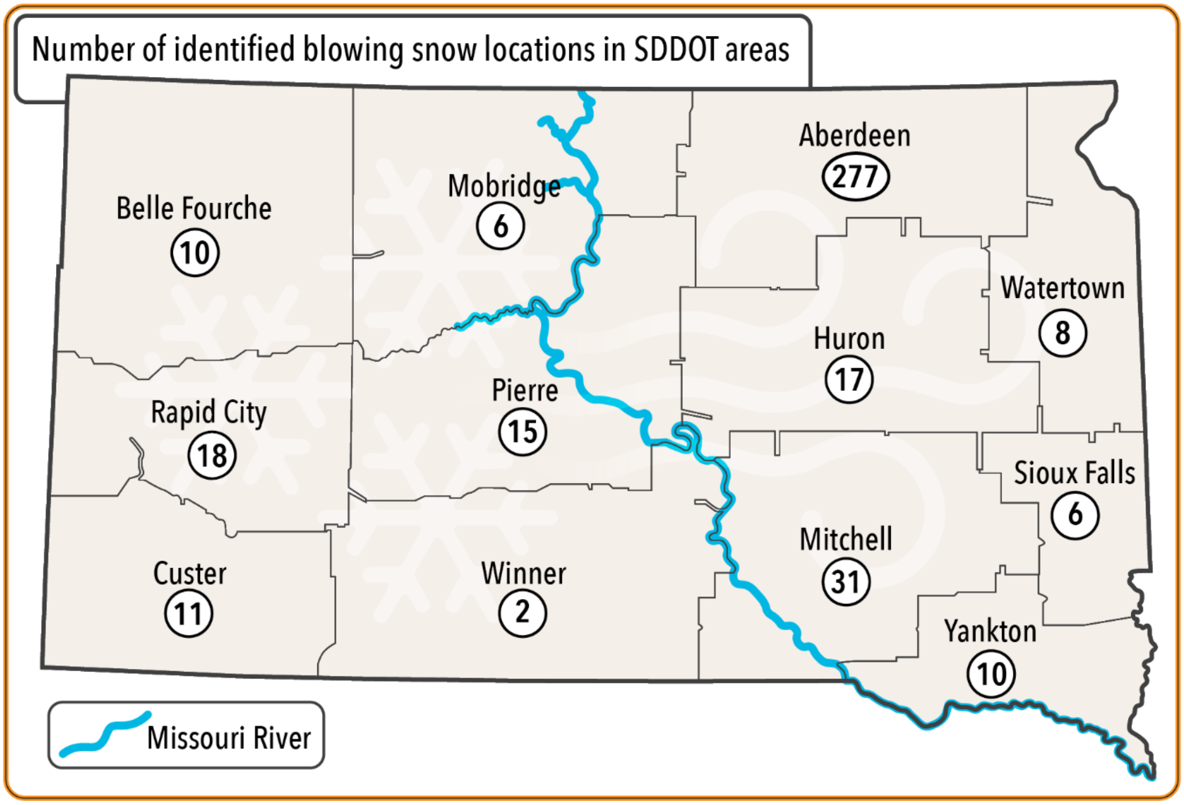

Figure 12: Number of blowing snow issue areas by maintenance area.

Overall, the challenges that were identified by the areas are summarized in Table 4.

Table 4: Challenges reported by maintenance areas.

Challenge	Rapid City Region			Pierre Region			Aberdeen Region			Mitchell Region		
	Belle Fourche	Rapid City	Custer	Mobridge	Pierre	Winner	Aberdeen	Huron	Watertown	Mitchell	Yankton	Sioux Falls
Buttes					X							
Rotation between soybeans and corn				X	X		X	X	X		X	
Cattle	X				X							
Ability to grow LSFs			X		X	X						
National Grassland			X		X							
Tribal coordination				X	X							
Lack of Landowner Interest	X	X	X			X	X	X		X	X	X

Challenge	Rapid City Region			Pierre Region			Aberdeen Region			Mitchell Region		
	Belle Fourche	Rapid City	Custer	Mobridge	Pierre	Winner	Aberdeen	Huron	Watertown	Mitchell	Yankton	Sioux Falls
Out-of-state landowners					X							
Bridges	X									X		
Emergency vehicles blocked by closed roadway					X							

Snow ridging was a common practice reported by almost all areas (Figure 13). The Winner Area suggested it was futile because it filled up too quickly. The Watertown Area reported not using this practice because of too many rocks.

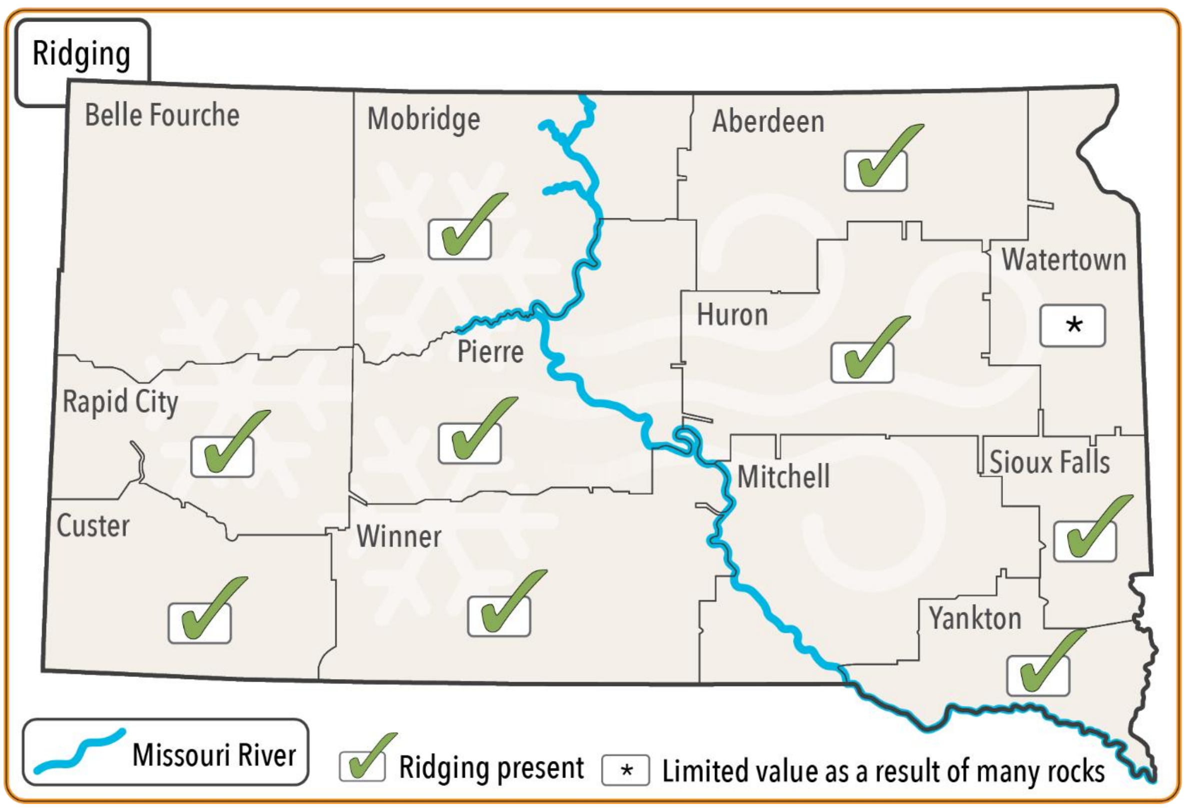

Figure 13: Areas using snow ridging.

Multiple areas reported issues with engaging landowners in annual contracts to leave corn rows or bales in place, to put up temporary snow fences, or to place longer-lasting snow fences. This is further compounded by corn rows that were not in the desired direction to prevent blowing and drifting snow, or the presence of other crop types that do not help mitigate blowing and drifting snow. Furthermore, while one area suggested that the presence of water would be desirable, another area suggested that wet areas in the field caused by retaining corn rows would not be desirable, as they could result in the farmer's combine getting stuck in the mud.

Several of the areas reported innovative snow fence practices:

- 2'x12' wooden board fence (Rapid City)
- Telespar (Custer)
- Repurposed w-beam guardrails (Mitchell/Sioux Falls)

There appears to be an opportunity where areas can exchange experience and information to potentially help mitigate blowing and drifting snow. For example, one area reported good success with willows; another area reported a desire to use willows. The use of w-beam guardrail as a temporary installation was exchanged between the Mitchell and Sioux Falls Areas. Some of the areas reported using the TLN. The availability of this resource could be shared with other areas.

Overall, there appears to be a preference for structural snow fence (Figure 14). While some SDDOT staff expressed an interest in LSFs during the interviews, they noted that the challenges of establishing them often mitigated their interest in using an LSF.

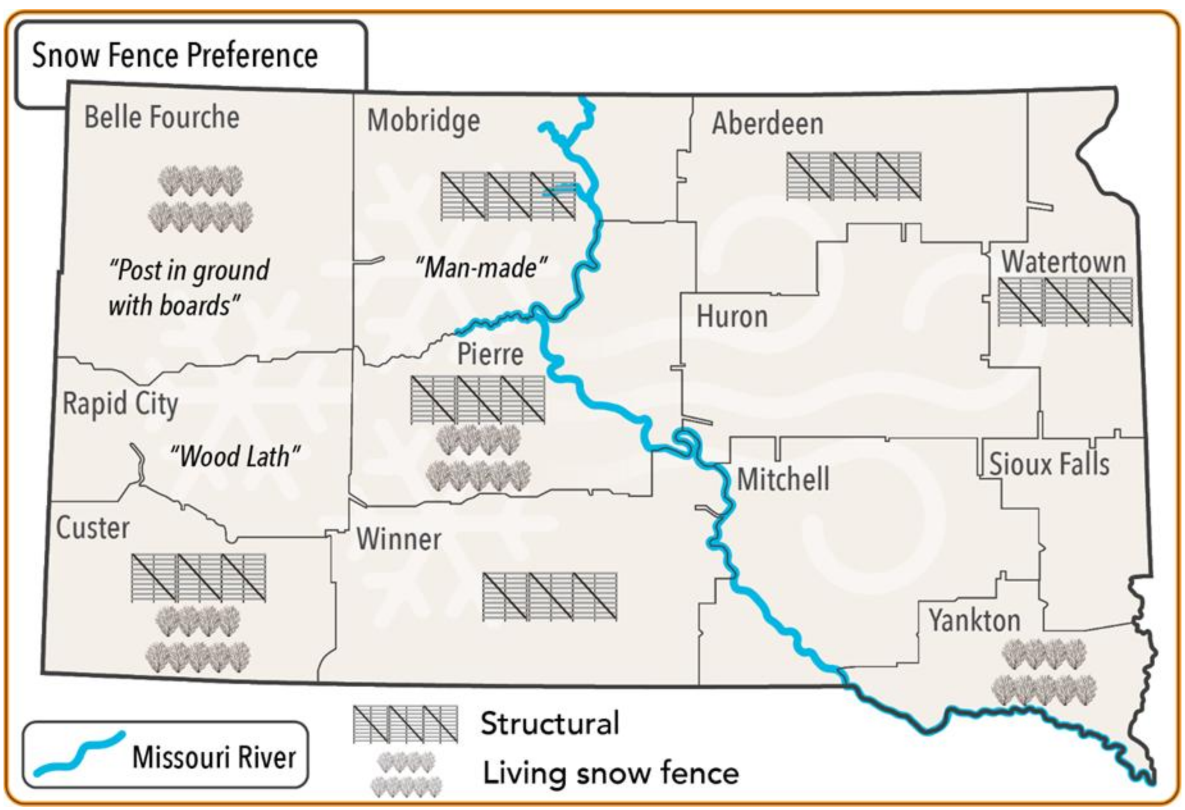

Figure 14: SDDOT preferred snow fence by area.

In large part, the prevailing winds are north or northwest (Figure 15).

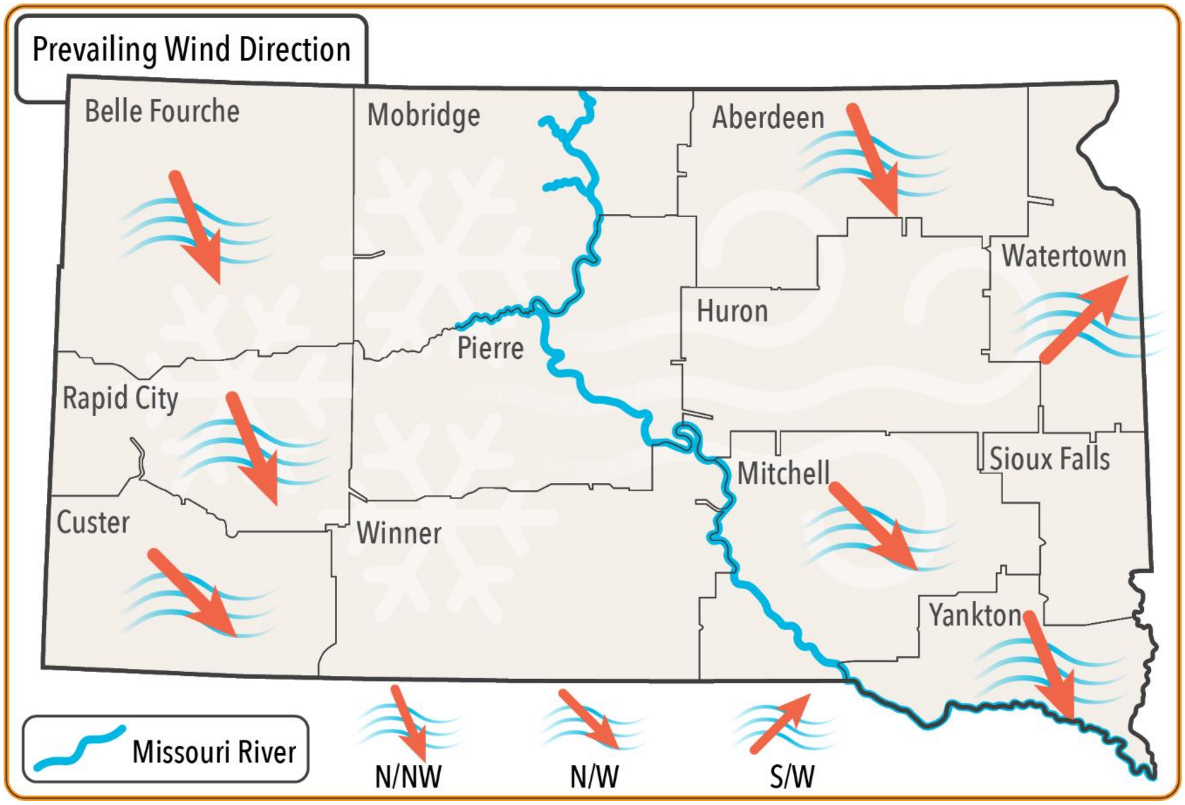

Figure 15: Prevailing winds by area.

Almost all the maintenance areas discussed the new legislation allowing them to officially close a secondary roadway, which was often used when the interstates were reported as blocked. Only the Mitchell Area reported using this new tool during the 2023-2024 winter.

Several of the areas had unique considerations. Two of the areas reported working with Tribal entities (Mobridge and Winner). Two of the areas reported working with federal National Grassland entities (Custer and Pierre).

4.5 Develop & Present, Technical Memorandum for Phase I

Prepare and present for approval of the project's technical panel a technical memorandum summarizing the findings of Tasks 2-4.

The Technical Memorandum for Phase I was presented to SDDOT on Thursday, October 31, 2024.

4.6 Identify Blowing Snow Locations

Based on the literature review and interviews, develop a plan to identify blowing snow locations, recommend the preferred mitigation strategies, and prioritize based on benefit-cost analysis. Parameters to be considered in the plan include prevailing wind direction, topography, crashes, adjoining land use, carbon sequestration and emissions, winter severity, soil type, future planning, context sensitivity, wildlife migration, habitat fragmentation, ongoing maintenance costs, and other site conditions.

In earlier tasks, which included a survey and interviews with SDDOT maintenance shop personnel and regional engineers, the research team identified locations with blowing snow challenges. SDDOT maintenance areas generally provided this information via listing a highway and the mileage reference markers (MRMs) associated with blowing snow challenges. The research team then mapped these locations and asked the maintenance area staff to confirm that the locations identified on the map were accurate and to provide feedback for any modifications.

This resulted in a list of 181 blowing snow problem areas along rural, non-interstate routes (blowing snow problem areas) for the state of South Dakota, see Figure 16 and Table 5.

The identified locations or segments have been converted into a GIS layer and have been shared with SDDOT.

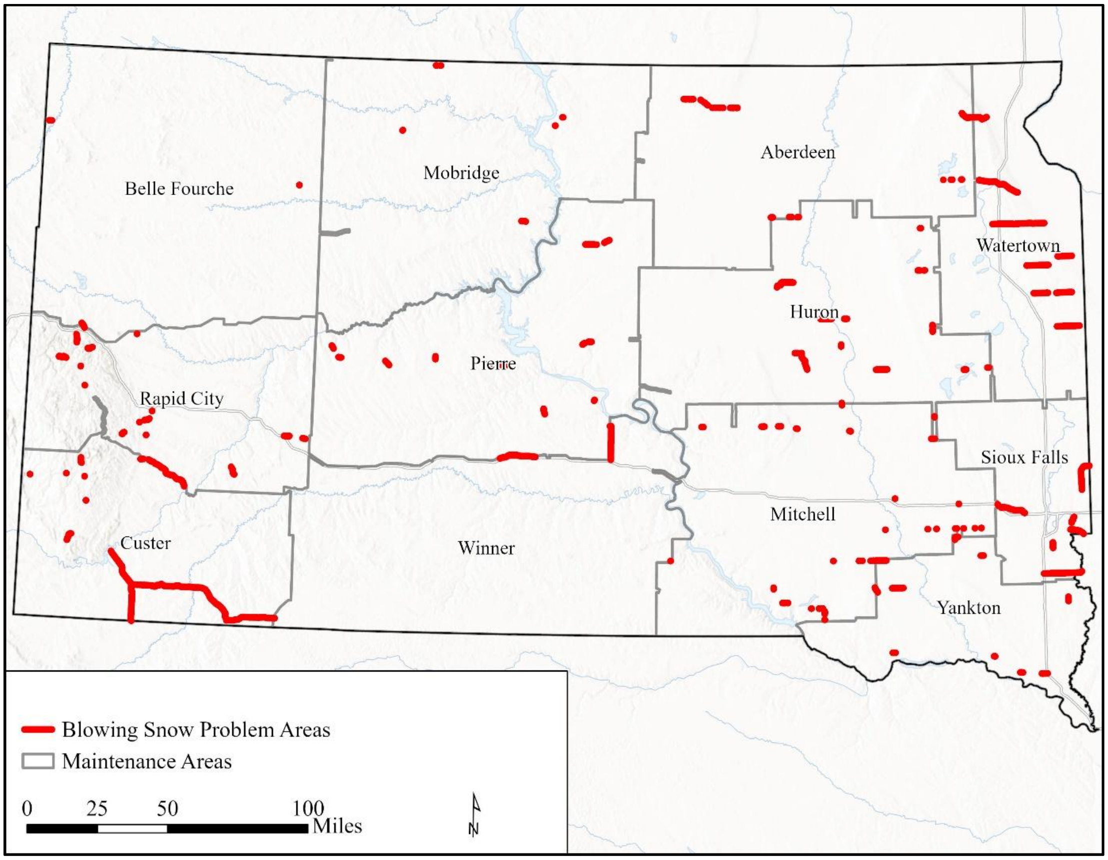

Figure 16: Identified blowing snow problem areas.

Table 5: Summary of identified blowing snow problem areas by maintenance area.

Maintenance Area	Number of Blowing Snow Problem Areas	Total Length of Blowing Snow Problem Areas (miles)
Aberdeen Area	53	8.69
Belle Fourche Area	3	3.03
Custer Area	14	122.32
Huron Area	16	29.65
Mitchell Area	32	11.83
Mobridge Area	6	2.49
Pierre Area	13	25.68
Rapid City Area	18	20.83
Sioux Falls Area	6	42.71
Watertown Area	8	67.43
Winner Area	2	24.99
Yankton Area	10	18.95
Grand Total	**181**	**378.60**

4.6.1 Variables used for Prioritization

This section describes the following variables used in the prioritization methodology to rank the top 100 blowing snow problem areas:

- Maintenance Area Feedback
- Crash & Incident Data
- Roadway Functional Classification
- Distance from Maintenance Shed
- Prevailing Wind Direction
- Land Ownership.

Additional variables were considered but ultimately were not used. A description of these variables can be found in Appendix E: Additional Variables Considered.

4.6.1.1 Maintenance Area Feedback

Each SDDOT maintenance area was asked to rank their identified blowing snow problem areas in order of priority (Figure 16, Table 5) (see Appendix C: Blowing Snow Problem Areas).

The maintenance area priority variable is viewed as the most important variable because the personnel who identified these locations are responsible for roadway maintenance and are keenly aware of trouble spots, site conditions, and common road weather phenomena. The researchers assume that the locations identified by the SDDOT maintenance areas are those that need regular treatment due to blowing snow issues, and that those ranked highest priority present the most challenges (e.g., cost the most time/resources to treat and/or present the greatest safety concern).

4.6.1.2 Crash & Incident Data

SDDOT provided crash data from 2014 to 2024 (n=188,993). Crashes that occurred on an interstate or within the boundary of a census place (town) were removed from the dataset as this effort is focused on rural, non-interstate routes. Additionally, crashes were filtered to include only crashes that occurred on rural, non-interstate highways (n=52,780) (see Roadway Functional Classification). This included the following roadway functional classifications: 2, 4, 6, 7, and 8.

The SDDOT crash data was filtered to create five datasets:

- **Blowing Snow Crashes**: The crashes were filtered to only those that contained “blowing snow” within the “Weather Condition” field in the crash attribute data (n=1,409).

- **Winter Weather Crashes**: These crashes were filtered to those that contained "blowing snow," "sleet," or "snow" within the "Weather Condition" field in the crash attribute data (n=4,091).
  - **Winter Weather Fatal & Injury Crashes**: The winter weather crashes were further filtered to those that contained "fatal injury," "incapacitating," "non-incapacitating," or "possible" in the "Injury Severity" field in the crash attribute data (n=823).
- **Winter Road Condition Crashes**: These crashes were filtered to those that contained "snow," "slush," "ice," or "frost" in the "Roadway Condition" field in the crash attribute data (n=6,395).
  - **Winter Road Condition Fatal & Injury Crashes**: The winter road condition crashes were further filtered to those that contained "fatal injury," "incapacitating," "non-incapacitating," or "possible" in the "Injury Severity" field in the crash attribute data (n=1,325).

Therefore, two of the crash-related measures represent weather (Blowing Snow Crashes) and one represents the roadway (Winter Road Condition Crashes). While the Blowing Snow Crashes and Winter Weather Crashes layers have overlap (e.g., they both draw from the "blowing snow" categorization), because the focus of the project is on blowing snow, the researchers felt that additional weight should be given to blowing snow problem areas where blowing snow crashes had been clearly identified via the crash data. "Blowing snow" was retained in the winter weather crashes, as it is a condition of "Winter Weather," thus the researchers did not want to exclude it from this category.

In addition to the SDDOT crash data, South Dakota Highway Patrol provided "slide-in" incident data from 2020 to 2024 (n=722). Slide-ins are believed to occur as a result of blowing snow where a crash report is not created. For example, if a vehicle hit snow that built up on the roadway and entered the clear zone without any damage caused, is it plausible that the vehicle may have been pulled out of the ditch without a crash report generated. Discussions with SDDOT maintenance areas indicated that slide-ins occur that were not always identified in the crash data.

ArcGIS spatial join analysis was used to analyze crashes and incident data from the six layers (Blowing Snow Crashes; Winter Weather Crashes; Winter Weather Fatal & Injury Crashes; Winter Road Condition Crashes; Winter Road Condition Fatal & Injury Crashes; and Slide-In Incidents) within a 250-foot buffer of each blowing snow problem area. The additional distance accounts for the possibility that a vehicle may have been impacted by blowing snow within the problem area, but the ultimate resting place for the vehicle when the crash or incident was recorded were outside of the problem area. Figure 17 through Figure 22 illustrates the location of these crashes and incidents within the problem areas.

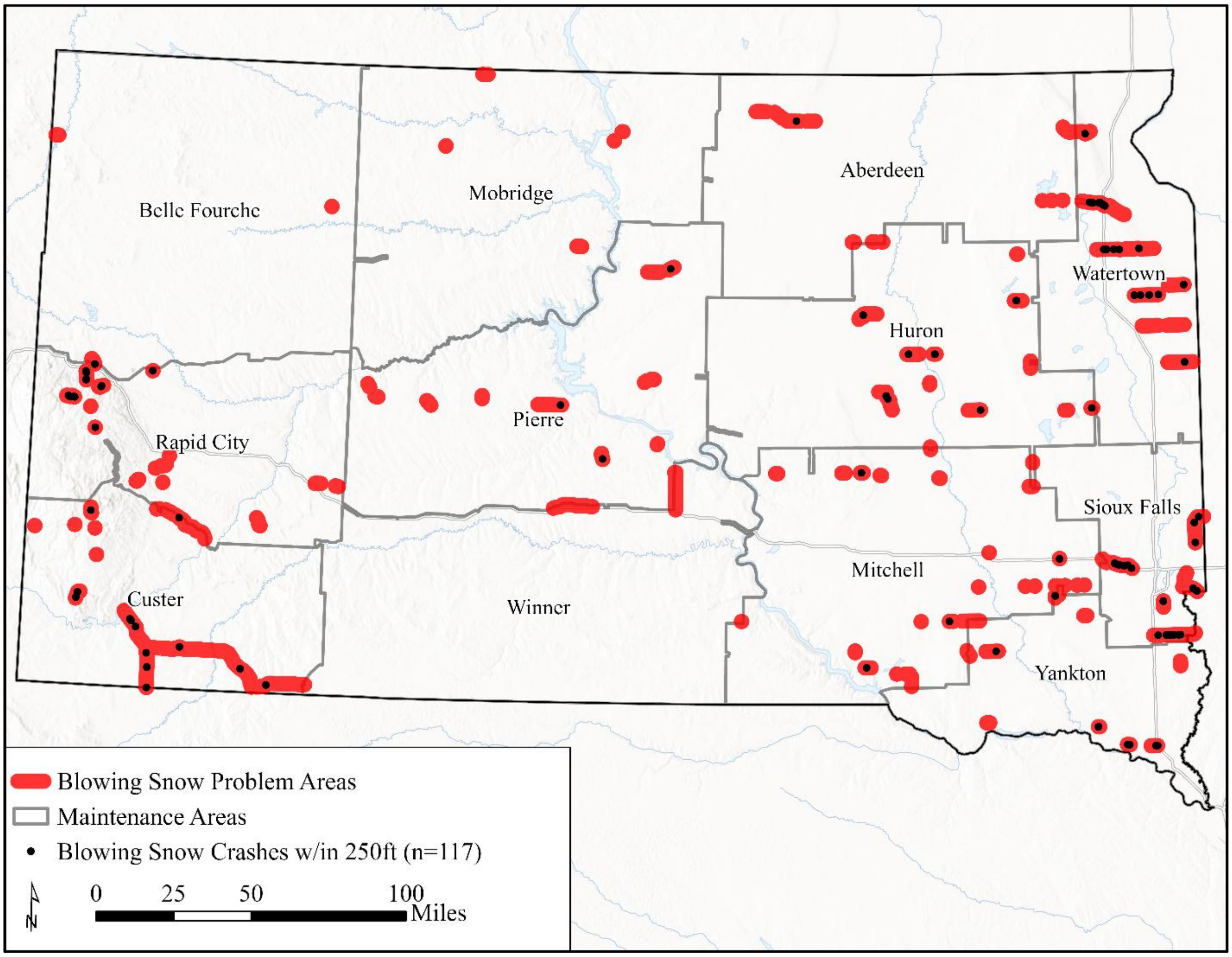

Figure 17: Blowing snow crashes (black circles) within 250 feet of a blowing snow problem area (red lines).

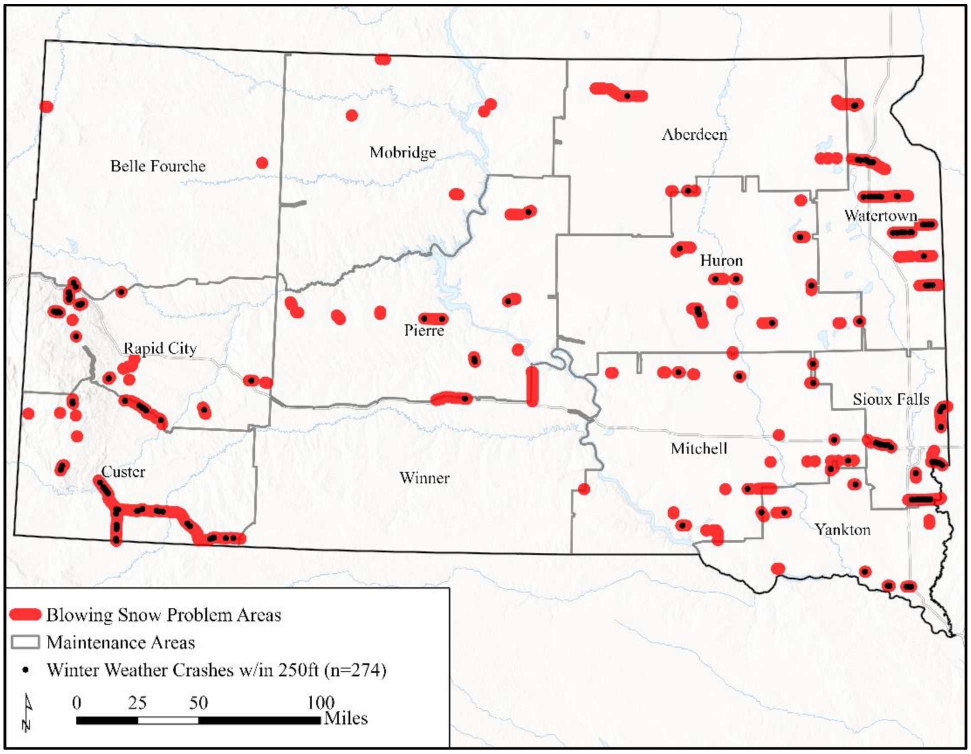

Figure 18: Winter weather crashes (black circles) within 250 feet of a blowing snow problem area (red lines).

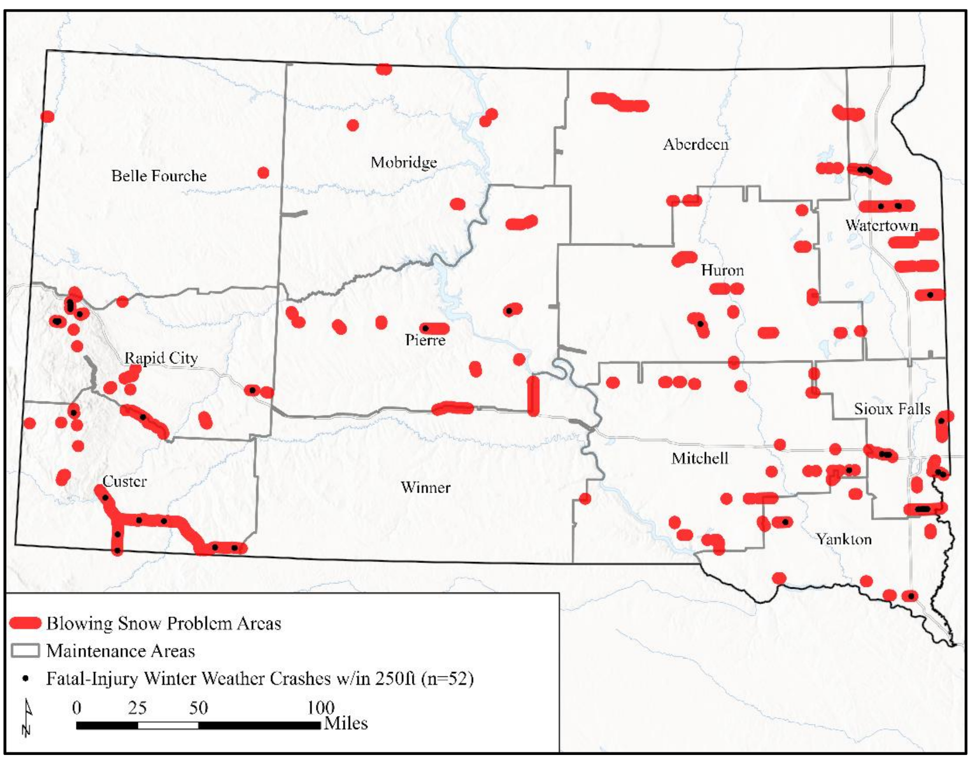

Figure 19: Fatal & Injury winter weather crashes (black circles) within 250 feet of a blowing snow problem area (red lines).

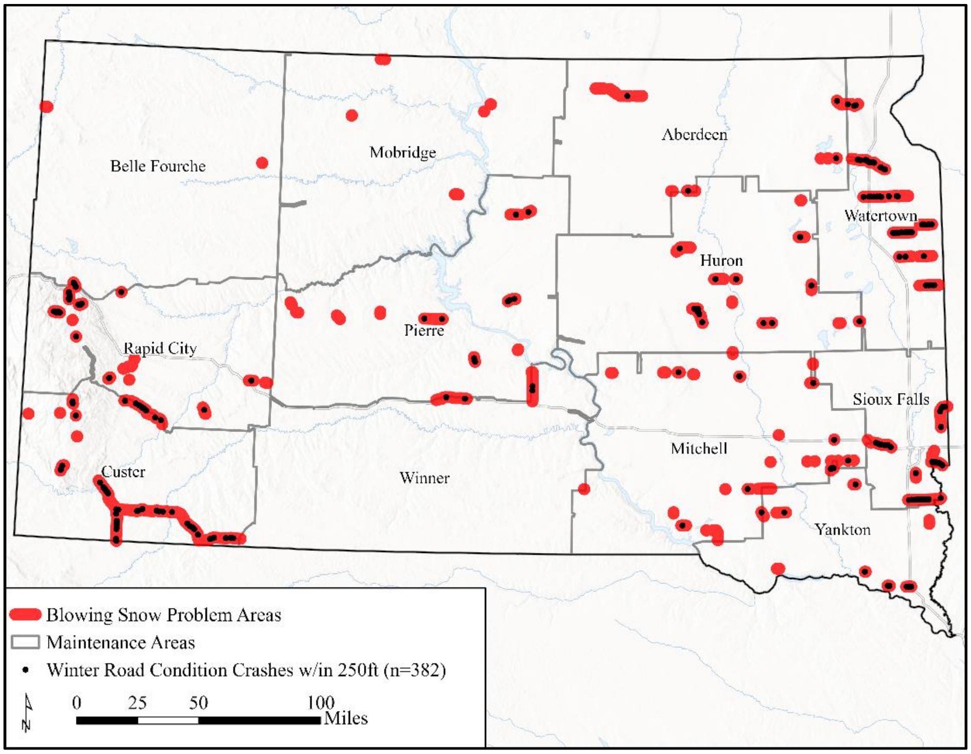

Figure 20: Winter road condition crashes (black circles) within 250 feet of a blowing snow problem area (red lines).

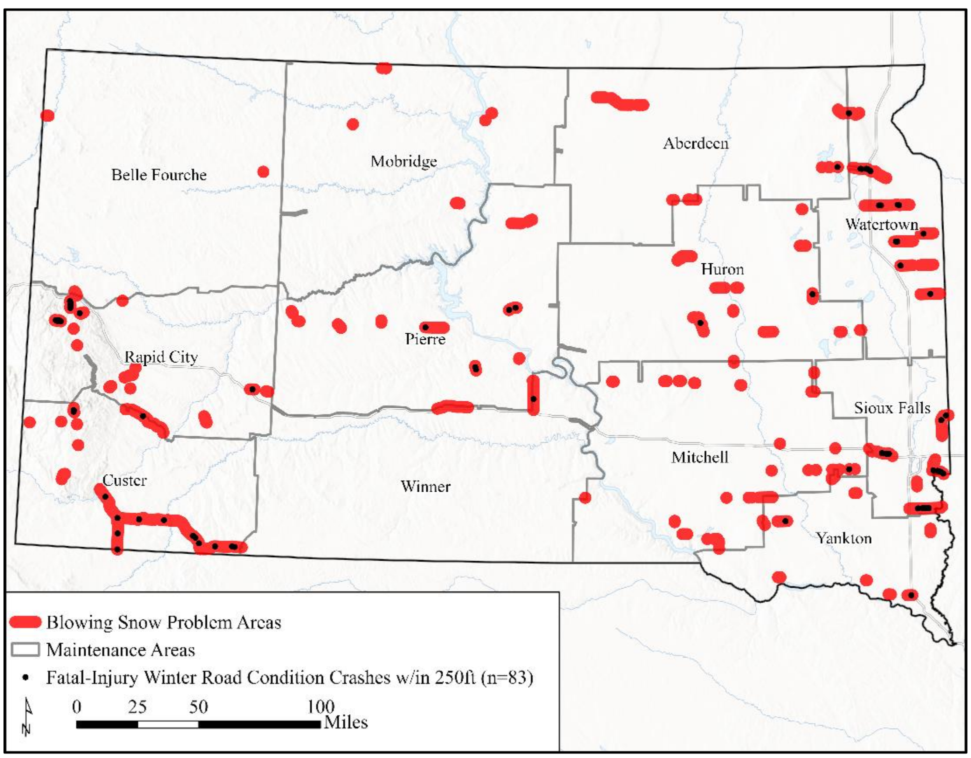

Figure 21: Fatal & Injury winter road condition crashes (black circles) within 250 feet of a blowing snow problem area (red lines).

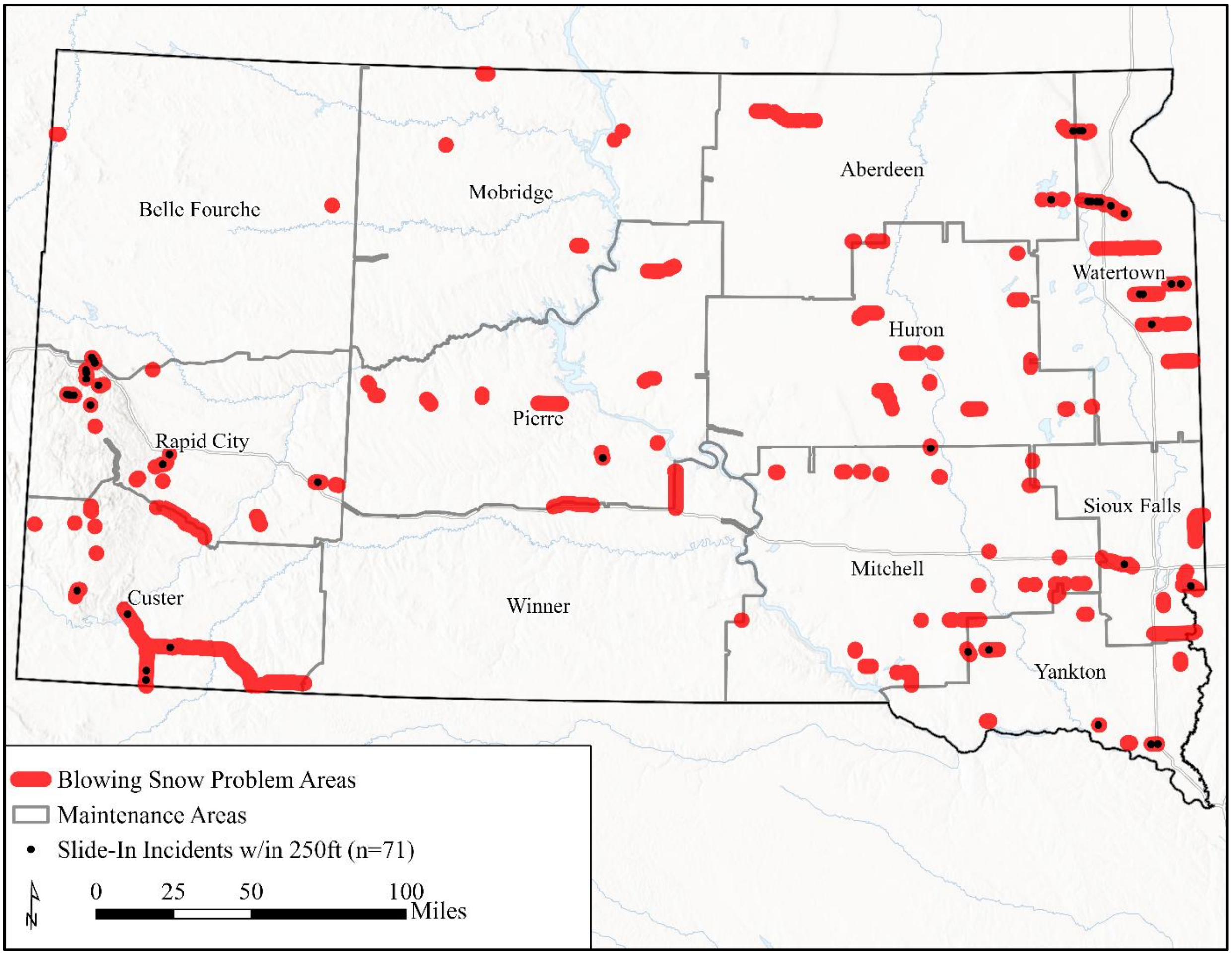

Figure 22: Slide-In incidents (black circles) within 250 feet of a blowing snow problem area (red lines).

For each blowing snow problem area, the crash or incident rate was calculated based on the total number of crashes or incidents divided by the length (in miles) of that segment. Locations with a higher crash rate were prioritized. (Note: Incidents were given a very low rating. It is acknowledged that incidents provide insight into crashes that could have occurred, but which were potentially avoided, there were concerns that they also represented a bias in reporting based on where South Dakota Highway Patrol was present.)

4.6.1.3 Roadway Functional Classification

SDDOT provided functional road classification descriptions and a GIS layer of roadway functional classes for the state (Table 6). The information was used to determine the importance of the route and serve as a proxy for annual average daily traffic (AADT). As there was no independent source of priority, AADT was not used because functional classification would redundantly represent a measure of traffic volumes. While the focus of this project is on rural roadways within South Dakota, there was still an interest by SDDOT in prioritizing those with larger functional classifications.

The roadway functional classification was identified for each blowing snow problem area. The majority of blowing snow problem areas are, as expected, based on the focus of the project, rural – principal arterials and minor arterials functional classifications (Table 6). Eight of the identified blowing snow problem areas near Rapid City and Sioux Falls, South Dakota, are outside the cities' limits but are located on routes with an "Urban" functional class. These were grouped as functional class "2 – Rural Freeways and Expressways" based on input from SDDOT for the scoring of this variable.

Table 6: SDDOT roadway function classes.

Functional Class	Description	Project Focus	Count of Blowing Snow Problem Areas	Percent of Blowing Snow Problem Areas
1	Rural – Principal Arterial - Interstate	No	0	0%
2	Rural – Freeways and Expressways	Yes	28	15.5%
4	Rural – Principal Arterials	Yes	47	26.0%
6	Rural – Minor Arterials	Yes	79	43.6%
7	Rural – Major Collector	Yes	19	10.5%
8	Rural – Minor Collector	Yes	0	0%
9	Rural – Local Roads	No	0	0%
11	Urban – Principal Arterial Interstate	No	0	0%
12	Urban – Principal Arterial – Expressways	No	6	3.3%
14	Urban – Other Principal Arterials	No	2	1.1%
16	Urban – Minor Arterial	No	0	0%
17	Urban – Major Collector	No	0	0%
18	Urban – Minor Collector	No	0	0%
19	Urban – Local Streets	No	0	0%

4.6.1.4 Distance from Maintenance Shop

SDDOT provided maintenance shop addresses. This data was used to determine the distance from each blowing snow problem area to the closest maintenance shop within the same maintenance area. This analysis was completed using the ArcGIS Closest Facility Analysis. Blowing snow problem areas farther from a maintenance shop were prioritized as these locations are likely to be more costly and resource-intensive for SDDOT to treat.

4.6.1.5 Cost to Treat the Segment

The distance from the closest maintenance shop was combined with the length of the blowing snow problem area segment to determine the total estimated travel distance for a plow operator to treat a blowing snow problem area. This travel estimate included the distance to travel to the blowing snow problem area from the maintenance shop, travel along the segment, and then back to the maintenance shop. These distance estimates are likely conservative as ArcGIS utilizes the shortest distance of travel, which may not consider appropriate spots for a snowplow to turn around, or actual routes used by SDDOT.

In addition to the prioritization methodology, this distance information will be used in the cost-benefit analysis, such that an estimated cost to perform maintenance at a location can also be deduced from the data. Combined, this information serves as a proxy for emissions and costs to address blowing snow on the road (winter maintenance costs).

Specific winter maintenance costs for each segment were not provided, but instead a deadhead rate of $40.34 per hour and $2.25 per mile, and a fully loaded rate of $207 per hour was provided by SDDOT. The fully loaded rate includes personnel, equipment, and deicing materials. According to the SDDOT Maintenance Handbook, snowplows should drive between 30-40 miles per hour during plowing operations. Using the provided rates and indicated snowplow speed, it costs roughly $3.42 per mile to drive to, or deadhead, a blowing snow problem area and $6.03 per mile to treat the area (when driving speed of 35 mph).

An estimated cost to travel to and treat each blowing snow problem area was calculated using the low and high cost per mile for deadheading and treating the segment. These costs were totaled to determine the total cost of treating each blowing snow problem area. Costs to treat the blowing snow segments range greatly from $5.28 to $450.77.

Addressing the blowing snow issue through grading or a snow fence could reduce the need for a snowplow to travel long distances to problem locations, resulting in time and cost savings. Thus, blowing snow problem areas that have a higher cost to treat (those that are farther away from a maintenance shop), should be prioritized over those that are located closer to a maintenance shop, as snow fences or other blowing snow mitigation strategies will provide the greatest cost saving for SDDOT.

4.6.1.6 Prevailing Wind Direction

SDDOT provided RWIS wind data from 2014 through 2024. The data included RWIS site names and identification numbers, date and time stamp, wind speed as maximum gust and wind speed (which was converted to miles per hour (mph)), and wind direction every five minutes. For this project, data were used from “winter months” defined as October through March. Note that the number of RWIS sites changed over time, with some RWIS sites being retired and new RWIS sites brought online over the 10-year time frame. As of 2024 there are 121 RWIS sites in South Dakota as shown in Figure 26. [Number of RWIS sites in South Dakota: 2014 (n=60), 2015 (n=73), 2016 (n=85), 2017 (n=86), 2018 (n=88), 2019 (n=89), 2020 (n=110), 2021 (n=110), 2022, 2023, and 2024 (n=121).]

Two variables were examined for this project: 1) wind direction, and 2) wind speed. Data for these variables was pulled from winter months, amounting to more than 33 million data points (n=33,481,478), which are visualized as wind rose diagrams. Wind rose diagrams are graphical charts that characterize speed and direction of wind presented in a circular format with the length of the spoke indicating the amount of time wind blows in a specific direction (64).

When all wind direction data is considered over the 10-year time frame during winter months, there is a high frequency of wind coming from the north-west (NW) direction (Figure 23).

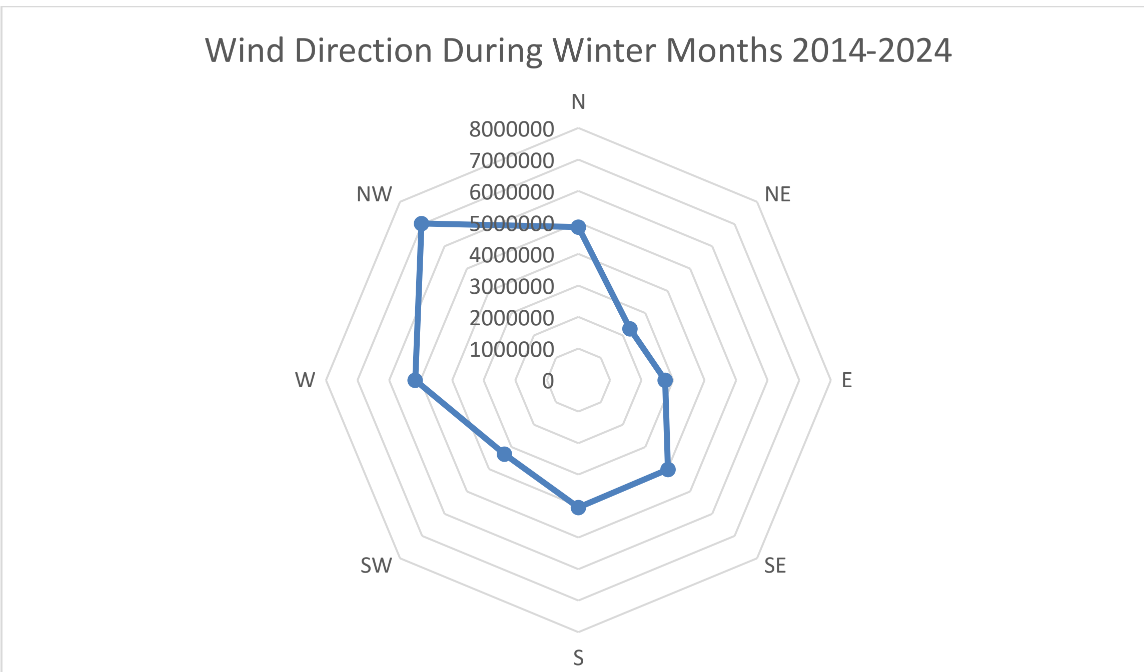

Figure 23: Wind direction from 2014-2024 during winter months (Oct, Nov, Dec, Jan, Feb, Mar) with the number of data points.

The research team then considered both wind direction and wind speed together. When wind speeds are 15 mph and greater (≥15mph), there is a greater probability that blowing snow can occur (Tabler, 2003). For this reason, the data in Figure 24 has been broken out as wind direction and wind speed from 0 mph to less than 15 mph (0-<15mph, orange) and wind direction and wind speed 15 mph and greater (blue). Figure 24 shows that wind speeds ≥15 mph can originate from all directions, but a disproportionate amount (~40%) originates from the NW (Table 7). Wind speeds of less than 15 mph are shown to come from all directions, but less so from the NW. This data shows that when there is a higher probability of blowing snow conditions present (e.g., winds are ≥15 mph), the wind typically comes from the NW. Over the 10-year time frame, South Dakota winds at 0 mph to less than 15 mph occurred ~77% of the time, and wind speeds 15 mph and greater occurred ~23% of the time.

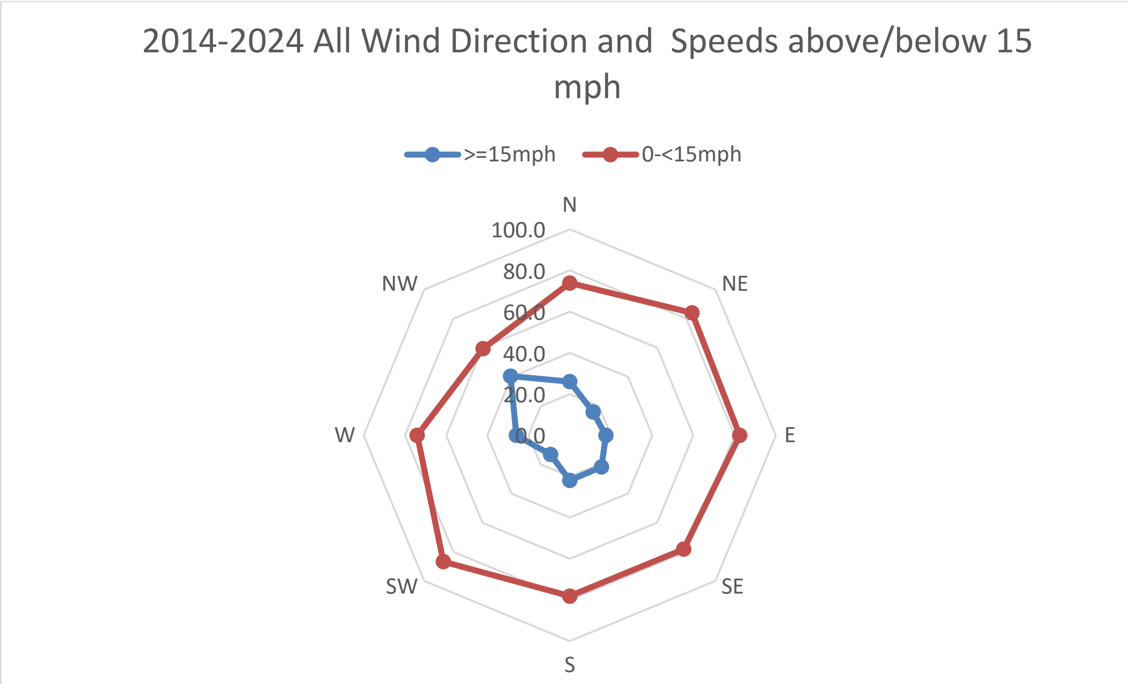

Figure 24: Wind rose diagram showing percent of occurrence wind direction and wind speed data as less than 15 mph (orange) and 15 mph and greater (blue) for the winter months (Oct, Nov, Dec, Jan, Feb, Mar) from 2014-2024.

Table 7: Summary data of wind direction and wind speed percent frequency at less than 15 mph or 15 mph and greater and the number of data elements.

Wind Direction	Wind Speed 0 to less than 15 mph (% frequency)	Wind Speed 15 mph and Greater (% frequency)	Number of Data Elements (n)
N	73.9	26.1	4,850,448
NE	84.0	16.0	2,309,266
E	82.5	17.5	2,749,273
SE	78.2	21.8	4,011,633
S	78.1	21.9	4,042,242
SW	86.8	13.2	3,320,986
W	74.0	26.0	5,170,667
NW	59.4	40.6	7,026,963

This information can be used by winter maintenance managers to inform operations and predict when blowing snow conditions may be present. This data is supported by feedback received in the maintenance staff interviews, which reported prevailing winds predominantly from the NW (Figure 25). (Note: Figure 25 was introduced earlier in this document as Figure 15.)

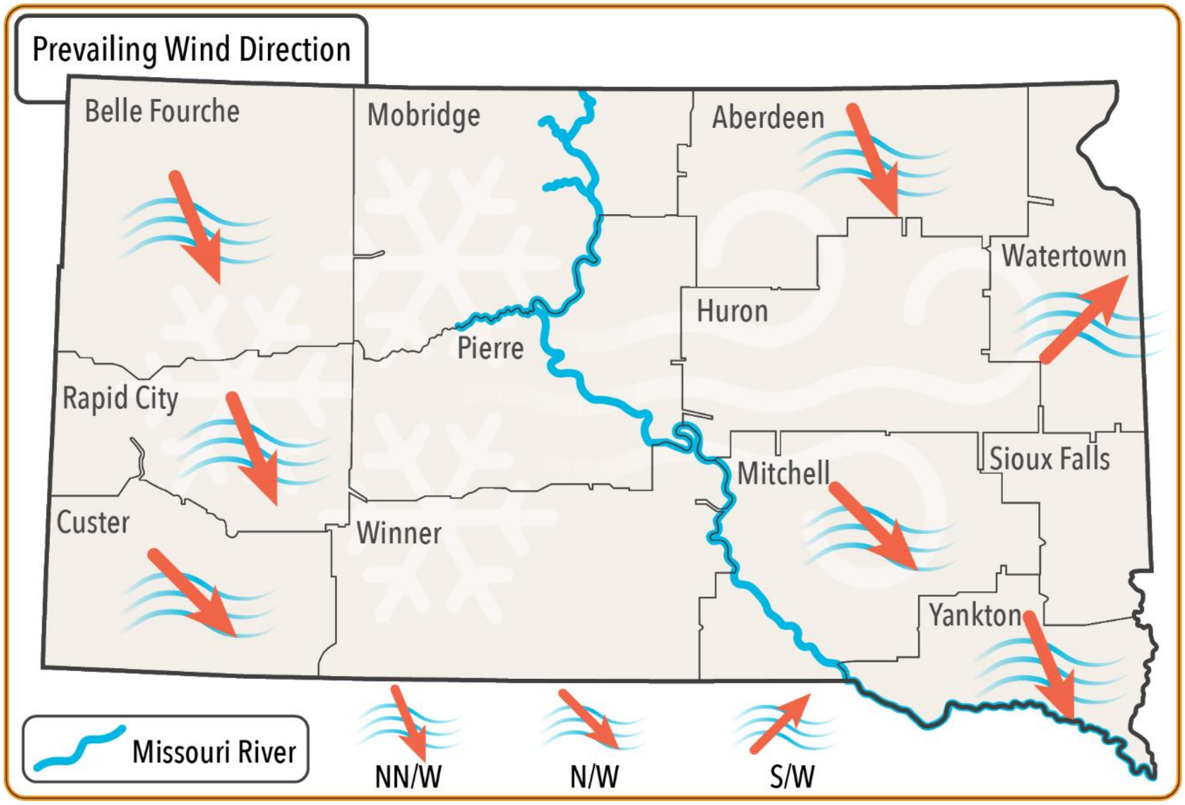

Figure 25: Prevailing wind direction based on feedback from SDDOT maintenance personnel.

Next, the researchers conducted an analysis of the percentage (%) of time (minutes) when an RWIS station reported winds 15 mph and greater for those near blowing snow road segments in the top 100 list. Figure 26 maps the 121 RWIS stations (black triangles with RWIS site number) in South Dakota and the blowing snow problem areas (shown in red). The percent time RWIS stations report wind speeds of 15 mph and greater is shown in Table 8.

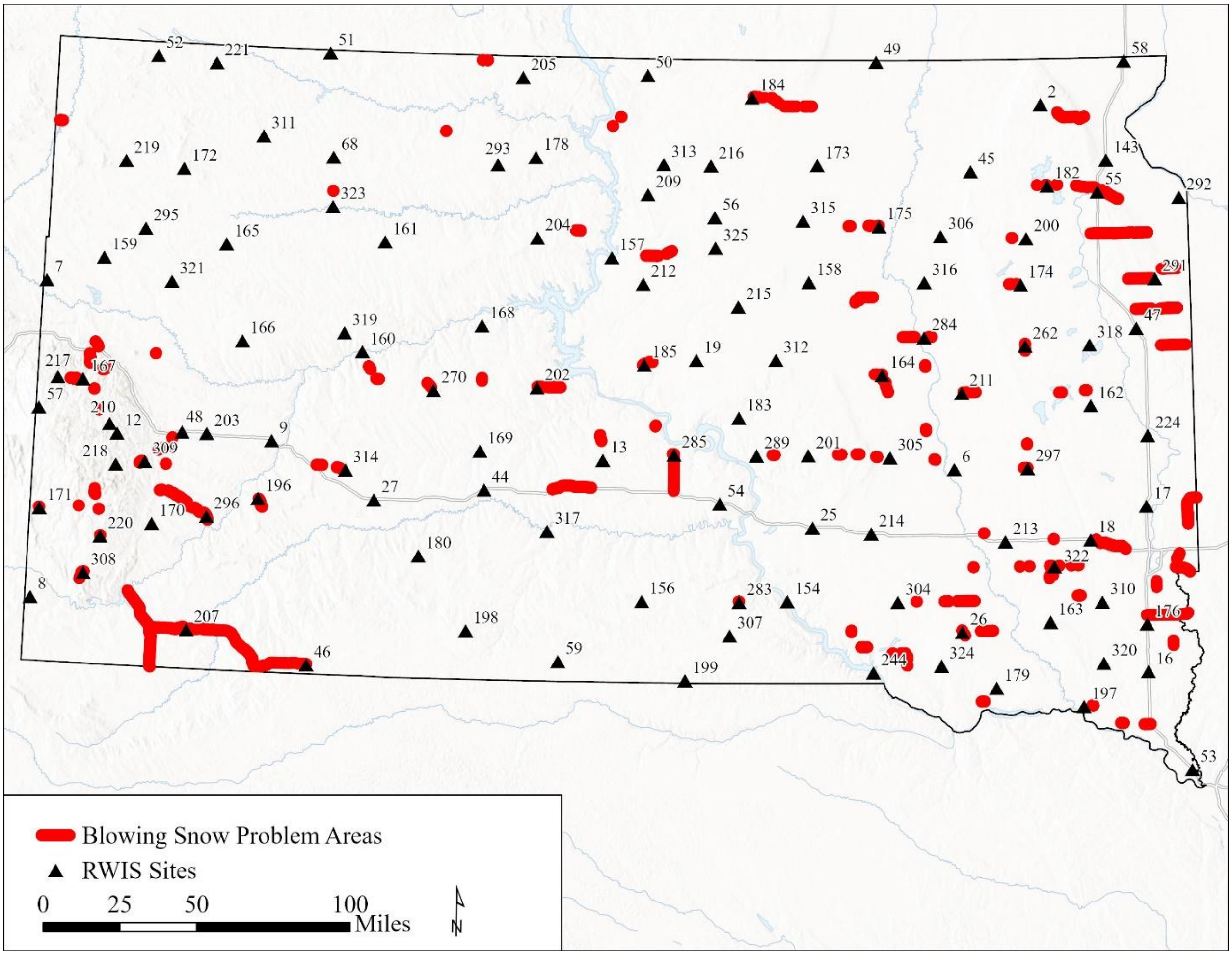

Figure 26: Map of South Dakota with RWIS sites (black triangle with number) along with identified blowing snow problem areas along rural road segments (red dots).

Table 8: Summary of 2022-2023 and 2023-2024 winter seasons RWIS based wind speed data ≥15 mph total minutes & % amount of time wind speed ≥15 mph by RWIS station located within 250 ft, 1 mile, and 5 miles of blowing snow problem areas (BSPA).

RWIS ID #	2022-2023 winter season wind ≥15mph (min)	2022-2023 winter season time ≥15 mph (% time)	2023-2024 winter season wind ≥15mph (min)	2023-2024 winter season time ≥15 mph (% time)	RWIS to BSPA Distance (250ft)	RWIS to BSPA Distance (1 mile)	RWIS to BSPA Distance (5 miles)
18	98,490	1.36	90,155	1.29			1
26	85,115	1.18	76,495	1.10	1		
46	57,520	0.80	48,445	0.70	1		
48	51,435	0.71	34,180	0.49			1
55	104,585	1.45	93,255	1.34		1	
162	35,770	0.50	41,125	0.59			1
164	65,945	0.91	55,350	0.79	1		
167	1,635	0.02	625	0.01			1
171	24,680	0.34	21,095	0.30	1		
174	79,235	1.10	74,810	1.07			1
175	72,035	1.00	58,840	0.84		1	
176	72,405	1.00	66,455	0.95			1
182	46,175	0.64	46,550	0.67		1	
184	73,920	1.02	73,485	1.06		1	
185	51,230	0.71	47,405	0.68	1		
196	56,870	0.79	44,745	0.64			1
197	64,955	0.90	43,560	0.63		1	
200	78,675	1.09	63,695	0.91			1
202	69,180	0.96	71,580	1.03		1	
207	69,070	0.96	50,865	0.73	1		
211	65,205	0.90	57,285	0.82		1	
217	3,860	0.05	2,470	0.04			1
220	12,135	0.17	10,670	0.15		1	
262	57,855	0.80	27,835	0.40	1		
270	88,405	1.22	95,315	1.37		1	
283	86,615	1.20	82,400	1.18	1		
284	85,010	1.18	66,055	0.95			1
285	73,415	1.02	64,840	0.93	1		
291	75,195	1.04	65,180	0.94			1
296	31,945	0.44	27,825	0.40	1		
297	73,460	1.02	56,605	0.81	1		
305	81,505	1.13	69,200	0.99			1
308	49,160	0.68	41,040	0.59	1		
309	28,635	0.40	20,745	0.30		1	
314	45,835	0.63	46,690	0.67			1
322	32,115	0.44	38,190	0.55		1	
323	32,650	0.45	52,770	0.76			1
Sum	**2,181,925**	**30.21**	**1,927,830**	**27.68**	**12**	**11**	**14**

The RWIS data is recorded in 5-minute intervals; therefore, this analysis assumes that each data element accounts for the full 5 minutes. This analysis was completed for RWIS stations located within 250 feet, 1 mile, and 5 miles of blowing snow problem areas for the two most recent winter seasons (2022-2023 and 2023-2024), as shown in Figure 27 and Figure 28, and additional maps shown in Appendix D: RWIS Blowing Snow Wind Speed Analysis.

Before 2022, fewer RWIS sites were present in South Dakota. For this reason, even though SDDOT provided RWIS data back to 2014, the researchers focused on the most robust RWIS data set for the state, which is represented by the two most recent winter seasons (2022-2023 and 2023-2024, n=121). In this analysis, 37 RWIS stations were located within 5 miles of blowing snow problem areas. These 37 RWIS stations provide wind data for 72 of the identified blowing snow problem areas. Unfortunately, many of the blowing snow problem areas lacked nearby wind data for the analysis. Note that, as the distance from the RWIS sites increases from the blowing snow problem area, the confidence decreases that the RWIS data accurately represents the blowing snow problem area. Figure 27 and Figure 28 show a clear trend of wind speeds ≥15 mph occurring a greater percentage of time East River in South Dakota, with a few exceptions.

A separate analysis of percent (%) time (minutes) when RWIS stations reported winds 15 mph and greater was completed for all RWIS stations in each South Dakota DOT maintenance area. This analysis found that RWIS sites in the Custer and Rapid City maintenance areas experience a lower percentage of time at or above this wind threshold (≥15 mph) when compared to the rest of the state.

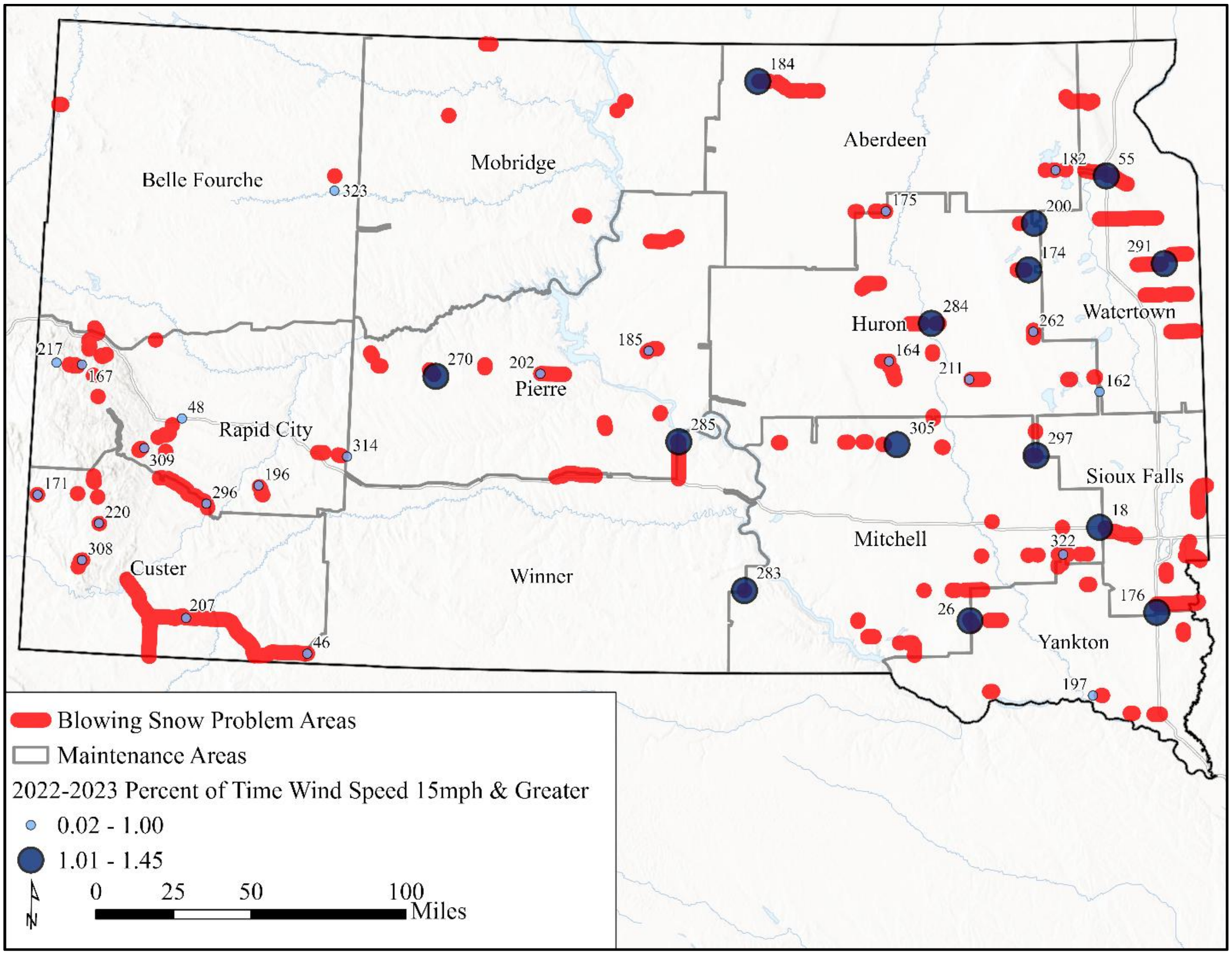

Figure 27: Map of South Dakota with blowing snow problem areas along rural road segments (red dots) and RWIS station wind data shown as percent (%) of time (minutes) that winds are ≥15 mph (blue circles) for the 2022-2023 winter season.

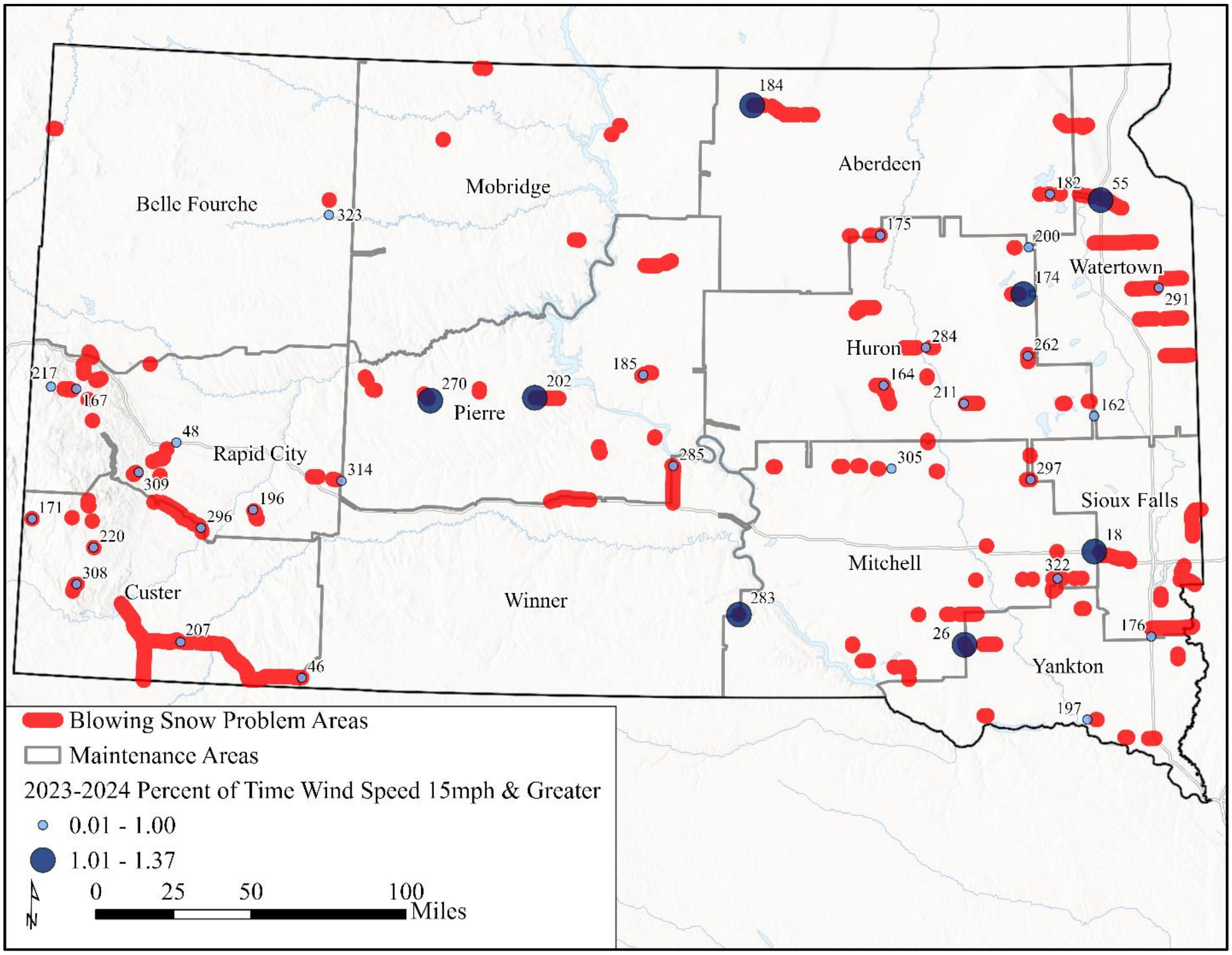

Figure 28: Map of South Dakota with blowing snow problem areas along rural road segments (red dots) and RWIS station wind data shown as percent (%) of time (minutes) that winds are ≥15 mph (blue circles) for the 2023-2024 winter season.

4.6.1.7 Land Ownership

Data from the Protected Areas Database of the United States (PAD-US) was used to determine if a blowing snow problem area was within the boundary of a federal land management agency (National Park Service, Bureau of Land Management, U.S. Forest Service, U.S. Fish and Wildlife Service, etc.) or Tribal Lands (65). A data source related to state-owned and privately owned land ownership was not readily available for South Dakota.

While this variable will not influence the ranking of a blowing snow problem area, locations falling within federal or tribal boundaries may require additional permissions or effort for approval; therefore, these locations are noted in the blowing snow problem area analysis spreadsheet (Blowing_Snow_Problem_Areas_Top100). Additional landownership considerations are discussed in Appendix E: Additional Variables Considered.

4.6.2 Prioritization Methodology – Variable Scoring

For the data elements described previously, the following methodology was used to determine the top 100 blowing snow problem areas for consideration for treatment (snow fence, grading) by South Dakota DOT. An Excel file (Blowing_Snow_Problem_Areas_Top100) with all data elements, scoring, and ranking has been provided to SDDOT.

4.6.2.1 Maintenance Priority

This variable had a possible maximum of 40 points assigned. As discussed in the Identify Blowing Snow Locations section, each maintenance area provided a varying number of blowing snow problem areas. Ten of the 12 maintenance areas reported at least 5 segments; therefore, points were assigned to blowing snow problem areas that ranked in the top 5 for each maintenance area as shown in Table 9. This point distribution was determined with input from the SDDOT project panel.

Table 9: Maintenance priority ranking of blowing snow problem areas and points assigned.

Maintenance Area Priority	Prioritization Methodology Score
1	40
2	32
3	24
4	16
5	8

(Note that in the Blowing_Snow_Problem_Areas_Top100 spreadsheet, blowing snow problem areas that were ranked in the top ten by each maintenance district are shown in red text.)

4.6.2.2 Roadway Functional Class

This variable had a possible maximum of five points assigned. Points were assigned based on the roadway functional classification, as shown in Table 10. This point distribution was determined with input from the SDDOT project panel.

Table 10: Roadway function classification and points assigned.

Roadway Functional Classification	Prioritization Methodology Score
Principal Arterial (Urban)/Freeway (Urban)	5
Freeway (Rural)	4
Principal Arterial (Rural)	3
Minor Arterial (Rural)	2
Minor/Major Collectors (Rural)	1

4.6.2.3 Distance and Cost

This variable had a possible maximum of 10 points assigned. The distance from the closest maintenance shop to a blowing snow problem area was used along with its length to determine an estimated cost to treat. Using the following calculations:

- The deadheading rate for a maintenance truck was provided by SDDOT as $2.25 per mile and a labor rate of $40.34 per hour.
- A fully loaded rate of $207.00 per hour was provided by SDDOT (includes the cost for personnel, vehicle, and roadway treatment).
- Using an assumed maintenance truck speed of 30 MPH and 40 MPH, the deadhead rate and fully loaded rate were converted into a cost per mile.

Table 11: Deadhead and treatment costs per mile.

Cost	Low Rate ($/mi)	High Rate ($/mi)
Deadhead Cost	$3.26	$3.59
Treatment Cost	$5.17	$6.90

For each blowing snow problem area, the deadhead cost and treatment cost were summed to provide a low and high estimated total cost (utilizing the low and high rates provided in Table 11 above). The average of the low and high costs was then calculated.

Figure 29 shows that for most blowing snow problem areas, the average cost to treat the location is less than $228.61 (n=169 out of 181). In order to normalize the extreme high outliers, every blowing snow problem area that cost $228.61 and greater was given 10 points and the remaining blowing snow problem areas were assigned points based on Equation 1.

$$Distance\ \&\ Cost\ Score = ([Cost\ to\ treat\ the\ Site]/228.61) * 10$$

Equation 1: Distance and cost point calculation for blowing snow problem areas that cost less than $228.61.

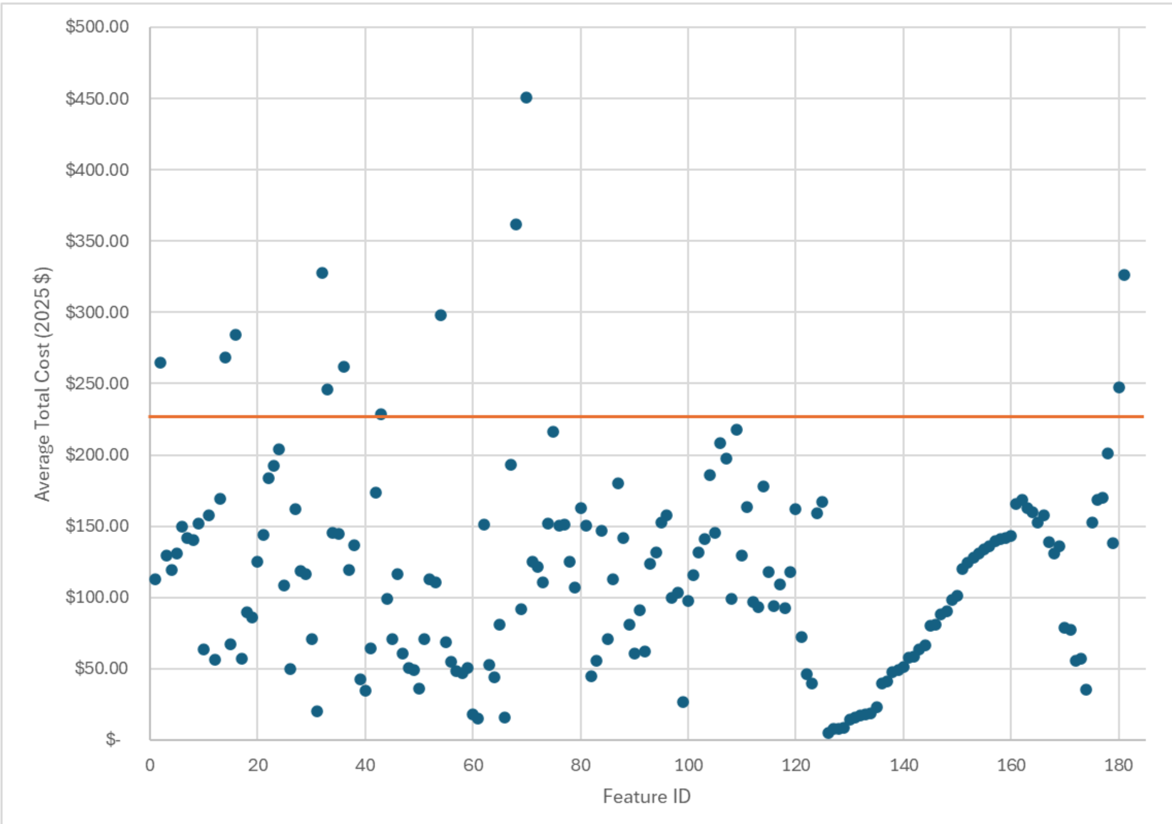

Figure 29: Average cost to treat a blowing snow problem area showing that most blowing snow problem areas can be treated for less than $228.61 (orange line).

4.6.2.4 Crashes & Incidents

This variable had a possible total of 30 points assigned. Points for the crash data elements are as follows, and the sum of the individual crash layer scores is applied. Scores from slide in incidents, winter road crash rate, fatal & injury winter road crash rate, winter weather crash rate, fatal & injury winter weather crash rate, and blowing snow crash rate were combined for this variable.

Slide In Incidents

Figure 30 shows that most blowing snow problem areas experienced a slide in incident rate of less than 3.39 (n=173 out of 181). To normalize the extreme high outliers, any blowing snow problem area with a slide in incident rate of 3.39 or higher received 1 point, all other blowing snow problem areas were assigned points using Equation 2.

$$Slide\ In\ Incident\ Score = [Slide\ In\ Incident\ Rate]/3.39*1$$

Equation 2:Slide incident score for blowing snow problem areas with an incident rate below 3.39.

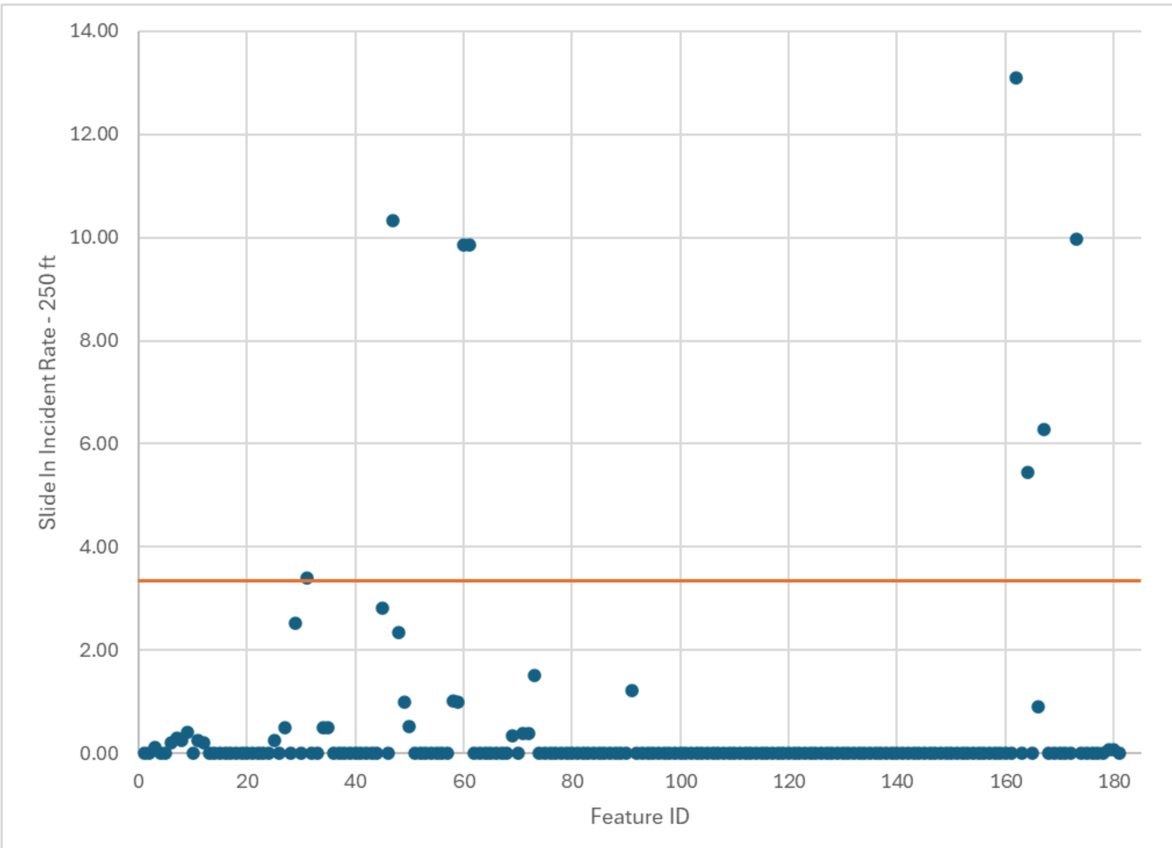

Figure 30: Slide in incident rate for each blowing snow problem area, showing that most areas had a rate of less than 3.39 (orange line).

Winter Road Crash Rate

Figure 31 shows that most blowing snow problem areas have a winter road crash rate of 5 or less (n=167 or 181). To normalize the extreme high outliers in the winter road crash rates, every blowing snow problem area with a winter road crash rate of 5 and greater was assigned 10 points, and all other blowing snow problem areas were assigned points which were calculated based on Equation 3.

$$Winter\ Road\ Crash\ Score = (\frac{[Winter\ Road\ Crash\ Rate]}{5}) * 10$$

Equation 3: Winter road crash score for blowing snow problem areas with a crash rate equal to or below 5.

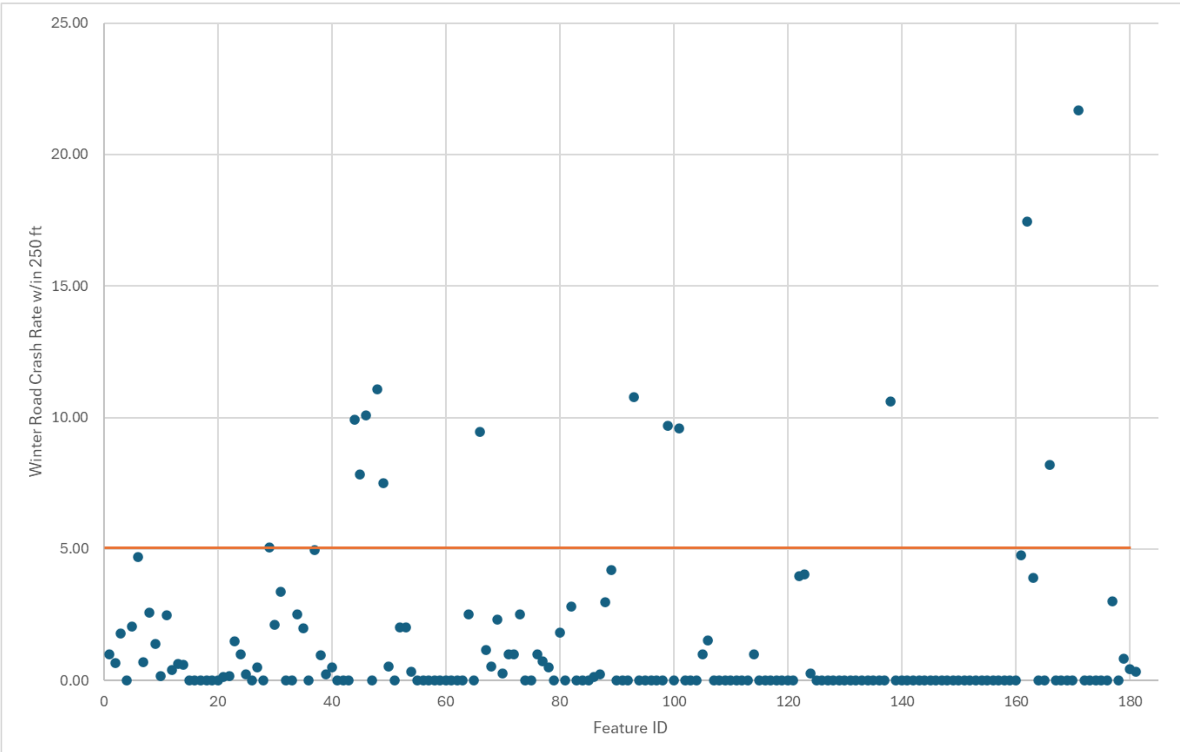

Figure 31: Winter road condition crash rates within 250ft of blowing snow problem areas, most have a rate less than 5 (orange line).

Winter Weather Crash Rate

Figure 32 shows that most blowing snow problem areas have a winter weather crash rate of 4 or less (n=168 of 181). To normalize the extreme high outliers in the winter weather crash rates, all blowing snow problem areas with a crash rate of 4 and greater were assigned 10 points, and all other blowing snow problem areas were assigned points based on Equation 4.

$$Winter\ Weather\ Crash\ Score = (\frac{[Winter\ Weather\ Crash\ Rate]}{4}) * 10$$

Equation 4: Winter weather crash rate score for blowing snow problem areas with a crash rate equal to or below 4.

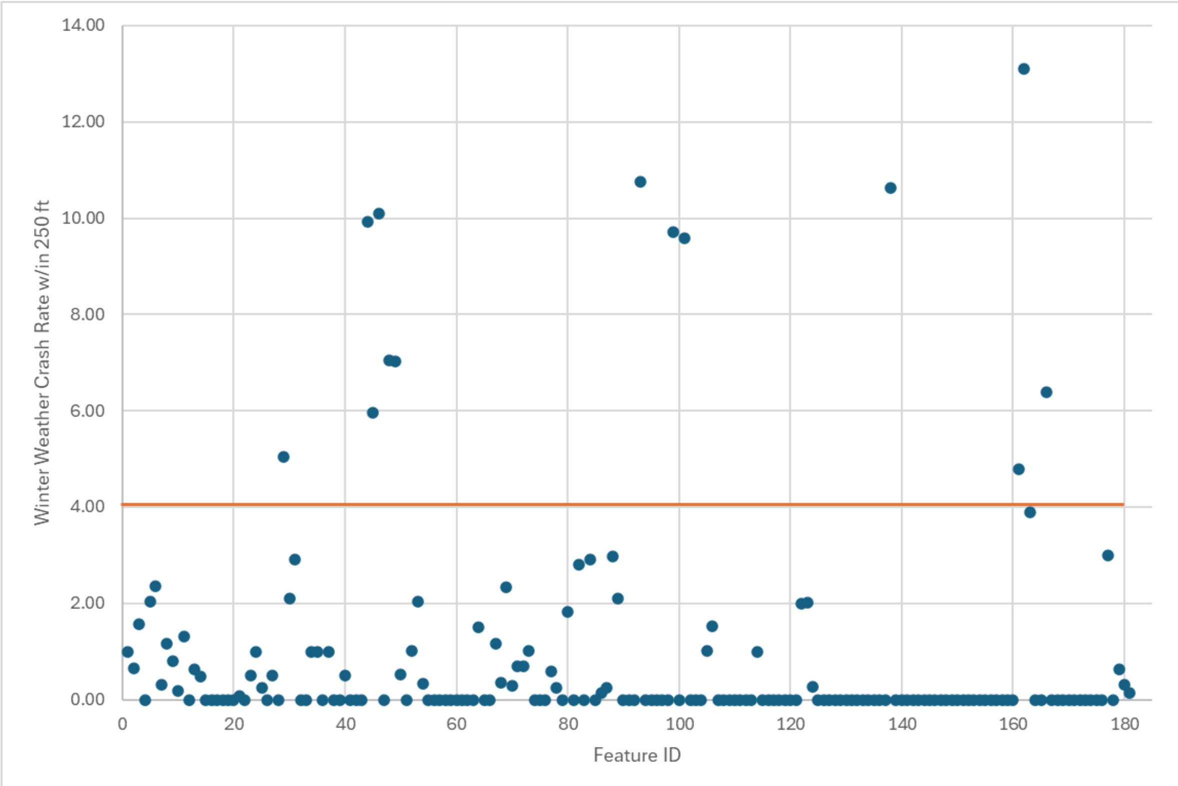

Figure 32: Winter weather crash rates within 250ft of blowing snow problem areas, most have a rate less than 4 (orange line).

Blowing Snow Crash Rate

Figure 33 shows that most blowing snow problem areas have a blowing snow crash rate of 2.81 or less (n=171 of 181). To normalize the extreme high outliers in the blowing snow crash rates, all blowing snow problem areas with a crash rate of 2.81 and greater were assigned 5 points, and all other blowing snow problem areas were assigned points based on Equation 5.

$$Blowing\ Snow\ Crash\ Score = \left(\frac{[Blowing\ Snow\ Crash\ Rate]}{2.81}\right) * 5$$

Equation 5: Blowing snow crash rate score for blowing snow problem areas with a score of below 2.80.

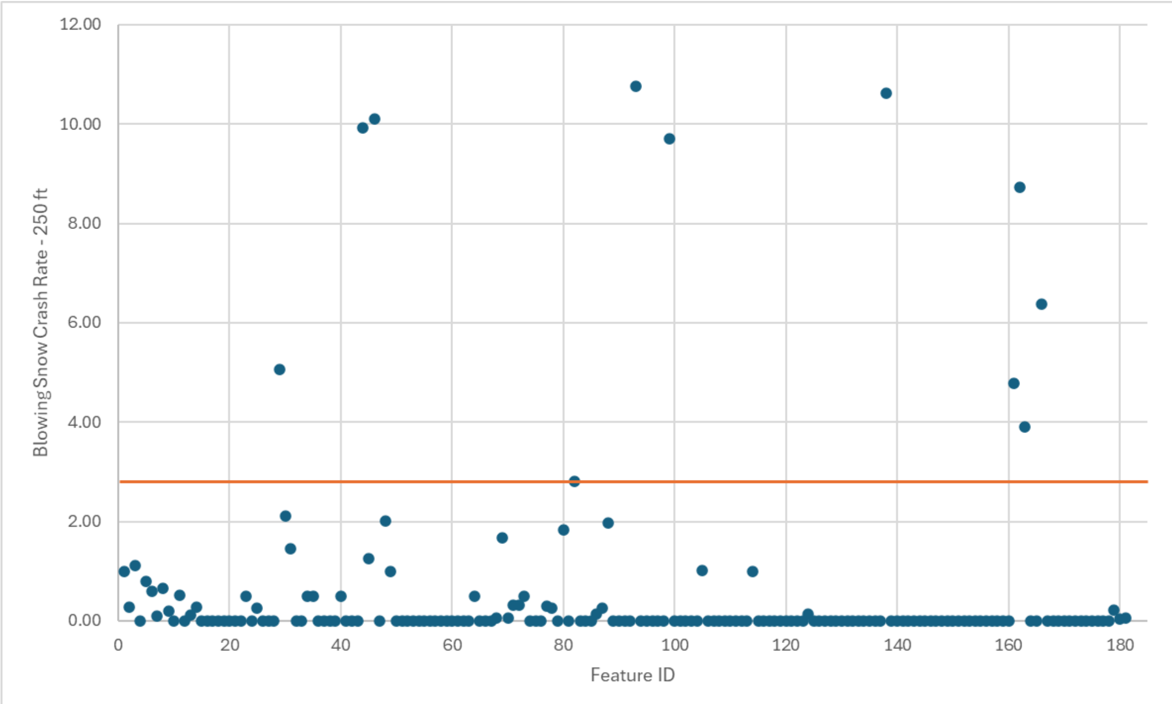

Figure 33: Blowing snow crash rates within 250ft of each blowing snow problem area, most have a rate less than 2.81 (orange line).

Fatal & Injury Winter Road Crash Rate

Figure 34 shows that most blowing snow problem areas have a fatal & injury winter road crash rate of 4.37 (n=178 out of 181). To normalize the extreme high outliers in the fatal & injury winter road crash rates, every blowing snow problem area with a winter road crash rate of 4.37 and greater was assigned 2 points, and all other blowing snow problem areas were assigned points which were calculated based on Equation 6.

$$Fat\ \&\ Inj\ Winter\ Road\ Crash\ Score = \left(\frac{[Fat\ \&\ Inj\ Winter\ Road\ Crash\ Rate]}{4.37}\right) * 2$$

Equation 6: Fatality and injury winter road crash rate score for blowing snow problem areas with a crash rate below 4.37.

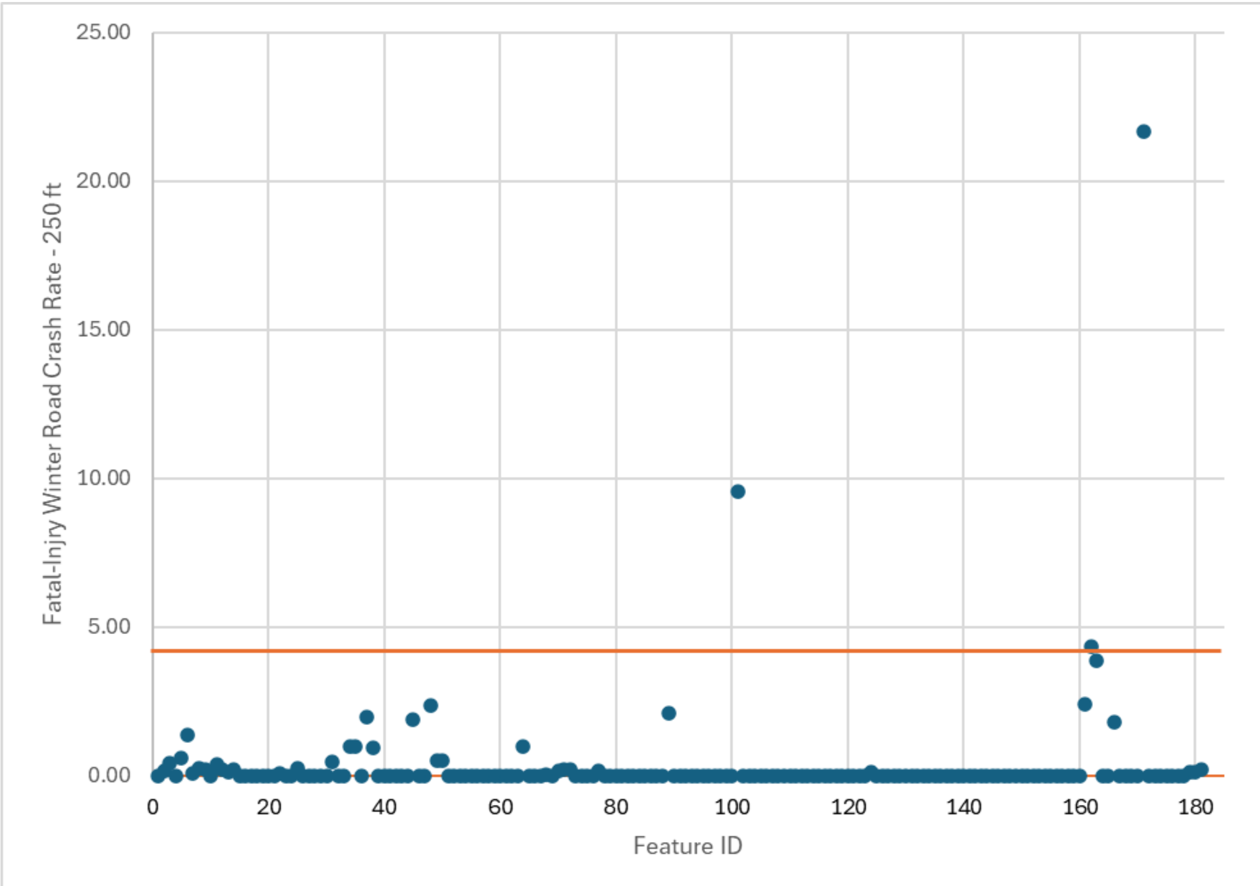

Figure 34: Fatal-injury winter road crash rate for each blowing snow problem area, show that most areas have a rate less than 4.37 (orange line).

Fatal & Injury Winter Weather Crash Rate

Figure 35 shows that most blowing snow problem areas have a fatal & injury winter weather crash rate of 2.39 or less (n=177 of 181). To normalize the extreme high outliers in the fatal & injury winter weather crash rates, all blowing snow problem areas with a crash rate of 2.39 and greater were assigned 2 points, and all other blowing snow problem areas were assigned points based on Equation 7.:

$$Fat\ \&\ Inj\ Winter\ Weather\ Crash\ Score = \left(\frac{[Fat\ \&\ Inj\ Winter\ Weather\ Crash\ Rate]}{2.39}\right) * 2$$

Equation 7: Fatality and injury winter weather crash score for blowing snow problem areas with a crash rate below 2.39.

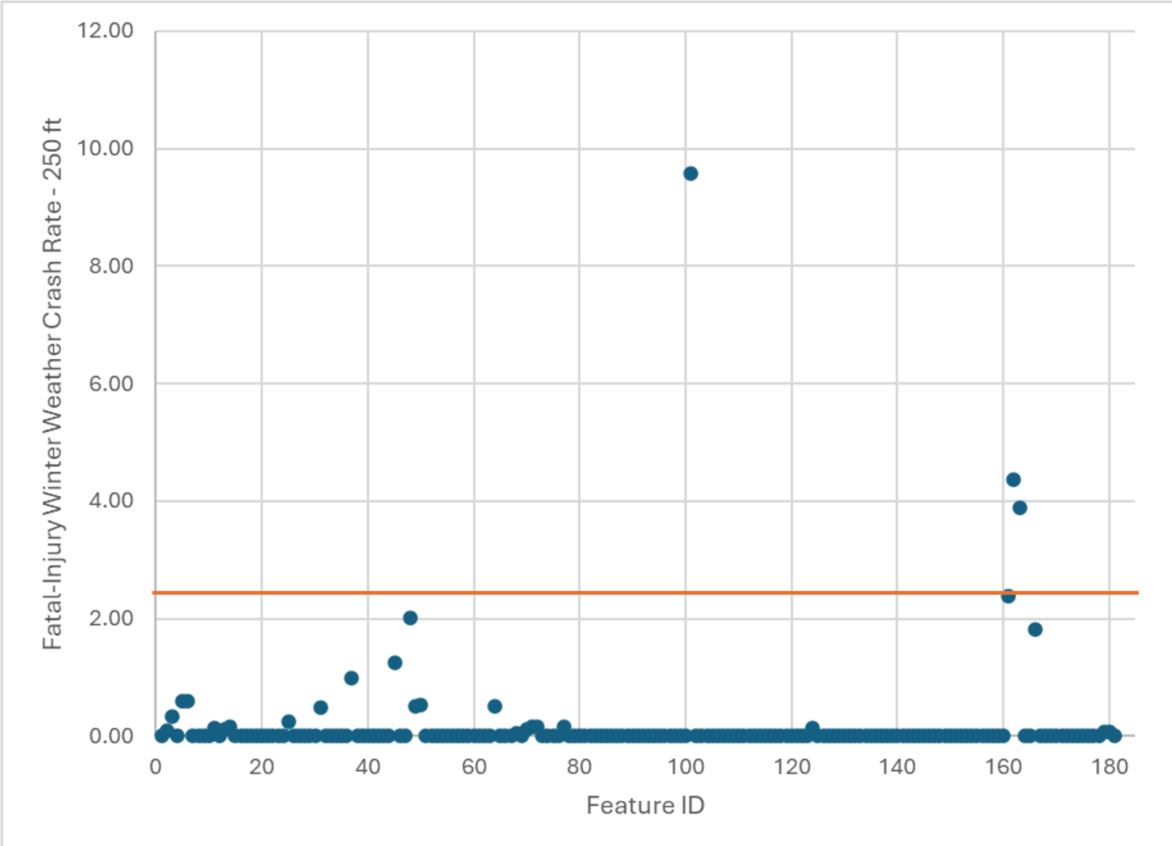

Figure 35: Fatal-injury winter weather crash rates within 250ft of each blowing snow problem area, most have a rate less than 2.39 (orange line).

4.6.2.5 Wind Threshold

This variable had a possible five points assigned. Points were assigned based on the percentage of time during which wind conditions were present, where blowing snow could occur. An analysis of the percentage of time in which an RWIS station measured wind speeds of 15 mph and greater was performed. This analysis found that RWIS sites in the Custer and Rapid City maintenance areas experience a lower percentage of time at or above this wind threshold when compared to the rest of the state. For blowing snow problem areas located within the Custer and Rapid City maintenance areas, two points were assigned; five points were assigned to blowing snow problem areas in all other maintenance areas.

4.7 Top 100 Blowing Snow Locations on South Dakota State Roadways

Upon approval of the technical panel of the plan developed in Task 6 [Identify Blowing Snow Locations], execute the analysis, and develop a prioritized list of the top 100 blowing snow mitigation locations with recommendations for the preferred mitigation strategies.

The final prioritization score was calculated by summing all of the variables as follows:

$$Final\ Score = [Maintenance\ Priority\ Score] + [Roadway\ Funcational\ Class\ Score] + [Distance\ and\ Cost\ Score] + [Crash\ Score] + [Wind\ Threshold\ Score]$$

Using this final score, the top 100 blowing snow problem areas on rural, non-interstate routes in South Dakota were generated (see Table 13).

Each maintenance area is represented in the top 100 list (Figure 36). A summary of the top 100 blowing snow problem segments list, including the total number of blowing snow problem areas and total length in miles for each maintenance area, is provided in Table 12.

Table 12: Summary of top 100 list by maintenance area.

Maintenance Area	Count of Blowing Snow Problem Areas in the Top 100 List	Sum of the Length of Blowing Snow Problem Areas in the Top 100 List (miles)
Aberdeen Area	11	4.41
Belle Fourche Area	3	3.03
Custer Area	11	122.02
Huron Area	12	20.62
Mitchell Area	15	6.89
Mobridge Area	5	2.21
Pierre Area	11	20.68
Rapid City Area	9	13.44
Sioux Falls Area	6	42.71
Watertown Area	7	62.37
Winner Area	2	24.99
Yankton Area	8	16.45
Grand Total	**100**	**339.82**

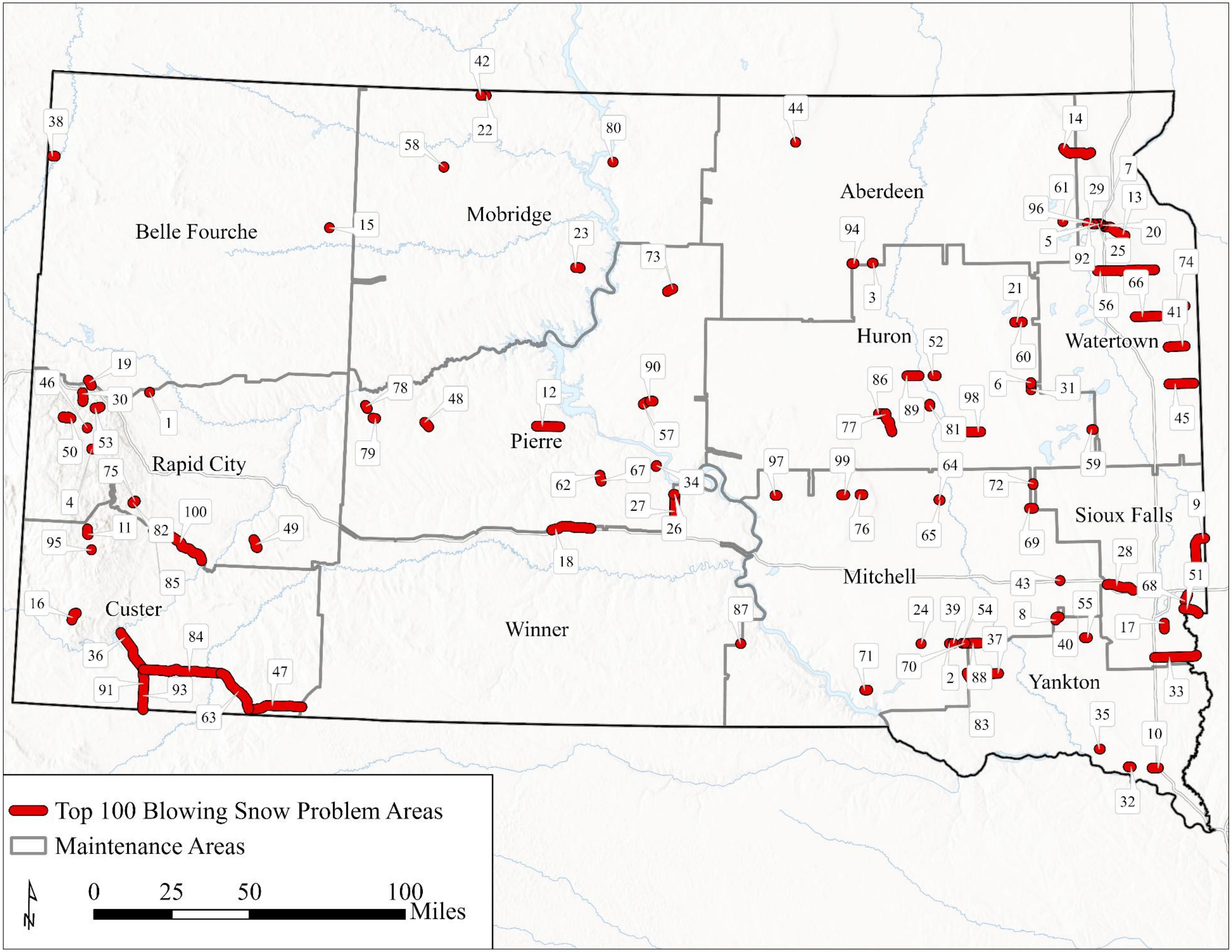

Figure 36: Top 100 blowing snow problem areas on rural, non-interstate highways in South Dakota.

Table 13: Top 100 blowing snow problem areas.

Original Feature ID	Name	Highway	Maintenance Area	Length (Miles)	Begin MRM	End MRM	Top 100 Rank
44	Hwy 34, MRM 48	Hwy 34	Rapid City Area	0.10	47.95	48.05	**1**
93	Hwy 44, MRM 343.24 County Line Bridge	Hwy 44	Mitchell Area	0.09	343.19	343.29	**2**
177	Hwy 20, MRM 318.22-318.56	Hwy 20	Aberdeen Area	0.33	318.22	318.56	**3**
46	Hwy 385, MRM 108	Hwy 385	Rapid City Area	0.10	107.95	108.05	**4**
163	Hwy 12 W, MRM 364.51-364.76	Hwy 12	Aberdeen Area	0.26	364.51	364.76	**5**
89	Hwy 28, MRM 319.4-319.9	Hwy 28	Huron Area	0.48	319.4	319.9	**6**
162	Hwy 12 W, MRM 364.96-365.19	Hwy 12	Aberdeen Area	0.23	364.96	365.19	**7**
23	Hwy 81, on Curve	Hwy 81	Yankton Area	2.01	44	46	**8**
2	Hwy 11 Garretson to MN	Hwy 11	Sioux Falls Area	10.65	92	102.55	**9**
31	Hwy 50W, MRM 415-417	Hwy 50 W	Yankton Area	2.06	415	417	**10**
64	Hwy 16, MRM 30-32	Hwy 16	Custer Area	2.00	30	32	**11**
124	Hwy 14, MRM 207.7-215.3	Hwy 14	Pierre Area	7.63	207.7	215.3	**12**
11	Hwy 12 Near Marvin	Hwy 12	Watertown Area	7.64	366.37	374	**13**
7	Hwy 10 Near Long Hollow	Hwy 10	Watertown Area	9.92	345	355	**14**
74	Hwy 73, MRM 196	Hwy 73	Belle Fourche Area	0.09	195.95	196.05	**15**
69	Hwy 18, MRM 22-25	Hwy 18	Custer Area	3.00	22	25	**16**
1	Hwy 115 Harrisburg	Hwy 115	Sioux Falls Area	2.00	76.33	78.34	**17**
21	Hwy 248	Hwy 248	Winner Area	12.98	208	221	**18**
73	Hwy 34, MRM 23-25	Hwy 34	Belle Fourche Area	1.99	23	25	**19**
161	Hwy 12 W, MRM 365.59-366.01	Hwy 12	Aberdeen Area	0.42	365.59	366.01	**20**
82	Hwy 212, MRM 349.8-350.5	Hwy 212	Huron Area	0.71	349.8	350.5	**21**
15	Hwy 12 Near MRM 141	Hwy 12	Mobridge Area	0.15	141.01	141.16	**22**
16	Hwy 212 Near MRM 193	Hwy 212	Mobridge Area	1.55	193.2	194.42	**23**
92	Hwy 44, MRM 334.1 Hoffman Bridge	Hwy 44	Mitchell Area	0.10	334.05	334.15	**24**
164	Hwy 12 W, MRM 363.69-364.31	Hwy 12	Aberdeen Area	0.55	363.69	364.31	**25**
32	Hwy 1806, MRM 138.46-139.5	Hwy 1806	Pierre Area	0.42	138.46	139.5	**26**
22	Hwy 273	Hwy 273	Winner Area	12.01	62	74	**27**
3	Hwy 38 Sioux Falls to Humboldt	Hwy 38	Sioux Falls Area	8.94	349	358	**28**
166	Hwy 12 W, MRM 361.66-362.76	Hwy 12	Aberdeen Area	1.10	361.66	362.76	**29**
48	Hwy 85, MRM 32-35	Hwy 85	Rapid City Area	2.98	32	35	**30**
85	Hwy 25, MRM 127-127.8	Hwy 25	Huron Area	0.80	127	127.8	**31**
30	Hwy 50, MRM 407-408	Hwy 50	Yankton Area	0.95	407	408	**32**
5	Hwy 18 E of I-29	Hwy 18	Sioux Falls Area	13.69	438.26	451.88	**33**
33	Hwy 1806, MRM 150.8-151.2	Hwy 1806	Pierre Area	0.41	150.8	151.2	**34**
29	Hwy 50W, MRM 396.5-397	Hwy 50 W	Yankton Area	0.40	396	396.5	**35**

Original Feature ID	Name	Highway	Maintenance Area	Length (Miles)	Begin MRM	End MRM	Top 100 Rank
179	Hwy 18, MRM 48-62.27	Hwy 18	Custer Area	14.25	42	62.27	**36**
25	Hwy 18, MRM 380-384	Hwy 18	Yankton Area	4.02	380	384	**37**
125	Hwy 20, MRM 2-3	Hwy 20	Belle Fourche Area	0.95	2	3	**38**
94	Hwy 44, MRM 344.43 Pekas Bridge	Hwy 44	Mitchell Area	0.11	344.38	344.48	**39**
101	Hwy 42, MRM 338.6 Shelter Belt	Hwy 42	Mitchell Area	0.10	338.55	338.65	**40**
10	Hwy 22 E of Clear Lake	Hwy 22	Watertown Area	5.49	372	377.59	**41**
17	Hwy 12 Near MRM 139	Hwy 12	Mobridge Area	0.21	139.44	139.61	**42**
99	Hwy 81, MRM 58.1 Willbur Ellis	Hwy 81	Mitchell Area	0.10	58.05	58.15	**43**
138	Hwy 10, MRM 251.61-251.71	Hwy 10	Aberdeen Area	0.09	251.61	251.71	**44**
13	Hwy 28 Near Toronto	Hwy 28	Watertown Area	8.03	367	375	**45**
47	Hwy 385, MRM 116	Hwy 385	Rapid City Area	0.10	115.95	116.05	**46**
70	Hwy 18, MRM 103.53-121	Hwy 18	Custer Area	17.46	103.53	121	**47**
42	Hwy 34, MRM 151-153	Hwy 34	Pierre Area	2.00	151	153	**48**
54	Hwy 44E, MRM 85-88	Hwy 44 E	Rapid City Area	3.01	85	88	**49**
45	Hwy 473, Lead to Ski Lodge	Hwy 473	Rapid City Area	3.19	91	94.16	**50**
6	Hwy 42 E of Sioux Falls	Hwy 42	Sioux Falls Area	5.11	373.04	378.17	**51**
88	Hwy 28, MRM 285.99	Hwy 28	Huron Area	1.01	285.49	286.49	**52**
49	Hwy 14A, MRM 46-48	Hwy 14A	Rapid City Area	2.00	46	48	**53**
95	Hwy 44, MRM 347.42 No Name Bridge	Hwy 44	Mitchell Area	0.10	347.37	347.47	**54**
24	Hwy 44, MRM 387-388	Hwy 44	Yankton Area	1.00	387	388	**55**
14	Hwy 20 Near South Shore Stockholm	Hwy 20	Watertown Area	18.55	416.45	435	**56**
37	Hwy 14 Near Junction of 14 and 83	Hwy 14	Pierre Area	1.00	246	247	**57**
18	Hwy 65 Near MRM 206	Hwy 65	Mobridge Area	0.15	206.11	206.36	**58**
80	Hwy 14, MRM 398.8-399.35	Hwy 14	Huron Area	0.55	398.8	399.35	**59**
83	Hwy 212, MRM 352-352.3	Hwy 212	Huron Area	0.30	352	352.3	**60**
171	Hwy 12, MRM 352.55-352.6	Hwy 12	Aberdeen Area	0.05	352.55	352.6	**61**
34	Hwy 83N, MRM 103-105	Hwy 83 N	Pierre Area	2.00	103	105	**62**
181	Hwy 18, MRM 88.03-103.53	Hwy 18	Custer Area	15.47	88.03	103.53	**63**
122	Hwy 34 W, MRM 333.5-334	Hwy 34 W	Mitchell Area	0.50	333.5	334	**64**
123	Hwy 34 E, MRM 333.5-334	Hwy 34 E	Mitchell Area	0.50	333.5	334	**65**
8	Hwy 212 Near Goodwin	Hwy 212	Watertown Area	7.73	389	397	**66**
35	Hwy 83S, MRM 103-105	Hwy 83 S	Pierre Area	2.01	103	105	**67**
4	Hwy 11 S of Brandon	Hwy 11	Sioux Falls Area	2.32	77.18	79.5	**68**
106	Hwy 34, MRM 363.7-365	Hwy 34	Mitchell Area	1.30	363.7	365	**69**
96	Hwy 44, MRM 348.24 Wolf Bridge	Hwy 44	Mitchell Area	0.09	348.19	348.29	**70**
114	Hwy 50, MRM 308.32-309.32 River Ranch Rd	Hwy 50	Mitchell Area	1.00	308.32	309.32	**71**
84	Hwy 25, MRM 96.5-96.85	Hwy 25	Huron Area	0.34	96.5	96.85	**72**

Original Feature ID	Name	Highway	Maintenance Area	Length (Miles)	Begin MRM	End MRM	Top 100 Rank
40	Hwy 212, MRM 227-229	Hwy 212	Pierre Area	2.00	227	229	**73**
9	Hwy 212 E of Hwy 15	Hwy 212	Watertown Area	5.01	403	408	**74**
53	Hwy 16W, MRM 56-57	Hwy 16 W	Rapid City Area	0.99	56	57	**75**
105	Hwy 34, MRM 307.6-308.6	Hwy 34	Mitchell Area	0.99	307.6	308.6	**76**
77	Hwy 14, MRM 326.10-333.4	Hwy 14	Huron Area	6.75	326.1	333.4	**77**
36	Hwy 14, MRM 129.3-130.5	Hwy 14	Pierre Area	1.22	129.3	130.5	**78**
43	Hwy 34, MRM 134-135	Hwy 34	Pierre Area	0.96	134	135	**79**
19	Hwy 1804 Near MRM 367	Hwy 1804	Mobridge Area	0.14	367.3	367.44	**80**
90	Hwy 37, MRM 136-136.7	Hwy 37	Huron Area	0.70	136	136.7	**81**
52	Hwy 16E, MRM 56-57	Hwy 16 E	Rapid City Area	0.99	56	57	**82**
27	Hwy 37, MRM 40-42	Hwy 37	Yankton Area	2.01	40	42	**83**
180	Hwy 18, MRM 62.27-88.03	Hwy 18	Custer Area	25.76	62.27	88.03	**84**
67	Hwy 40, MRM 47-47.8	Hwy 40	Custer Area	0.86	47	47.8	**85**
76	Hwy 14, MRM 324-325	Hwy 14	Huron Area	0.99	324	325	**86**
109	Hwy 44, MRM 274.48 44-47 Junction	Hwy 44	Mitchell Area	0.11	274.43	274.53	**87**
75	Hwy 44, MRM 349-353	Hwy 44	Yankton Area	4.00	349	353	**88**
87	Hwy 28, MRM 277-281	Hwy 28	Huron Area	3.98	277	281	**89**
38	Hwy 14, Near Blunt Cemetery	Hwy 14	Pierre Area	1.04	248.5	249.5	**90**
71	Hwy 385 SB, MRM 0-13	Hwy 385 SB	Custer Area	13.02	0	13	**91**
167	Hwy 12 W, MRM 360.62-361.26	Hwy 12	Aberdeen Area	0.64	360.62	361.26	**92**
72	Hwy 385 NB, MRM 0-13	Hwy 385 NB	Custer Area	13.02	0	13	**93**
178	Hwy 20, MRM 311.67-312.36	Hwy 20	Aberdeen Area	0.68	311.67	312.36	**94**
66	Hwy 385, 64.5	Hwy 385	Custer Area	0.11	64.45	64.55	**95**
165	Hwy 12 W, MRM 363-363.06	Hwy 12	Aberdeen Area	0.06	363	363.06	**96**
107	Hwy 34, MRM 280.2-280.9	Hwy 34	Mitchell Area	0.69	280.2	280.9	**97**
78	Hwy 14, MRM 358-362	Hwy 14	Huron Area	4.00	358	362	**98**
104	Hwy 34, MRM 301.6-302.7	Hwy 34	Mitchell Area	1.09	301.6	302.7	**99**
68	Hwy 40, MRM 50-67	Hwy 40	Custer Area	17.09	50	67	**100**

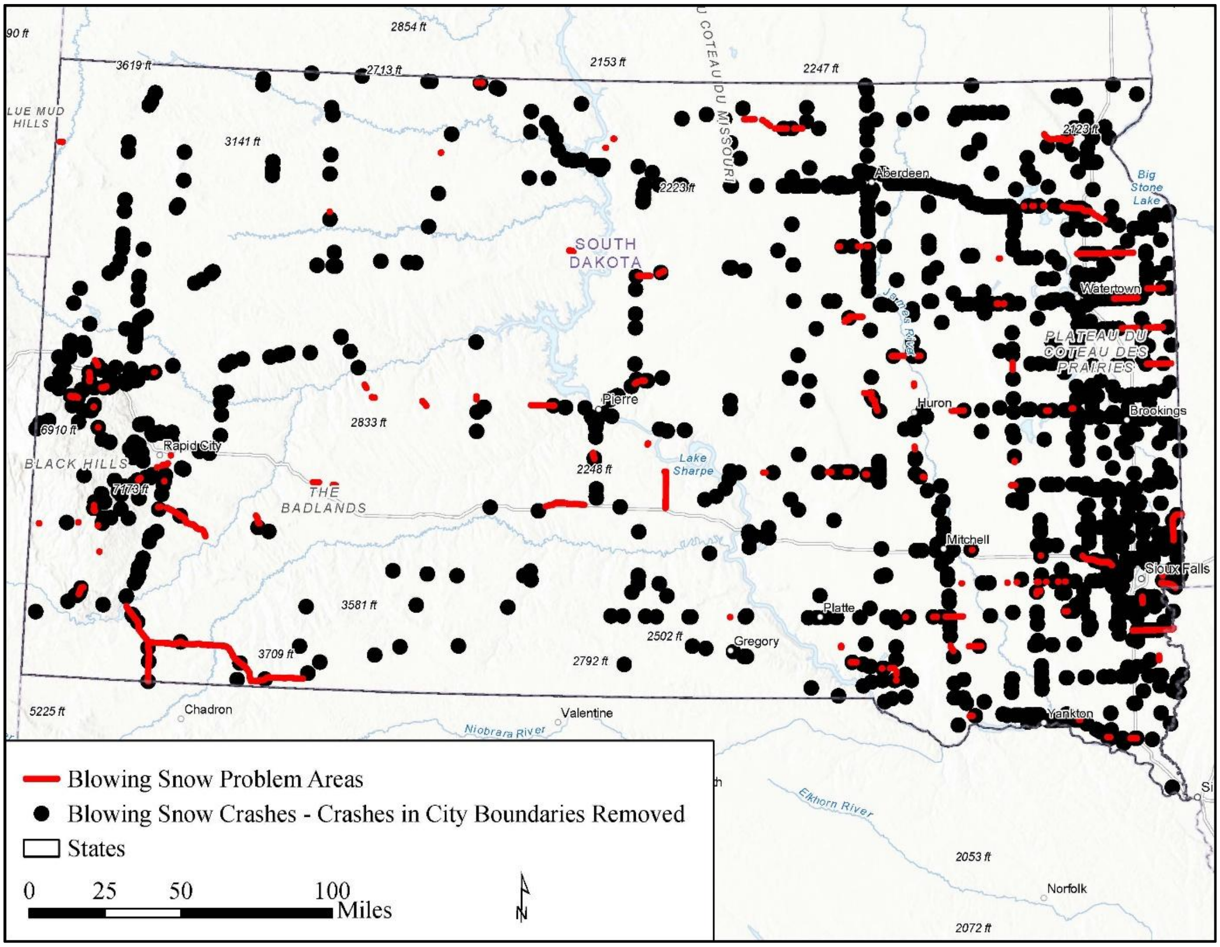

Figure 37: Blowing snow crashes (black dots) and blowing snow problem areas (red lines).

4.8 Develop & Present, Technical Memorandum for Phase II

Prepare and present for approval of the project's technical panel a technical memorandum summarizing the findings of Tasks 6 and 7.

The Technical Memorandum for Phase II was presented to SDDOT on Monday, June 2, 2025.

4.9 Develop a Guidance Document

Develop a guidance document to implement a blowing snow mitigation program in South Dakota. The document shall include the methodology developed in Task 6 [Identify Blowing Snow Locations] to identify blowing snow locations and choose the preferred mitigation strategy. Include a defined process for coordination with state departments and identifying preferred funding. Include guidance to enable partnerships with landowners, including best practices to approach, discuss, educate, and negotiate.

This section provides guidance on blowing snow mitigation options for the top 100 blowing snow problem areas identified previously and a framework to conduct a cost-benefit analysis for the various treatment strategies. For most blowing snow problem areas, many treatment options can be used, but for each location, additional parameters should be considered including but not limited to: available space (inside and outside of the right of way (ROW)), the need to work with adjacent landowners, preference for treatment type by the Maintenance Area, maintenance required, and longevity of the treatment. This report will provide guidance on how to navigate key relevant parameters to determine the most appropriate blowing snow treatment.

Previously, through interviews with each SDDOT Maintenance Area, the research team recorded snow fence preferences for most of the Maintenance Areas (Figure 38), with structural and LSF being the most common. (Note: Figure 38 was introduced earlier as Figure 14.) Understanding current blowing snow treatments in use and the challenges and lessons learned from SDDOT maintenance staff will help inform the treatment recommendations associated with this effort.

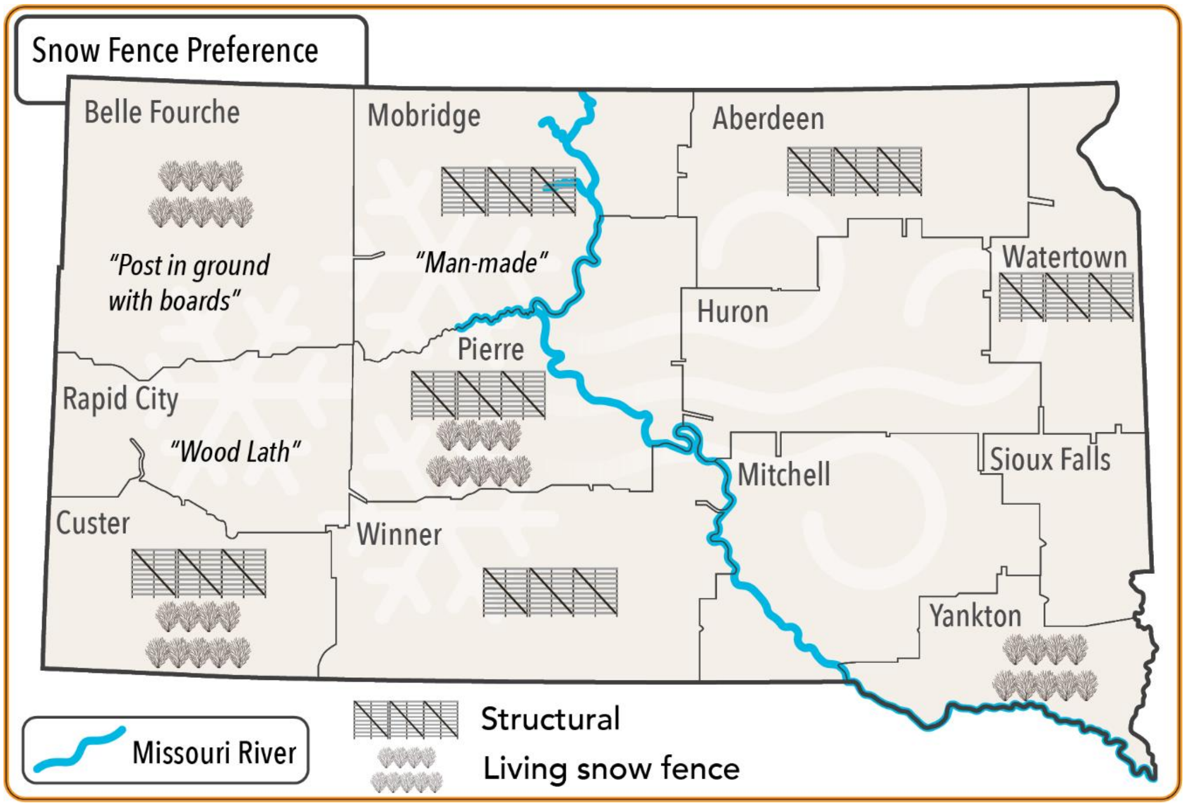

Figure 38: Reported snow fence preferences by SDDOT maintenance areas.

Feedback from surveys and interviews of SDDOT maintenance staff identified challenges that may affect the use of blowing snow treatments in general and the adoption of specific types of treatments. The most common challenges identified were regarding the use of standing crops as LSFs and the need for annual crop rotation and a lack of landowners adjacent to roadways who are interested in participating in snow fence programs (Table 14). The challenges identified in Table 14, may be specific to each Maintenance Area should be considered when deciding upon blowing snow treatments.

Table 14: Challenges associated with the application of various blowing snow areas or treatment strategies identified by SDDOT maintenance staff.

Challenge	Rapid City Region			Pierre Region			Aberdeen Region			Mitchell Region		
	Belle Fourche	Rapid City	Custer	Mobridge	Pierre	Winner	Aberdeen	Huron	Watertown	Mitchell	Yankton	Sioux Falls
Buttes					X							
Rotation between soybeans and corn				X	X		X	X	X		X	
Cattle	X				X							

Ability to grow LSFs			X		X	X						
National Grassland			X		X							
Tribal coordination				X	X							
Lack of Landowner Interest	X	X	X			X	X	X		X	X	X
Out-of-state landowners					X							
Bridges	X									X		
Emergency vehicles blocked by impassible/closed roadway					X							

The guidance document is laid out in three sections: Blowing Snow Mitigation Options which outlines structural, temporary, LSF, and grading strategies; Blowing Snow Mitigation Selection which provides guidance on mitigation strategies for consideration at each of top 100 blowing snow problem areas, and Cost & Benefits of Blowing Snow Mitigation which provides a framework for SDDOT to conduct a high-level lifecycle cost analysis for various blowing snow mitigation strategies and resources to conduct a cost-benefit analysis.

4.9.1 Blowing Snow Mitigation Options

The following blowing snow mitigation options are presented for use in South Dakota:

1. Structural Snow Fences
    a. Wyoming
    b. Vertical
    c. Lath or cribbing
2. Temporary Snow Fences
    a. Plastic sheet fencing
    b. Wooden lath
3. Living Snow Fences
    a. Native trees and shrubs
    b. Standing corn rows
    c. Hay bales
4. Grading
    a. Earthwork

    i. Pre-construction
    ii. Post-construction
  b. Snow Ridging
5. Non-Traditional Snow Fences

As new mitigation strategies to manage blowing and drifting snow become available, they should be considered as well.

4.9.1.1 Structural Snow Fences

Structural snow fences are typically built of wood, polymer straps with wood, or I-beam supports that are designed for snow quantity and wind direction. Structural snow fences can run from 4 to 14 feet high, and are anchored with rebar, helical anchors, or embedded posts. Types of structural snow fences include Wyoming, vertical, and lath or cribbing snow fence.

Wyoming Snow Fence

Wyoming styled snow fences are wood fences with wood supports typically anchored with rebar or helical anchors (Figure 39). The Wyoming style snow fence has a 15˚ angle from vertical in the downwind direction, has a bottom gap of 10% of the height, and a porosity of 50%.

Figure 39: Wyoming style snow fence, McDonald Pass, MT.

Vertical Snow Fence

Vertical snow fence can be made of a variety of materials but are typically made of wood (Figure 40) and are typically 50% porosity, can vary in height from 4 to 12 foot, and have a bottom gap that can be less than 10% of the height. This small gap is due to the lack of a buried supporting structure, a feature present in designs such as the Wyoming fence. Vertical snow fences use embedded posts and can be used anywhere where a smaller snow fence footprint is desired or where there is more limited ROW. Embedded posts should be drilled deep enough so that the posts extend past the frost zone. Vertical fences can reduce maintenance time as the fence tends to work as a single unit instead of individual panels. They have a smaller footprint so farmers can usually plant around them. Figure 41 shows a delineating wood fence that works in a smaller capacity as a vertical snow fence. (Note: Figure 41 was introduced earlier in this document as Figure 8.)

Figure 40: Vertical snow fence made of wood with posts anchored approximately 9 ft deep in the soil (WYDOT, K. Ahlenius).

Figure 41: Wooden structural snow fence along the ROW (SDDOT).

Lath or Cribbing Snow Fence

Lath or cribbing fence can easily be place on ROW fencing where there is enough snow storage (Figure 42 and Figure 43). It is available from most lumberyards or Do-It-Yourself stores. It can also be self-supporting with the proper support structure. It is critical that the fence is pulled tight when mounting. While this fence can be temporary, typically it is left up year-round and is repaired or replaced as necessary.

Figure 42: Lath, or cribbing, fence secured along an existing barbed wire fence line (WYDOT, K. Ahlenius).

Figure 43: Lath, or cribbing, fence free standing (WYDOT, K. Ahlenius).

4.9.1.2 Temporary Snow Fences

Temporary snow fence is a catch all category for any snow fence that is expected to last for a short time, one season, or that has a more durable construction but is movable.

Plastic Sheet

Plastic sheet fence is available at most lumber yards or Do-It-Yourself stores. The orange blaze color is most common, but it can be purchased in green and tan to match a couple of landscape colors (Figure 44 and Figure 45). It needs to be pulled tight and fastened well, or it will rip off the fence it is attached to.

Figure 44: Plastic orange temporary snow fence affixed to wooden posts (WYDOT, K. Ahlenius).

Figure 45: Plastic black temporary snow fence affixed to wooden frame (MnDOT, K. Ahlenius).

Moveable Structures

Temporary wooden lath, or cribbing, fencing can be put up at the beginning of the winter season and taken back down at the end of the season (Figure 42 and Figure 43). There are also wood fences using lumber that can be placed seasonally (Figure 46).

Figure 46: Temporary wooden snow fence bordering United States Forest Service (USFS) lands.

Hay Bales

Hay bales have been used to impede roadway drifting in cultivated field areas (Figure 47). This temporary fencing can act like a solid fence so there is a need for storage upwind, downwind, and for plow cast. Stacked, large, square bales have also been used to create a taller fence. Typically, this fence has a gap of one-third the size of the hay bale on the bottom row and the top row spans the gap. Again, adequate snow storage is required.

Figure 47: Hay bales placed parallel to the road as a blowing snow treatment. (Iowa DOT)

4.9.1.3 Living Snow Fences

LSFs can be composed of trees, shrubs, or standing corn rows and are used in several states. They consist of one to three rows planted using trees and shrubs most likely to grow in the area or native to the area. A structural snow fence can be used in concert with the LSF to help get moisture to the plants and to do the work of a snow fence while the LSF grows to a sufficient size (Figure 48 and Figure 49). Additionally, fencing can be used to keep wildlife and livestock away from maturing LSFs to prevent damage. Once the plants are healthy and large enough to retain the snow, the structural snow fence can be removed. It is important to keep in mind the height of the fully grown trees or shrubs when designing an LSF.

LSFs can be a positive way to work with landowners and community partners. Conservation districts, Future Farmers of America (FFA), and other groups have come together to build LSFs to help with public safety. Other state DOTs have also reported that LSFs ability to support pollinators can be of value to farmers and that some homeowners appreciate that LSFs can provide habitat for songbirds.

Figure 48: LSF in concert with a wooden structure snow fence (WYDOT, K. Ahlenius).

Figure 49: Newly planted LSF with weed cloth in concert with lath fencing and surrounded with fencing to keep livestock out (WYDOT, K. Ahlenius).

Standing Corn Rows

Standing corn rows are typically comprised of 8 to 16 rows of standing corn (or 30+ ft wide), planted near the roadway (Figure 50). Two key design features of standing corn rows are the setback, or distance from the roadway, which helps to prevent snow from drifting onto the roadway and the direction of planting to the road. Therefore, Maintenance Area staff should work with farmers to both obtain an agreement and identify the preferred location to retain the standing corn. "A typical standing corn row snow fence is one-quarter mile long and 33 feet wide, covering an average of 1 acre" (MnDOT, Blowing Snow/Standing Corn Row.pdf, Appendix F: Informational Pamphlets). There is monetary compensation for leaving the corn stalks in the field; however, the corn itself can be handpicked. As hand-picking is labor-intensive, FFA groups or other community groups can be leveraged so as not to put the burden on the farmer.

Figure 50: Standing corn rows left in place serving as a LSF (Iowa DOT).

In many areas, corn is planted in alternating years; thus, standing corn rows for blowing snow mitigation is not an option every year. SDDOT should consider alternate mitigation strategies for the off-cycle years, such as temporary installations (see Temporary Snow Fences).

Conveying the Purpose of LSFs

During interviews with SDDOT Maintenance Areas, the researchers heard about resistance by farmers in participating in standing corn rows because of a belief that neighbors would question why farmers retained some corn stalks at the end of the season. Other states have addressed these concerns by providing public service announcements in proximity to where the standing corn rows are to be retained (Figure 51).

Figure 51: Messaging used by Iowa DOT to show why corn rows remain standing in winter (Iowa DOT).

Furthermore, the researchers were informed that some LSFs that had been installed decades earlier were no longer understood by contemporary staff or landowners to serve a purpose and were removed, consequently resulting in blowing and drifting snow. Therefore, similar to standing corn rows, information can be provided that conveys the value of LSFs to agencies and the public (Figure 52, Figure 53).

Figure 52: Messaging used by Wyoming DOT to show an LSF.

Figure 53: Additional examples of signage used in Wyoming by Conservation Districts and private parties to provide information on LSFs.

4.9.1.4 Grading

Earthwork

Earthwork grading can be used to modify existing topography near roads that experience reoccurring blowing and drifting snow (Figure 54, Figure 55). Cutting back the slope and creating flat-bottom ditches on one or both sides of the road allows for additional snow storage from blowing snow, back drift, and plow cast. Due to the cost, this is typically done during a construction project where the borrowed material can be used elsewhere on the project. Storage for plow cast and blowing snow is critical and should be included in any design plans on roadways where blowing snow is a problem. If snow storage is inadequate, maintenance staff should plan to routinely clear out the snow storage area.

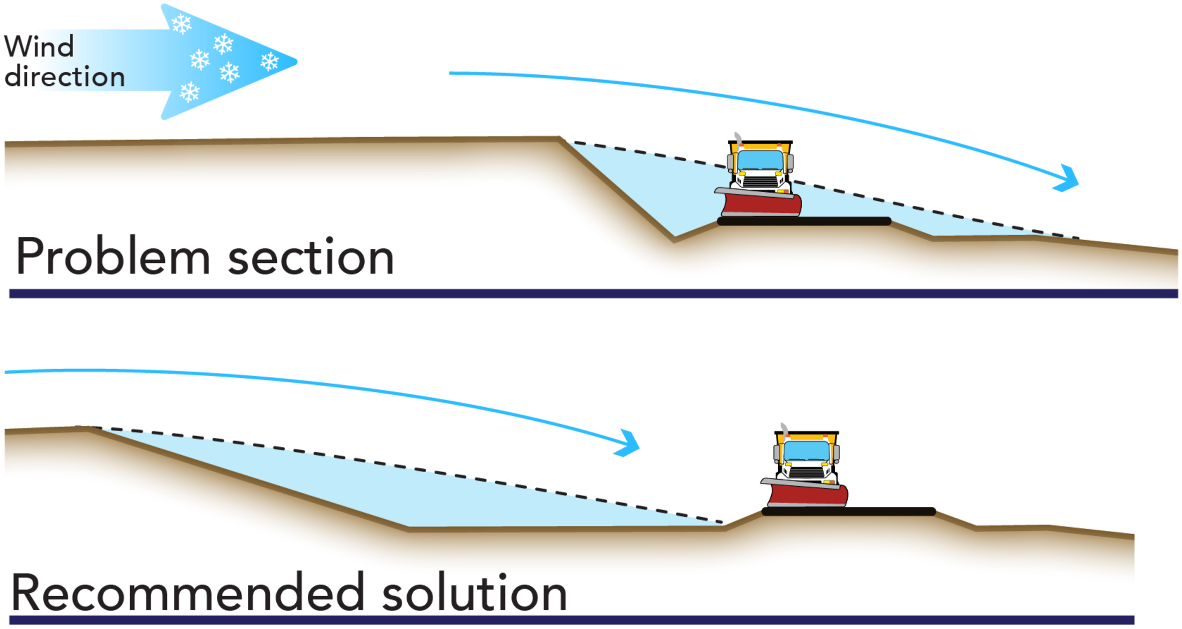

Figure 54: Earthwork grading to cut back slopes and create flat bottom ditches that allows for snow storage from blowing snow and plow cast.

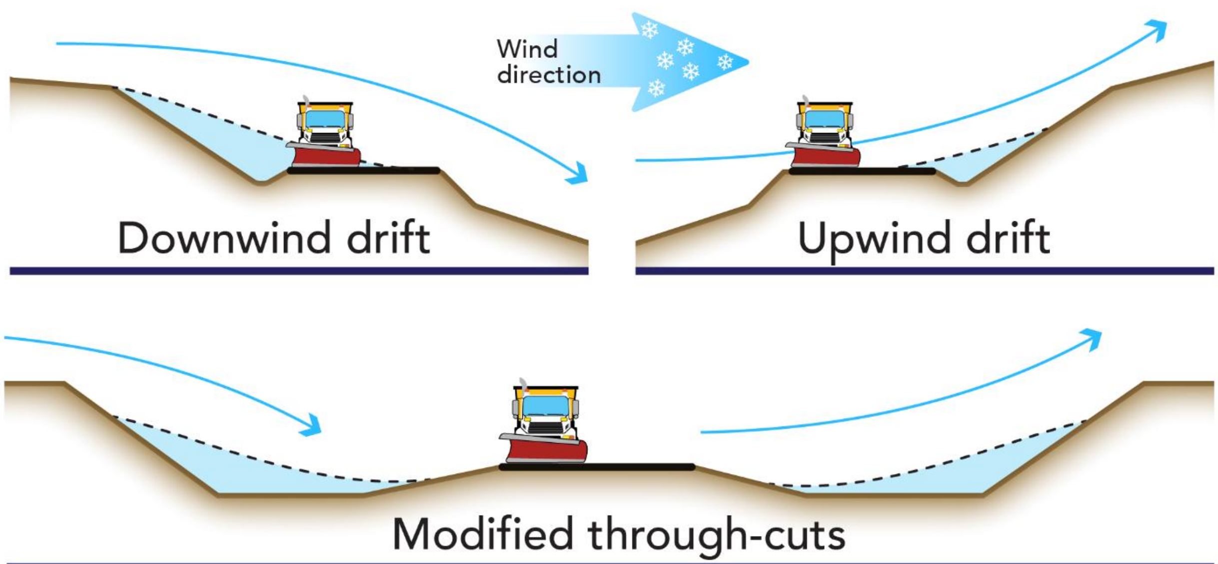

Figure 55: Earthwork grading to cut back slopes and create flat bottom ditches creating snow storage locations on both sides of road for back drifting and plow cast.

Snow Ridging

Snow ridging, or berming, is a practice where a bulldozer or grader is brought into a field to create snow berms or ridges out of the snow (Figure 56). These are temporary installations. The number of rows will depend on how much snow is coming upwind of the road. The snow swales will need to be “cleaned out” during the winter, sometimes more than once, depending upon the type of winter the area is experiencing. While this can be labor-intensive, snow ridging can be useful in many areas and land uses. (Note: Figure 56 was introduced earlier in this document as Figure 4.)

Figure 56: Snow ridging or berming as a blowing snow treatment (K. Ahlenius).

4.9.1.5 Non-Traditional Snow Fences

There have been many snow fences created that are made of non-traditional materials. This section highlights a few examples of innovative materials, the use of materials that were on hand, or creative and context-sensitive snow fences that have been created.

Solar Snow Fences

Solar snow fences have been built and tested in a few demonstration projects. One project used solar panels that tracked the sun but could be locked in place during blowing snow events (Figure 57) and others have used solar panels in place of wooden boards (MnDOT/NDSU) ((12), (66)). Besides a high initial cost for solar fences, challenges faced include connection to the grid and the state DOT essentially functioning as a utility. Solar fences are typically not cost-effective for runs of snow fence under one mile. In one application, 10 to 30 kilowatts (kW) per day of energy was produced, enough to power a household. In another project, the energy produced is being used to power heat pads on the ground to melt accumulated snow (66). The collected energy could be used to power road weather stations or other equipment (e.g., intelligent transportation systems) to support state DOT operations.

Figure 57: Longboard Power, LLC Solar snow fence (12).

Snow Fences of Recycled or Extra Materials

Snow fences can be constructed of recycled or extra material. Two examples of this are concrete beams (Figure 58) and w-beams (Figure 59). (Note: Figure 59 was introduced earlier in this document as Figure 10.) When faced with blowing snow problems and limited budgets, maintenance personnel can be very inventive. Using the materials at hand, a snow fence made of jersey barrier with plastic sheet fencing helped this crew on their low-volume road (Figure 60).

Figure 58: Concrete beam snow fence, Havre, MT (M. Ladenburg).

Figure 59: Snow fences built using w-beam guardrail by SDDOT (left) and WYDOT (right).

Figure 60: A snow fence built on existing fencing and extended using jersey barrier with plastic fencing to increase the height (WYDOT).

Snow Fences Around Buried Utilities

While not a typical occurrence, some locations where snow fences have been proposed for installation were found to have underground utilities. Therefore, before installation, staff should ensure that no utilities are present. However, if underground utilities are present, there are two potential solutions. First, avoid embedding posts or rebar within the easement of the utility. Second, bridge the utility using a “floating fence”, which uses large, heavy concrete blocks up and downwind on the sill plate of the fence (Figure 61).

Figure 61: Wooden Wyoming style snow fence anchored with concrete blocks allows for roadway protection over underground utilities (WYDOT, K. Ahlenius).

Snow Snake Fencing

While never intended to be permanent, Snow Snakes can safely be placed in the ROW, median, or clear zone to help trap moisture (Figure 62) (67). Snow Snakes consist of a polymer sheet fence attached to 4’ hoops that are fastened to the ground. Snow Snakes can help with blowing snow close to the roadway, and can help with revegetation after construction (68).

Figure 62: Snow snake fencing (WYDOT, K. Ahlenius).

Woven willow snow fence has also been used which merges structural and LSF concepts (Figure 63).

Figure 63: Woven willow snow fence in Browning, MT (69).

In other instances, you can let nature do the work for you. While using tumbleweeds as an LSF may cause ROW fence issues, tumbleweeds can be effective to keep snow off the roadway (Figure 64). The same applies for naturally occurring vegetation, like tall grasses. As long as the natural vegetation is in a location to reduce blowing snow impacts to the roadway, leaving it in place can provide natural support during times of blowing snow (Figure 65).

Figure 64: ROW fence line with trapped tumble weeds acting as a snow fence (WYDOT, K. Ahlenius).

Figure 65: Natural vegetation serving to trap blowing and drifting snow (K. Ahlenius).

4.9.1.6 Resources

The following resources provide information specifically on snow fences and how they can be effectively applied to capture blowing and drifting snow, and more detailed design information for those wanting to learn more.

- Controlling Blow and Drifting Snow with Snow Fences and Road Design (1) (https://transportation.org/winter-weather-management/wp-content/uploads/sites/50/2023/03/NCHRP-20-07147_Controlling-Blowing-Snow-Snow-Fence_Tabler_2003-1.pdf)
- Snow Fence Guide (70) (https://onlinepubs.trb.org/onlinepubs/shrp/shrp-h-320.pdf)
- MnDOT Living Snow Fence Resources (https://www.dot.state.mn.us/environment/livingsnowfence/)
- Forest Service Living Snow Fence Guide (https://www.fs.usda.gov/nac/assets/documents/workingtrees/brochures/livingsnowfenceforweb.pdf) (71)
- Design of Living Barriers to Reduce the Impacts of Snowdrifts on Illinois Freeways (72) (https://www.ideals.illinois.edu/items/116539)
- Snow Fence: Designing for Roadway Safety (https://www.translearning.org/ops/details.php?id=1286)

4.9.2 Blowing Snow Mitigation Selection

This section of the guidance document outlines a process for selecting feasible blowing snow mitigation strategies. Previous efforts identified the top 100 rural blowing snow problem areas in South Dakota. Once a blowing snow problem area has been selected for treatment, it is recommended that consideration of the adjacent land and working with landowners be addressed next, followed by consideration of the various blowing snow mitigation strategies in which site-specific considerations can be addressed.

4.9.2.1 Adjacent Land & Working with Landowners

Once a location has been selected for a blowing snow mitigation strategy, it is important to assess the adjacent land use, identify the landowner, and determine SDDOT's communication strategy. Once the landowner(s) is identified, contact with the landowner can be initiated. Discussions should include information on SDDOT's blowing snow mitigation program and identification of all applicable mitigation strategies so that the landowner can make the best possible decision. Based on the feasibility of placement, the type of blowing snow mitigation strategy can then be determined.

> ***Working with Landowners***
>
> *1. Develop contacts*
>
> *2. Develop information materials*
>
> *3. Outreach & Training to individuals and communities*
>
> *4. Reinforce relationships, continued outreach*

Communicating with landowners may be determined by SDDOT policy or by less formal methods, such as SDDOT Maintenance Area staff talking with local landowners. In some areas, community meetings with partners like Conservation Districts and Farm Bureaus are highly effective. These gatherings can help landowners recognize the benefits of snow fences from a land use perspective, rather than just seeing them as a DOT project. At these events, brochures and one-page information sheets can be handed out, and questions can be answered. These events and resources should be developed and coordinated with the help of SDDOT's Public Affairs office. Example brochures and information sheets developed for the public are provided in Appendix F: Informational Pamphlets.

A recent effort, Promoting the Adoption of Snow Fences through Landowner Engagement, recommends (2):

- To most effectively reach landowners, a blended approach of outreach to individuals and communities and relevant organizations is recommended. Using many formats like "lunch and learn" events, online and community trainings, and person-to-person outreach was found to be very effective. Early engagement is recommended.

- Public safety and transportation were identified as the strongest motivators for landowners to participate in snow fence programs. Specifically, landowners were motivated by improved traffic conditions, reduced crashes, a sense of civic duty (creating a sense of purpose, involvement, and participation), followed by financial compensation and then conservation.
- Landowners indicated they want more information about the issues involved in installation and maintenance of snow fences from a trusted source, peer, or testimonials. Knowing this, SDDOT can work to establish local points of contact, work with landowners with existing snow fence installations to get testimonials and to serve as a point of contact. Case Studies are provided that SDDOT can use as a framework for information capture for testimonials.
- Training materials, a database and reporting tool, and a web-based tool were developed. Web-based training for Standing Corn Rows can be access here: UMN & MnDOT Standing Corn Rows Kickoff - YouTube (www.youtube.com/watch?v=GkTmQg0JnXy, 53 minutes). The farmmaps.umn.edu provides a map view and additional information on snow fence locations and testimonials in Minnesota. SDDOT could pursue the development of similar training materials, databases, and a web-based tool for information sharing.
- Recommended fixes to the program included
    - No taxing of easement land
    - Certainty on annual contracts
    - Consistent DOT staff contact
    - Compensation tied to commodity prices
    - Increased compensation
    - A review or option to choose annual or lump sum payments
    - Opportunity to sell or rent snow cache areas to the DOT
    - Design fencing to accommodate turning radius of farm equipment, flexible design
- Identified programmatic enhancements included
    - Use of fruit bearing trees and shrubs
    - Provide more information about plant species used, why they were chosen, and other species options
    - Continued management of aging fences
    - Provide more flexible fence design

    - Provide information on how effective the fence is

- Recommended information to be shared with landowner participants
    - Before and after crash data, data on salt and fuel saved, other cost saving data
    - Data and stories (testimonials) from other landowners and rural bus drivers
    - Statewide 1 pager with real-time benefit-cost savings information
    - Report the number of stranded drivers that did not need to be rescued due to blowing snow mitigation.
    - A public Thank You to participants through the local paper or social media

- All supporting information – report, web-based tools, and training materials can be found at cinram.umn.edu, search snow fences or Farm Maps.

To support using private land for blowing snow mitigation, formal agreements and memorandums of understanding (MOUs) are used. If not already developed, SDDOT should work with its legal department and the landowners to craft specific language that everyone can agree with.

- Action: Identify or review MOUs associated with the successful implementation of blowing snow mitigation in South Dakota.

The land directly adjacent to the blowing snow problem area might not be privately owned, and instead may be tribal lands, federal, state, or other Federal Land Management Area (FLMA). If land is managed by one of these groups, discussions with the appropriate agencies and personnel are a good starting place for the establishment of agreements.

Implementation of blowing snow mitigation strategies on private land routinely comes with compensation as reimbursement upfront, or annual payments to the landowner. A previous study found that landowners perceive payments for the installation and maintenance of snow fences as an important incentive (2). Landowners noted that the addition of snow fences on their property lead to an increase in operating costs due to labor, equipment, or reduced yields outside of the compensated areas, but that compensation generally accounted for this. SDDOT should clearly define the payment rates for each blowing snow mitigation strategy and work with the landowners to ensure the payments provide sufficient compensation.

- Action: Identify or review compensation strategies that align both with SDDOT policies and provide fair compensation for landowners.
    - Example compensation strategies to consider:
        - Wisconsin DOT has shifted to reimbursement of $150 for every 100 ft of blowing snow mitigation, because bushel rates are highly variable.

- Iowa DOT – reimbursement for standing corn rows based on average statewide bushel rate plus $2, and $1 per ft for hay bales; on annual contracts.
- Minnesota DOT uses both 1 to 15-year contracts with annual payments and lump sum payments for permanent easements.

The primary constraint to adoption of snow fences by landowners was maintenance (2). Targeted training, messaging, and compensation can be developed to overcome this challenge. If a landowner is still not a willing participant with blowing snow mitigation on their property, keeping it within the ROW or along the ROW fencing may be the best option.

The ROW adjacent to blowing snow problem areas can be used for snow storage, and the ROW fencing can be used for snow fencing. For example, lath or 4-foot wooden snow fence on ROW fence (Figure 42). ROW fencing will help protect the roadway until it fills the snow storage area; then, clearing of the storage area will be required. Other considerations for the ROW are mowing practices. For example, mowing the full ROW can allow snow to blow across the road. Mowing near the ROW fence but leaving tall grass near the road can help trap blowing snow before it blows onto the roadway and create snow storage areas. Finally, not mowing at all allows the tall grass to help trap the blowing snow. SDDOT can consider all of these options on a case-by-case basis.

When considering different snow fence types based on land use, where land is under cultivation, standing corn rows, vertical fence, or ROW fence can be used. Note that in many locations, crops are rotated; therefore, every other year, standing corn may be a feasible option. For the years when corn is not planted, temporary fencing that is installed and removed seasonally may be a viable option in place of the standing corn rows. Where land use tends towards rangeland, Wyoming snow fences or LSFs are viable options because they have a larger footprint. Wherever there is a larger population, you will have more planted vegetation and structures to help prevent blowing and drifting snow (Figure 66). Equipment and rail storage can both cause snow drifting on the roadway and function as snow fencing (Figure 67). As shown in the aforementioned examples - structures, vegetation, equipment, etc., affect snow drifting on roadways, which can be examples of benefits from population density to reduce snow drifting. The flip side of an increased population is the need to manage more road users.

Figure 66: Blowing snow causing drifting on roadways that can be attributed to development near the roadway.

Figure 67: Equipment storage in the ROW functions to prevent blowing and drifting snow on the road and can cause snow drifts on roadways.

4.9.2.2 Feasibility of Blowing Snow Mitigation Strategies

Following the determination of adjacent landowners, the feasibility of the various blowing snow mitigation strategies can be considered for each site. For each of the top 100 blowing snow problem areas, the land within 100 feet of a blowing snow problem area is identified as being Tribal, FLMA, crop, pastureland/hay or range land, or cultivated crops. For each land type, specific blowing snow mitigation strategies may be considered and are noted as yes, maybe, or no. If the SDDOT Maintenance Areas indicated they have used various blowing snow mitigation strategies or are interested in using them, they are shown yes, maybe, no, or no feedback (NF). The outcome of this is summary tables for each Maintenance Area, shown in Table 15 for the Aberdeen Area; Table 16 for the Belle Fourche;

Table 17 for the Custer Area; Table 18 for the Huron Area; Table 19 for the Mitchell Area; Table 20 for the Mobridge Area; Table 21 for the Pierre Area; Table 22 for the Rapid City Area; Table 23 for the Sioux Falls Area; Table 24 for the Watertown Area;

Table 25 for the Winner Area; and Table 26 for the Yankton Area. The end results are tables of the top 100 blowing snow problem areas in each Maintenance Area. These tables assess the feasibility of various mitigation strategies, helping SDDOT determine the most effective treatment option for each location.

For example, cultivated crops such as corn are candidates for discussions with landowners to leave standing corn rows for winter. If adjacent land is pastureland, federal, or tribal lands, permanent mitigation strategies like Wyoming snow fence or LSF are a good option.

Table 15: Guidance on blowing snow treatment options for Aberdeen Maintenance Area based on location, length, ranking, adjacent land, and maintenance staff feedback.

Top 100 List Ranking	Segment ID	Segment Name	Length (Miles)	Adjacent to Tribal Land	Adjacent to FLMA Land	Adjacent to Crops or Pastureland	Adjacent to Cultivated Crops	Adjacent to Pastureland/Hay	LSF	Maintenance Area Feedback on LSF	Standing Corn Rows	Maintenance Area Feedback on Standing Corn Rows	Structural Snow Fence	Maintenance Feedback on Structural Snow Fence	Temporary Snow Fence	Grading
3	177	Hwy 20, MRM 318.22-318.56	0.334	No	No	Yes	Yes	Yes	Yes	NF	Yes	Maybe	Yes	Yes	Maybe	No
5	163	Hwy 12 W, MRM 364.51-364.76	0.257	Yes	Yes	No	No	No	No	NF	No	Maybe	Yes	Yes	Maybe	No
7	162	Hwy 12 W, MRM 364.96-365.19	0.229	Yes	Yes	No	No	No	No	NF	No	Maybe	Yes	Yes	Maybe	No
20	161	Hwy 12 W, MRM 365.59-366.01	0.418	Yes	Yes	No	No	No	No	NF	No	Maybe	Yes	Yes	Maybe	No
25	164	Hwy 12 W, MRM 363.69-364.31	0.550	Yes	Yes	No	No	No	No	NF	No	Maybe	Yes	Yes	Maybe	Yes
29	166	Hwy 12 W, MRM 361.66-362.76	1.097	Yes	Yes	Yes	Yes	No	Yes	NF	Yes	Maybe	Yes	Yes	Maybe	Yes
44	138	Hwy 10, MRM 251.61-251.71	0.094	No	Yes	No	No	No	No	NF	No	Maybe	Yes	Yes	Maybe	No
61	171	Hwy 12, MRM 352.55-352.6	0.046	No	No	No	No	No	No	NF	No	Maybe	Yes	Yes	Maybe	No
92	167	Hwy 12 W, MRM 360.62-361.26	0.636	Yes	Yes	Yes	Yes	No	Yes	NF	Yes	Maybe	Yes	Yes	Maybe	Yes
94	178	Hwy 20, MRM 311.67-312.36	0.684	No	No	Yes	Yes	Yes	Yes	NF	Yes	Maybe	Yes	Yes	Maybe	Yes
96	165	Hwy 12 W, MRM 363-363.06	0.062	Yes	Yes	No	No	No	No	NF	No	Maybe	Yes	Yes	Maybe	No

Table 16: Guidance on blowing snow treatment options for Belle Fourche Maintenance Area based on location, length, ranking, adjacent land, and maintenance staff feedback.

Top 100 List Ranking	Segment ID	Segment Name	Length (Miles)	Adjacent to Tribal Land	Adjacent to FLMA Land	Adjacent to Crops or Pastureland	Adjacent to Cultivated Crops	Adjacent to Pastureland/Hay	LSF	Maintenance Area Feedback on LSF	Standing Corn Rows	Maintenance Area Feedback on Standing Corn Rows	Structural Snow Fence	Maintenance Feedback on Structural Snow Fence	Temporary Snow Fence	Grading
15	74	Hwy 73, MRM 196	0.095	No	No	No	No	No	No	Yes	No	NF	Yes	Yes	NF	No
19	73	Hwy 34, MRM 23-25	1.986	No	No	No	No	No	No	Yes	No	NF	Yes	Yes	NF	Yes
38	125	Hwy 20, MRM 2-3	0.953	No	No	Yes	No	Yes	Yes	Yes	No	NF	Yes	Yes	NF	Yes

Table 17: Guidance on blowing snow treatment options for Custer Maintenance Area based on location, length, ranking, adjacent land, and maintenance staff feedback.

Top 100 List Ranking	Segment ID	Segment Name	Length (Miles)	Adjacent to Tribal Land	Adjacent to FLMA Land	Adjacent to Crops or Pastureland	Adjacent to Cultivated Crops	Adjacent to Pastureland/Hay	LSF	Maintenance Area Feedback on LSF	Standing Corn Rows	Maintenance Area Feedback on Standing Corn Rows	Structural Snow Fence	Maintenance Feedback on Structural Snow Fence	Temporary Snow Fence	Grading
11	64	Hwy 16, MRM 30-32	1.997	No	No	No	No	No	No	Yes	No	NF	Yes	Yes	NF	Yes
16	69	Hwy 18, MRM 22-25	2.997	No	No	Yes	Yes	Yes	Yes	Yes	Yes	NF	Yes	Yes	NF	Yes
36	179	Hwy 18, MRM 48-62.27	14.251	No	No	Yes	Yes	Yes	Yes	Yes	Yes	NF	Yes	Yes	NF	Yes
47	70	Hwy 18, MRM 103.53-121	17.457	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	NF	Yes	Yes	NF	Yes
63	181	Hwy 18, MRM 88.03-103.53	15.466	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	NF	Yes	Yes	NF	Yes
84	180	Hwy 18, MRM 62.27-88.03	25.763	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	NF	Yes	Yes	NF	Yes
85	67	Hwy 40, MRM 47-47.8	0.856	No	No	Yes	Yes	Yes	Yes	Yes	Yes	NF	Yes	Yes	NF	Yes
91	71	Hwy 385 SB, MRM 0-13	13.024	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	NF	Yes	Yes	NF	Yes
93	72	Hwy 385 NB, MRM 0-13	13.019	No	Yes	Yes	No	Yes	Yes	Yes	No	NF	Yes	Yes	NF	Yes
95	66	Hwy 385, 64.5	0.106	No	No	No	No	No	No	Yes	No	NF	Yes	Yes	NF	No
100	68	Hwy 40, MRM 50-67	17.087	No	No	Yes	Yes	Yes	Yes	Yes	Yes	NF	Yes	Yes	NF	Yes

Table 18: Guidance on blowing snow treatment options for Huron Maintenance Area based on location, length, ranking, adjacent land, and maintenance staff feedback.

Top 100 List Ranking	Segment ID	Segment Name	Length (Miles)	Adjacent to Tribal Land	Adjacent to FLMA Land	Adjacent to Crops or Pastureland	Adjacent to Cultivated Crops	Adjacent to Pastureland/Hay	LSF	Maintenance Area Feedback on LSF	Standing Corn Rows	Maintenance Area Feedback on Standing Corn Rows	Structural Snow Fence	Maintenance Feedback on Structural Snow Fence	Temporary Snow Fence	Grading
6	89	Hwy 28, MRM 319.4-319.9	0.477	No	No	Yes	Yes	No	Yes	NF	Yes	Maybe	Yes	NF	Maybe	No
21	82	Hwy 212, MRM 349.8-350.5	0.711	No	Yes	Yes	Yes	No	Yes	NF	Yes	Maybe	Yes	NF	Maybe	Yes
31	85	Hwy 25, MRM 127-127.8	0.802	No	No	Yes	Yes	No	Yes	NF	Yes	Maybe	Yes	NF	Maybe	Yes
52	88	Hwy 28, MRM 285.99	1.012	No	No	Yes	Yes	Yes	Yes	NF	Yes	Maybe	Yes	NF	Maybe	Yes
59	80	Hwy 14, MRM 398.8-399.35	0.547	No	No	Yes	Yes	No	Yes	NF	Yes	Maybe	Yes	NF	Maybe	Yes
60	83	Hwy 212, MRM 352-352.3	0.302	No	No	Yes	Yes	No	Yes	NF	Yes	Maybe	Yes	NF	Maybe	No
72	84	Hwy 25, MRM 96.5-96.85	0.344	No	No	Yes	Yes	No	Yes	NF	Yes	Maybe	Yes	NF	Maybe	No
77	77	Hwy 14, MRM 326.10-333.4	6.748	No	No	Yes	Yes	Yes	Yes	NF	Yes	Maybe	Yes	NF	Maybe	Yes
81	90	Hwy 37, MRM 136-136.7	0.698	No	No	Yes	Yes	No	Yes	NF	Yes	Maybe	Yes	NF	Maybe	Yes
86	76	Hwy 14, MRM 324-325	0.994	No	Yes	Yes	Yes	Yes	Yes	NF	Yes	Maybe	Yes	NF	Maybe	Yes
89	87	Hwy 28, MRM 277-281	3.978	No	Yes	Yes	Yes	Yes	Yes	NF	Yes	Maybe	Yes	NF	Maybe	Yes
98	78	Hwy 14, MRM 358-362	4.004	No	Yes	Yes	Yes	Yes	Yes	NF	Yes	Maybe	Yes	NF	Maybe	Yes

Table 19: Guidance on blowing snow treatment options for Mitchell Maintenance Area based on location, length, ranking, adjacent land, and maintenance staff feedback.

Top 100 List Ranking	Segment ID	Segment Name	Length (Miles)	Adjacent to Tribal Land	Adjacent to FLMA Land	Adjacent to Crops or Pastureland	Adjacent to Cultivated Crops	Adjacent to Pastureland/Hay	LSF	Maintenance Area Feedback on LSF	Standing Corn Rows	Maintenance Area Feedback on Standing Corn Rows	Structural Snow Fence	Maintenance Feedback on Structural Snow Fence	Temporary Snow Fence	Grading
2	93	Hwy 44, MRM 343.24 County Line Bridge	0.093	No	No	Yes	Yes	Yes	Yes	No	Yes	Maybe	Yes	Yes	Yes	No
24	92	Hwy 44, MRM 334.1 Hoffman Bridge	0.096	No	No	Yes	Yes	Yes	Yes	No	Yes	Maybe	Yes	Yes	Yes	No
39	94	Hwy 44, MRM 344.43 Pekas Bridge	0.106	No	No	Yes	Yes	No	Yes	No	Yes	Maybe	Yes	Yes	Yes	No
40	101	Hwy 42, MRM 338.6 Shelter Belt	0.104	No	No	Yes	Yes	No	Yes	No	Yes	Maybe	Yes	Yes	Yes	No
43	99	Hwy 81, MRM 58.1 Willbur Ellis	0.103	No	No	Yes	No	Yes	Yes	No	No	Maybe	Yes	Yes	Yes	No
54	95	Hwy 44, MRM 347.42 No Name Bridge	0.103	No	No	Yes	Yes	Yes	Yes	No	Yes	Maybe	Yes	Yes	Yes	No
64	122	Hwy 34 W, MRM 333.5-334	0.502	No	No	Yes	No	Yes	Yes	No	No	Maybe	Yes	Yes	Yes	Yes
65	123	Hwy 34 E, MRM 333.5-334	0.495	No	No	Yes	No	Yes	Yes	No	No	Maybe	Yes	Yes	Yes	No
69	106	Hwy 34, MRM 363.7-365	1.304	No	Yes	Yes	Yes	Yes	Yes	No	Yes	Maybe	Yes	Yes	Yes	Yes
70	96	Hwy 44, MRM 348.24 Wolf Bridge	0.093	No	No	Yes	Yes	Yes	Yes	No	Yes	Maybe	Yes	Yes	Yes	No
71	114	Hwy 50, MRM 308.32-309.32 River Ranch Rd	1.004	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Maybe	Yes	Yes	Yes	Yes
76	105	Hwy 34, MRM 307.6-308.6	0.993	No	No	Yes	Yes	No	Yes	No	Yes	Maybe	Yes	Yes	Yes	Yes

Top 100 List Ranking	Segment ID	Segment Name	Length (Miles)	Adjacent to Tribal Land	Adjacent to FLMA Land	Adjacent to Crops or Pastureland	Adjacent to Cultivated Crops	Adjacent to Pastureland/Hay	LSF	Maintenance Area Feedback on LSF	Standing Corn Rows	Maintenance Area Feedback on Standing Corn Rows	Structural Snow Fence	Maintenance Feedback on Structural Snow Fence	Temporary Snow Fence	Grading
87	109	Hwy 44, MRM 274.48 44-47 Junction	0.110	No	No	Yes	Yes	Yes	Yes	No	Yes	Maybe	Yes	Yes	Yes	No
97	107	Hwy 34, MRM 280.2-280.9	0.694	No	Yes	Yes	Yes	No	Yes	No	Yes	Maybe	Yes	Yes	Yes	Yes
99	104	Hwy 34, MRM 301.6-302.7	1.087	No	Yes	Yes	Yes	Yes	Yes	No	Yes	Maybe	Yes	Yes	Yes	Yes

Table 20: Guidance on blowing snow treatment options for Mobridge Maintenance Area based on location, length, ranking, adjacent land, and maintenance staff feedback.

Top 100 List Ranking	Segment ID	Segment Name	Length (Miles)	Adjacent to Tribal Land	Adjacent to FLMA Land	Adjacent to Crops or Pastureland	Adjacent to Cultivated Crops	Adjacent to Pastureland/Hay	LSF	Maintenance Area Feedback on LSF	Standing Corn Rows	Maintenance Area Feedback on Standing Corn Rows	Structural Snow Fence	Maintenance Feedback on Structural Snow Fence	Temporary Snow Fence	Grading
22	15	Hwy 12 Near MRM 141	0.154	Yes	Yes	No	No	No	No	Yes	No	Maybe	Yes	Yes	NF	No
23	16	Hwy 212 Near MRM 193	1.551	Yes	Yes	No	No	No	No	Yes	No	Maybe	Yes	Yes	NF	Yes
42	17	Hwy 12 Near MRM 139	0.215	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Maybe	Yes	Yes	NF	No
58	18	Hwy 65 Near MRM 206	0.153	Yes	Yes	No	No	No	No	Yes	No	Maybe	Yes	Yes	NF	No
80	19	Hwy 1804 Near MRM 367	0.142	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Maybe	Yes	Yes	NF	No

Table 21: Guidance on blowing snow treatment options for Pierre Maintenance Area based on location, length, ranking, adjacent land, and maintenance staff feedback.

Top 100 List Ranking	Segment ID	Segment Name	Length (Miles)	Adjacent to Tribal Land	Adjacent to FLMA Land	Adjacent to Crops or Pastureland	Adjacent to Cultivated Crops	Adjacent to Pastureland/Hay	LSF	Maintenance Area Feedback on LSF	Standing Corn Rows	Maintenance Area Feedback on Standing Corn Rows	Structural Snow Fence	Maintenance Feedback on Structural Snow Fence	Temporary Snow Fence	Grading
12	124	Hwy 14, MRM 207.7-215.3	7.628	No	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Maybe	Yes
26	32	Hwy 1806, MRM 138.46-139.5	0.418	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Maybe	No
34	33	Hwy 1806, MRM 150.8-151.2	0.406	Yes	Yes	No	No	No	No	Yes	No	Yes	Yes	Yes	Maybe	No
48	42	Hwy 34, MRM 151-153	2.002	No	No	No	No	No	No	Yes	No	Yes	Yes	Yes	Maybe	Yes
57	37	Hwy 14 Near Junction of 14 and 83	1.004	No	No	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Maybe	Yes
62	34	Hwy 83N, MRM 103-105	1.998	No	Yes	No	No	No	No	Yes	No	Yes	Yes	Yes	Maybe	Yes
67	35	Hwy 83S, MRM 103-105	2.008	No	Yes	No	No	No	No	Yes	No	Yes	Yes	Yes	Maybe	Yes
73	40	Hwy 212, MRM 227-229	2.002	No	No	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Maybe	Yes
78	36	Hwy 14, MRM 129.3-130.5	1.216	No	No	No	No	No	No	Yes	No	Yes	Yes	Yes	Maybe	Yes
79	43	Hwy 34, MRM 134-135	0.958	No	No	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Maybe	Yes
90	38	Hwy 14, Near Blunt Cemetery	1.041	No	No	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Maybe	Yes

Table 22: Guidance on blowing snow treatment options for Rapid City Maintenance Area based on location, length, ranking, adjacent land, and maintenance staff feedback.

Top 100 List Ranking	Segment ID	Segment Name	Length (Miles)	Adjacent to Tribal Land	Adjacent to FLMA Land	Adjacent to Crops or Pastureland	Adjacent to Cultivated Crops	Adjacent to Pastureland/Hay	LSF	Maintenance Area Feedback on LSF	Standing Corn Rows	Maintenance Area Feedback on Standing Corn Rows	Structural Snow Fence	Maintenance Feedback on Structural Snow Fence	Temporary Snow Fence	Grading
1	44	Hwy 42, MRM 48	0.101	No	No	Yes	No	Yes	Yes	NF	No	NF	Yes	Yes	Yes	No
4	46	Hwy 385, MRM 108	0.099	No	Yes	No	No	No	No	NF	No	NF	Yes	Yes	Yes	No
30	48	Hwy 85, MRM 32-35	2.979	No	Yes	Yes	No	Yes	Yes	NF	No	NF	Yes	Yes	Yes	Yes
46	47	Hwy 385, MRM 116	0.097	No	No	No	No	No	No	NF	No	NF	Yes	Yes	Yes	No
49	54	Hwy 44E, MRM 85-88	3.010	No	Yes	No	No	No	No	NF	No	NF	Yes	Yes	Yes	Yes
50	45	Hwy 473, Lead to Ski Lodge	3.186	No	Yes	No	No	No	No	NF	No	NF	Yes	Yes	Yes	Yes
53	49	Hwy 14A, MRM 46-48	1.995	No	Yes	No	No	No	No	NF	No	NF	Yes	Yes	Yes	Yes
75	53	Hwy 16W, MRM 56-57	0.985	No	No	No	No	No	No	NF	No	NF	Yes	Yes	Yes	Yes
82	52	Hwy 16E, MRM 56-57	0.992	No	No	No	No	No	No	NF	No	NF	Yes	Yes	Yes	Yes

Table 23: Guidance on blowing snow treatment options for Sioux Falls Maintenance Area based on location, length, ranking, adjacent land, and maintenance staff feedback.

Top 100 List Ranking	Segment ID	Segment Name	Length (Miles)	Adjacent to Tribal Land	Adjacent to FLMA Land	Adjacent to Crops or Pastureland	Adjacent to Cultivated Crops	Adjacent to Pastureland/Hay	LSF	Maintenance Area Feedback on LSF	Standing Corn Rows	Maintenance Area Feedback on Standing Corn Rows	Structural Snow Fence	Maintenance Feedback on Structural Snow Fence	Temporary Snow Fence	Grading
9	2	Hwy 11 Garretson to MN	10.649	No	No	Yes	Yes	Yes	Yes	Maybe	Yes	Maybe	Yes	NF	Yes	Yes
17	1	Hwy 115 Harrisburg	2.001	No	No	Yes	Yes	Yes	Yes	Maybe	Yes	Maybe	Yes	NF	Yes	Yes
28	3	Hwy 38 Sioux Falls to Humboldt	8.936	No	No	Yes	Yes	Yes	Yes	Maybe	Yes	Maybe	Yes	NF	Yes	Yes
33	5	Hwy 18 E of I-29	13.692	No	No	Yes	Yes	Yes	Yes	Maybe	Yes	Maybe	Yes	NF	Yes	Yes
51	6	Hwy 42 E of Sioux Falls	5.111	No	No	Yes	Yes	Yes	Yes	Maybe	Yes	Maybe	Yes	NF	Yes	Yes
68	4	Hwy 11 S of Brandon	2.317	No	No	Yes	Yes	Yes	Yes	Maybe	Yes	Maybe	Yes	NF	Yes	Yes

Table 24: Guidance on blowing snow treatment options for Watertown Maintenance Area based on location, length, ranking, adjacent land, and maintenance staff feedback.

Top 100 List Ranking	Segment ID	Segment Name	Length (Miles)	Adjacent to Tribal Land	Adjacent to FLMA Land	Adjacent to Crops or Pastureland	Adjacent to Cultivated Crops	Adjacent to Pastureland/Hay	LSF	Maintenance Area Feedback on LSF	Standing Corn Rows	Maintenance Area Feedback on Standing Corn Rows	Structural Snow Fence	Maintenance Feedback on Structural Snow Fence	Temporary Snow Fence	Grading
13	11	Hwy 12 Near Marvin	7.636	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Maybe	Yes	Yes	Maybe	Yes
14	7	Hwy 10 Near Long Hollow	9.923	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Maybe	Yes	Yes	Maybe	Yes
41	10	Hwy 22 E of Clear Lake	5.492	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Maybe	Yes	Yes	Maybe	Yes
45	13	Hwy 28 Near Toronto	8.030	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Maybe	Yes	Yes	Maybe	Yes
56	14	Hwy 20 Near South Shore Stockholm	18.551	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Maybe	Yes	Yes	Maybe	Yes
66	8	Hwy 212 Near Goodwin	7.730	No	Yes	Yes	Yes	No	Yes	Yes	Yes	Maybe	Yes	Yes	Maybe	Yes
74	9	Hwy 212 E of Hwy 15	5.006	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Maybe	Yes	Yes	Maybe	Yes

Table 25: Guidance on blowing snow treatment options for Winner Maintenance Area based on location, length, ranking, adjacent land, and maintenance staff feedback.

Top 100 List Ranking	Segment ID	Segment Name	Length (Miles)	Adjacent to Tribal Land	Adjacent to FLMA Land	Adjacent to Crops or Pastureland	Adjacent to Cultivated Crops	Adjacent to Pastureland/Hay	LSF	Maintenance Area Feedback on LSF	Standing Corn Rows	Maintenance Area Feedback on Standing Corn Rows	Structural Snow Fence	Maintenance Feedback on Structural Snow Fence	Temporary Snow Fence	Grading
18	21	Hwy 248	12.976	No	No	Yes	Yes	Yes	Yes	Maybe	Yes	Maybe	Yes	Yes	Maybe	Yes
27	22	Hwy 273	12.011	Yes	Yes	Yes	Yes	Yes	Yes	Maybe	Yes	Maybe	Yes	Yes	Maybe	Yes

Table 26: Guidance on blowing snow treatment options for Yankton Maintenance Area based on location, length, ranking, adjacent land, and maintenance staff feedback.

Top 100 List Ranking	Segment ID	Segment Name	Length (Miles)	Adjacent to Tribal Land	Adjacent to FLMA Land	Adjacent to Crops or Pastureland	Adjacent to Cultivated Crops	Adjacent to Pastureland/Hay	LSF	Maintenance Area Feedback on LSF	Standing Corn Rows	Maintenance Area Feedback on Standing Corn Rows	Structural Snow Fence	Maintenance Feedback on Structural Snow Fence	Temporary Snow Fence	Grading
8	23	Hwy 81, on Curve	2.008	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Maybe	Yes	Maybe	Maybe	Yes
10	31	Hwy 50W, MRM 415-417	2.063	No	No	Yes	Yes	No	Yes	Yes	Yes	Maybe	Yes	Maybe	Maybe	Yes
32	30	Hwy 50, MRM 407-408	0.948	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Maybe	Yes	Maybe	Maybe	Yes
35	29	Hwy 50W, MRM 396.5-397	0.396	No	No	Yes	Yes	No	Yes	Yes	Yes	Maybe	Yes	Maybe	Maybe	No
37	25	Hwy 18, MRM 380-384	4.019	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Maybe	Yes	Maybe	Maybe	Yes
55	24	Hwy 44, MRM 387-388	1.000	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Maybe	Yes	Maybe	Maybe	Yes
83	27	Hwy 37, MRM 40-42	2.009	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Maybe	Yes	Maybe	Maybe	Yes
88	75	Hwy 44, MRM 349-353	4.004	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Maybe	Yes	Maybe	Maybe	Yes

The following supplemental information for each blowing snow treatment includes general guidance on duration, maintenance, cost, and landowner involvement.

- Living Snow Fence
    - A good, long-term option that will last 20+ years with routine maintenance (e.g., water, replacing dead plants).
    - May take 5-20 years to mature and function as designed. An additional structural snow fence may be installed at LSF location to allow for immediate effectiveness. The structural snow fence can be removed once the LSF is mature.
    - Moderate to high upfront cost, but overall, a very cost-effective option overall.
    - Requires landowner permission and a long-term agreement.
- Standing corn rows
    - Review how the planting direction of the corn and prevailing wind direction relate to the orientation of the road.
    - Since they are typically planted every other year, an alternative blowing snow mitigation strategy is needed during crop rotation years. Temporary snow fences, like lath or plastic orange fencing, are options.
    - Good communication with landowners is required.
    - Least expensive option.
- Structural snow fence
    - A good, long-term option that will last 20+ years with routine maintenance (e.g., checking and replacing boards as necessary).
    - Moderate to high upfront cost, but overall, a very cost-effective option in the long run.
    - Requires landowner permission and a long-term agreement.
- Temporary snow fence
    - Temporary snow fence may be a product designed to last only one to two seasons. One example is orange plastic fencing (Figure 44). Structural snow fences that are moved seasonally, like wooden lath fencing (Figure 43), or hay bales (Figure 47) can also be used.
    - A good option for landowners who do not want a permanent structure on their land.
    - High maintenance, requiring extra personnel and equipment hours to install and remove the fences seasonally.
    - Good communication with landowners is required. Seasonal installation requires consideration of timing for land use.
    - Upfront cost is low, but seasonally installing and taking down can significantly increase the cost and complications.

- Grading
    - Earthwork
        - Pre-construction: make sure road designers are aware of blowing snow problem areas so adequate storage and slope layback can be designed into the project.
        - Post-construction: In blowing snow areas, are there backslopes that can be cut back? Is there enough room to flatten the ditch bottom to increase snow storage? Important considerations include upland terrain and land use adjacent to the blowing snow problem area.
        - As this solution often requires significant investment, it should be paired with planned road work. A benefit, however, is that it is a permanent solution.
    - Snow Ridging
        - Need landowner permission to routinely access during winter months to form and reform as they fill in with snow. As a result, this solution requires good communication with landowners.
        - Care must be taken not to gouge the land surface when creating berms.
        - Snow grading is a temporary solution that requires routine maintenance.

Maintenance Effort

When deciding the best blowing snow mitigation strategy for each location, the level of effort to install and maintain the mitigation strategy and the associated costs should be considered. In theory, the cost of a permanent structural fence decreases over time. There is the initial cost, then maintenance for the first 2-3 years can be high as the wood continues to dry out and screws become loose. With a properly constructed fence, once this initial weathering is done, there should be little need for maintenance other than walking the fences to check for failed/failing members.

Depending on location, an LSF can take up to 20+/- years to grow sufficiently and can suffer plant loss that may require replacement. While the LSF is maturing, a structural snow fence is recommended to help protect the roadway and add additional moisture to the LSF.

Temporary fencing may be the cheapest way to limit drifting snow (depending on the amount of snow, wind, and ROW). It is easy to put up and can be highly effective in the right locations. That said, it cannot be the only fence if the area upwind of the roadway is greater than one-half mile. If the temporary fence is seasonally placed, the labor costs of putting up the fence and taking it down every season will make this an expensive and time-intensive option and should be integrated into fall and spring maintenance planning.

Note that any blowing snow treatment option needs to be considered on a case-by-case basis, and additional work may be required to ensure success beyond the installation of the treatment option. One consideration may include training and support for SDDOT staff in working with landowners on maintenance of installed blowing snow mitigation strategies.

4.9.2.3 Site Specific Considerations

Following the determination of blowing snow mitigation strategies that may best apply for each blowing snow problem area, consideration of additional information may aid in the final decision-making of each mitigation strategy. Additional considerations include:

- Basic Design Considerations
- Geology
- Terrain
- Context Sensitivity & Land Use Planning
- Existing Snow Fences
- Wildlife Data

The following sections provide more details on these additional considerations.

Basic Design Considerations

Based on prior research by Tabler (2003), the following are basic design considerations that should be taken into account when designing and placing snow fence (1). Tabler (2003) will provide detailed information on all aspects of snow fence design.

- Long and tall fences: Long and tall fences hold more snow. A 12-foot, 50% porosity fence can hold up to 49.5 tons of snow per linear foot, whereas an 8-foot, 50% porosity fence can hold 20.3 tons of snow per linear foot.
- Adequate snow storage capacity: Snow storage capacity should not only consider the storage from snow fences, but also the additional storage needed from plowing activities.
- Proper placement: A properly engineered snow fence helps to prevent drifts, improve visibility, improve road surface conditions, reduce crashes, and ultimately reduce winter maintenance costs. Other aspects that need to be considered are:
    - Setback: Ideally, the setback of the fence should be far enough from the roadway to prevent drift encroachment, which is why ROW is often a significant factor in snow fence design. Setback distance for each snow fence treatment is related to snow fence height and porosity, and the surrounding terrain. Supporting information on setback distances and design can be found in Tabler (2003) (1).
    - Location of fence ends: When placing snow fence, the fences should extend 30° on either side of the prevailing wind direction to account for wind variations and the reduction of snow trapping at the ends of the fence (Figure 68).

- Alignment: Snow fences with an attack angle (the angle between prevailing wind and the roadway) between 55° and 90° should be placed parallel to the roadway (Figure 69). For oblique fences, fences should be placed within +/- 10° of perpendicular to prevailing winds.
- Openings: On fences with a bracing supportive structure, it is important to have a bottom gap of 10-12% to prevent burial of the supporting structure. A 50% porosity fence has been shown to form the largest drifts. That said, by changing the porosity of a fence and the bottom gap, the size and location of the drift can be changed.

Tabler (2003, pg. 25) states "On flat terrain, the minimum setback for 50% porous snow fences is 35H." "Snow fences may be set back farther to prevent drifts from burying right-of-way fences, or if terrain will encourage longer drifts." ***Each site is unique and requires a site investigations and design****, which Tabler (2003) can be used for.*

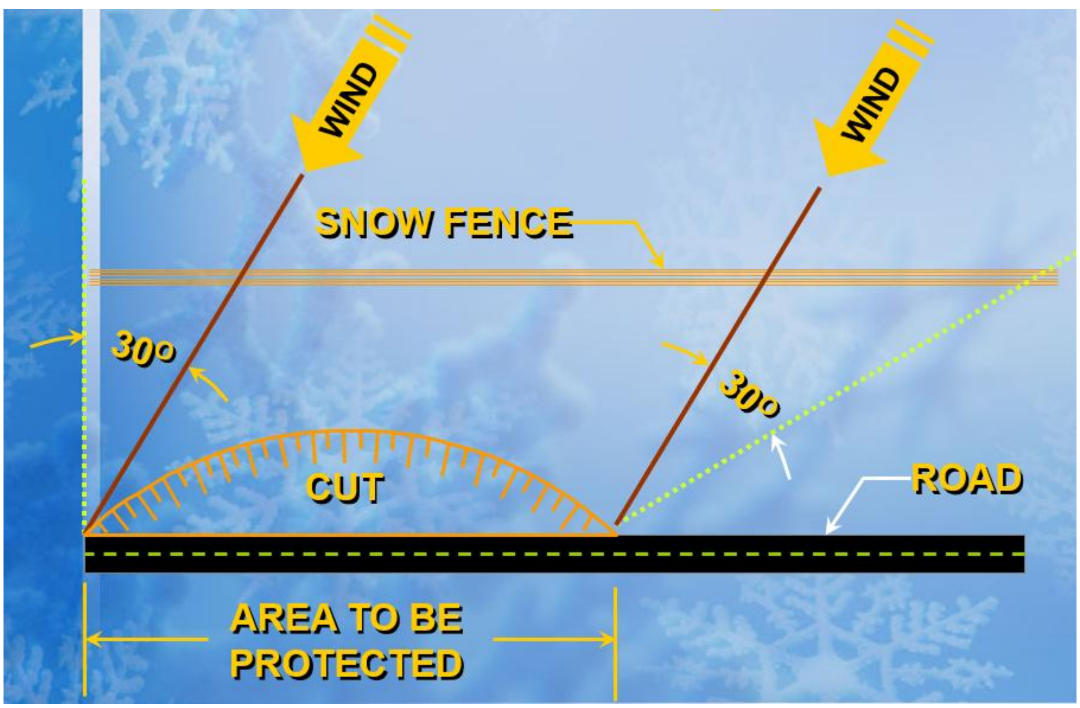

Figure 68: Snow fence layout showing fence ends extended at 30° on either side to intercept with prevailing wind direction (1).

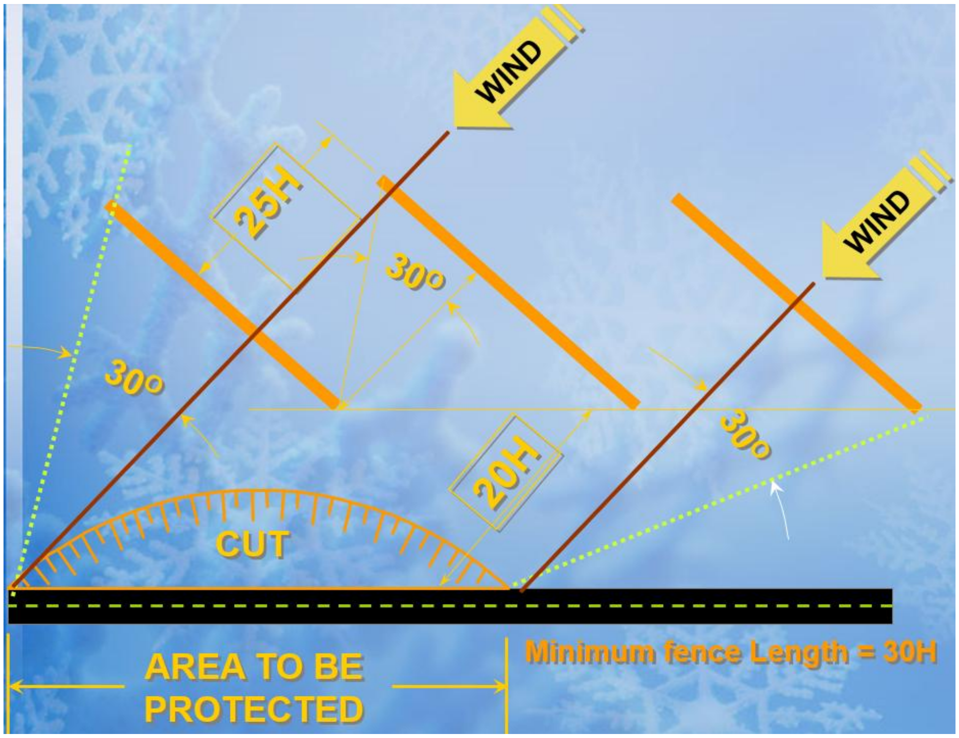

Figure 69: Snow fence layout showing alignment of attach angles.

These are just a few of the things to think about when designing and placing snow fence. Detailed design methods can be found in “Controlling Blowing and Drifting Snow with Snow Fence and Road Design” (1).

Soils

Soils data could be obtained through the United States Department of Agriculture National Resource Conservation Service Soil Surveys, which provides soil characteristics at the county level. Soils data can be used to inform the viability of an LSF. It can also provide the designer with an understanding of the anchoring required for structural snow fences. Because this data is available at the county level, site-specific locations should be investigated on a case-by-case basis.

Geology

SDDOT provided South Dakota geology data, which describes the distribution of geologic features across the state. Geologic data helps determine the frost depth, the type of anchoring that would work best, which leads to the type of snow fence for each site. Knowing the geology and depth to bedrock will give maintenance and contractors some idea of the equipment that might be needed for the installation.

Terrain

Terrain, or ground surface features, or structures are specific to each site and may be the cause or contributor of blowing snow issues on roadways. Note that any terrain feature can contribute to blowing snow, including knobs, ponds, lakes, streams, trees, tall grass, flat land, shrubs, buildings, billboards, etc. For example, flat land and frozen lakes function in the same way as cultivated fields, such that there is nothing in the fetch to stop or slow the blowing snow. Therefore, the snow will blow through or relocate. Whereas terrain and vegetation can trap snow. If you have open land, you need to design for that using wind direction, larger fencing, multiple fences, patterns of fencing, etc.

For each blowing snow location identified, the surrounding terrain should be assessed to determine if it is the cause or a contributing factor. This should be assessed on a case-by-case basis. Site-specific terrain mapping could be used by SDDOT once blowing snow problem locations are identified and selected for treatment. This will aid in the determination of the blowing snow mitigation strategy.

Context Sensitivity & Land Use Planning

Land use plans, future construction, roadway expansion plans, and potential growth centers should be considered for each blowing snow problem location. Where blowing snow is a known problem, communities and roadways may be planned for expansion. If development is planned to occur, SDDOT could coordinate with the project to address blowing snow problem areas through earthwork gradings.

Other considerations include route importance. Is this a primary route into and out of town? Is it a school bus route? Is the route used by emergency response personnel? Does the route provide access to medical facilities? Does the route connect to grocery stores? If the roadway is the primary route to services such as medical and shopping, then there is a greater need to keep the roadway open.

Existing Snow Fences

SDDOT has provided a GIS file of existing snow fence locations with information on the type of snow fence. This information can be used to determine the level of experience a Maintenance Area has with the installation and maintenance of snow fences, provide insights into snow fence types that work in the area, and local knowledge of existing landowner agreements and communication practices. Additionally, SDDOT may consider expanding an existing mitigation strategy if the problem area is adjacent to an existing snow fence installation.

Wildlife Data

SDDOT provided wildlife-vehicle collision (WVC) reported crashes and carcass data and global positioning system (GPS) collar locations for four wildlife species (e.g., white-tailed deer, mule deer, elk, and pronghorn). Overall, there is little existing guidance regarding how different snow fence types may or may not impact various species. SDDOT could work with the South Dakota Game, Fish, and Parks division to obtain professional opinions regarding potential impacts. White tailed deer, mule deer, elk, pronghorn, and pheasants are species across South Dakota that may be impacted, either positively or negatively, by the installation of snow fences. One Maintenance Area had discussed how their use of hay bales attracted elk, which is not preferable near a roadway. Thus, if elk migrate within a corridor, this treatment may not be preferred.

Shrubs integrated into an LSF benefit pollinators, which in turn benefit farming, and consequently could encourage the application of an LSF in proximity to cultivated land. In addition, if a landowner has an interest in songbirds, they may be interested in supporting an LSF, which is viewed as providing habitat. If LSFs are installed with the intention of providing wildlife habitat, the rows should not be tightly spaced. Tall wheatgrass, alfalfa, and grain sorghum integrated into LSF can catch and store snow as well as provide a food source for wildlife. The use of 4 to 6 ft fencing around LSFs may be needed to keep livestock and wildlife from grazing. Pheasants use tree stripes for thermal cover in the winter. This could be a benefit to landowners who are interested in making wildlife habitat improvements.

Additional considerations include creating gaps in snow fences over 1200 ft long for livestock and wildlife to cross through the fence.

Snow fences are believed to be beneficial to elk, deer, pheasants, turkeys, and grouse in that they provide shelter. In contrast, snow fences are viewed as reducing habitat for pronghorn, as pronghorn rely heavily on their vision to detect predators from a distance. Consequently, they avoid wooded areas and prefer habitats with less vegetation and cover.

Minnesota is currently considering whether the presence of snow fences may or may not correlate with deer collisions. As the analysis was still underway at the time of the writing of the guidance document, no conclusions can be shared at this time. Wildlife with migratory patterns (e.g., pronghorn) were believed to potentially be impacted differently than animals that do not have strong migratory patterns (e.g., white-tailed deer).

4.9.2.4 Funding Blowing Snow Treatments

Funding sources to support the installation of blowing snow treatments have been identified as limited, with typical funding for blowing snow treatments coming from project and operational funds. Additional funding sources that can be pursued to support these efforts include federal, state, and private money. Examples of funding sources used for blowing snow treatments include PROJECT (Promoting Resilient Operations for Transformative, Efficient, and Cost-saving Transportation) program funds, Environmental and Natural Resource Trust Funds, Trunk Highway Funds, USDA's CP17A Living Snow Fence, Highway Safety Improvement Program (HSIP), Conservation Reserve Program (CRP), and private grants. For some states, fees are collected when plants are removed by businesses; these fees then pay for snow fencing. In some instances, funds can be used to leverage environmentally focused funding or farmer reimbursements. It is recommended that once blowing snow treatment locations have been identified, statewide personnel work with local maintenance personnel, and landowners to determine costs and identify potential funding sources that can be pursued.

4.9.3 Cost & Benefits of Blowing Snow Mitigation

4.9.3.1 Blowing Snow Mitigation Costs

Identified costs for various blowing snow mitigation strategies are provided in Table 27. Note that these costs are pulled directly from the literature and may not accurately reflect current costs in South Dakota due to the variability of costs at each location and the change in costs over time. Additionally, cost values are reported in variable units and with caveats (e.g., include cost of site preparation, include maintenance costs, etc.).

Table 27: Blowing snow treatments, estimated costs, and lifespan.

Blowing Snow Treatment	Cost Per Unit	Years of Treatment Effectiveness	Reference and Year Published
Living Snow Fence	$3 (mile/yr per unit of snow)	50 - 75	(73) [1999] (74) [2025]
Living Snow Fence	$2,260 (acre) (Establishment cost – geo-textile, seedling planting, site prep. Maintenance cost: $44 - $384 (acre)) $40 - $530 (mile/yr/row) (Estimated amounts based on inflation from 1986 to 2025)	50 – 75	(7) [2012]

Wood slat fence (4ft)	$185 (mile/yr per unit of snow)	5 - 7	(73) [1999] (10) [1988]
Wyoming/wood structural snow fence	$400 - $600 per panel $370– $5,600 (mile/yr/row) (Estimated amounts based on inflation from 1986 to 2025)	25	(10) [1988] (14) [2000]
Standing Corn Rows	$405 - $555 (acre) or $4.50 (per bushel) $3 (ft)	1	(7) [2012] (74) [2025] (10) [1988]
Standing Corn Rows - Reimbursement	Market price + up to $5 per bushel *Corn commodity price - $4.09 (July 2025)	1	SDDOT [2025] *Corn Commodity pricing.
Temporary fence – orange plastic	$7.25 (ft)(cost of installation, maintenance, and removal)	1-3	(74) [2025]

The South Dakota Department of Agriculture and Natural Resources reported for every $1 spent on LSF, the program saw a return of $17 or a 17:1 benefit-cost ratio (3). All snow fence types have been asserted as providing greater costs than benefits, with LSFs having the greatest benefit-cost ratio ((10), (14)). More specifically, the benefit-cost ratio for LSFs has been reported as 1.70, with the benefits outweighing the costs after 10 years (72). For structural snow fences, it was 1.81 and 4.5 years. For standing corn rows, it was 6.11, with 1 year. Reinforcing blowing snow mitigation effectiveness, it was found that plowing a road is 100 times more expensive than installing an LSF, and all snow fences were found to have a benefit-cost ratio of 50 to 100:1 compared to snow removal costs ((5), (74)).

Cost estimates for standing corn rows range from $405 - $ 555 per acre (7). While the corn can be hand-harvested in the fall, which is labor-intensive, the stalks need to be removed in the spring before planting can begin, and this can create a burden due to the farmer having to make a specific trip out to the location of the stalks to remove them. Construction cost of an extensive system of snow fences can be "amortized in less than 10 years" (75). Longer snow fence installations were found to be most cost-effective (76). Wooden and fixed snow fences were found to be very cost-effective snow fence types due to maximum volume of snow storage, cost to build, and required maintenance (23).

LSF site preparation costs for labor, tilling, and herbicide use were estimated at $60 - $ 82 per acre. Planting costs (planting and matting) were estimated at $1,474 - $3,046 per acre. Watering 5 to 10 times per year was estimated to cost $200 - $400 per acre (US Dollars in 2012) (7). Additional costs for mowing, replanting, and spot spraying are provided. These practices vary by location and, therefore, not all of these costs apply in all locations.

4.9.3.2 Blowing Snow Mitigation Benefits

Benefits associated with the use of the various blowing snow mitigation strategies include:

- **Carbon sequestration** – LSFs and standing corn rows have the added benefit of sequestering carbon. Carbon sequestration rates vary based on plant species and age of plants. General values for grasses, shrubs, and trees can be used to develop estimates, until actual plant species are determined. Example carbon sequestration rates are provided in Table 28.

Table 28: Plant species carbon sequestration rates.

Plant	Carbon Sequestration Rate	Reference
Aspen	1.6 – 1.8 mega grams of carbon (Mg C)/hectare per year	(77)
Pine	1.3 – 1.7 Mg C/hectare per year	(77) (78)
Spruce	1.0 – 1.4 Mg C/hectare per year	(77)
Willow, shrub	~ 1.9 Mg C/hectare per year	(79)
Upland plants, grasses and shrubs	0.4 – 2.6 Mg C/hectare	(80)

- **Reduced emissions** – A 100ft LSF is estimated to reduce CO_2 emission by 10.4 lbs/ft ((2), (7)). Estimates for treatment of drifting snow and blow ice using a single axel plow truck are 8.1 and 2.3 pounds of carbon dioxide (CO_2) per year (7). Emission values can be determined for each blowing snow problem area based on vehicle type used and round-trip distance to treat the location (7). Additionally, reduced emissions can be realized from public vehicle travel time with the road remaining open and passable through the prevention of traffic and stoppages.

- **Cost savings** – Cost savings from reduced winter maintenance operations include personnel, equipment time, and fuel consumption. A 1,040 ft 3-row LSF with a 50-year life only needs to reduce one accident every 23 years or 6 hours per year of plowing to offset the cost (81).
- **Reduced need for winter maintenance treatment (plowing and deicing)** – Blowing snow treatments should reduce or eliminate the snow drifts on roads and thereby reduce the need to plow and apply deicer treatment at these locations, saving money, materials, and reducing impacts to the environment ((7), (54), (59)).
- **Improved safety** – Blowing snow treatments should reduce or eliminate snow drifts on roads and blow ice, which are hazards to the driving public. They can be particularly problematic as they can occur in isolated locations in what appears to be an otherwise clear roadway. Additionally, visibility for drivers should improve at these locations. Past efforts have found a 40-70% improvement in safety from the installation of snow fences ((5), (14), (54), (56)). A 1,040 ft 3-row LSF with a 50-year life only needs to reduce one accident every 23 years or 6 hours per year of plowing to offset the cost (81).
- **Wildlife habitat** - Snow fences may provide habitat for deer and elk, and shelter for range animals like cows. Adequate spacing is needed between parallel rows of trees and fencing in order to provide space for food and cover for wildlife in the winter (10). To increase the benefits for livestock and wildlife, planting tall wheatgrass, alfalfa, and grain sorghum around the LSFs may assist with the storage of snow and support wildlife (10). LSFs may be beneficial to upland birds.

4.9.3.3 Cost-Benefit Tools

The University of Minnesota developed an LSF costs and benefits calculator (https://www.dot.state.mn.us/environment/livingsnowfence/cost-benefit.html) (82) as part of the research project *Economic and Environmental Costs and Benefits of Living Snow Fences: Safety, Mobility, and Transportation Authority Benefits, Farmer Costs, and Carbon Impacts* (7). This tool is available in Excel or as an online tool but only applies to LSF.

Another Cost-Benefit analysis tool for a Snow Fence, developed for Illinois DOT, can be found in *Evaluating the Costs and Benefits of Snow in Illinois: Phase 2* (https://www.ideals.illinois.edu/items/116556) (72). Cost and other data elements required for the analysis are shown in Figure 70.

To conduct a cost-benefit analysis for blowing snow treatment options at the top 100 blowing snow sites in South Dakota, a substantial amount of effort is required. It is recommended that if SDDOT is interested in pursuing this, a separate effort that considers both methodologies ((7), (72)) be pursued.

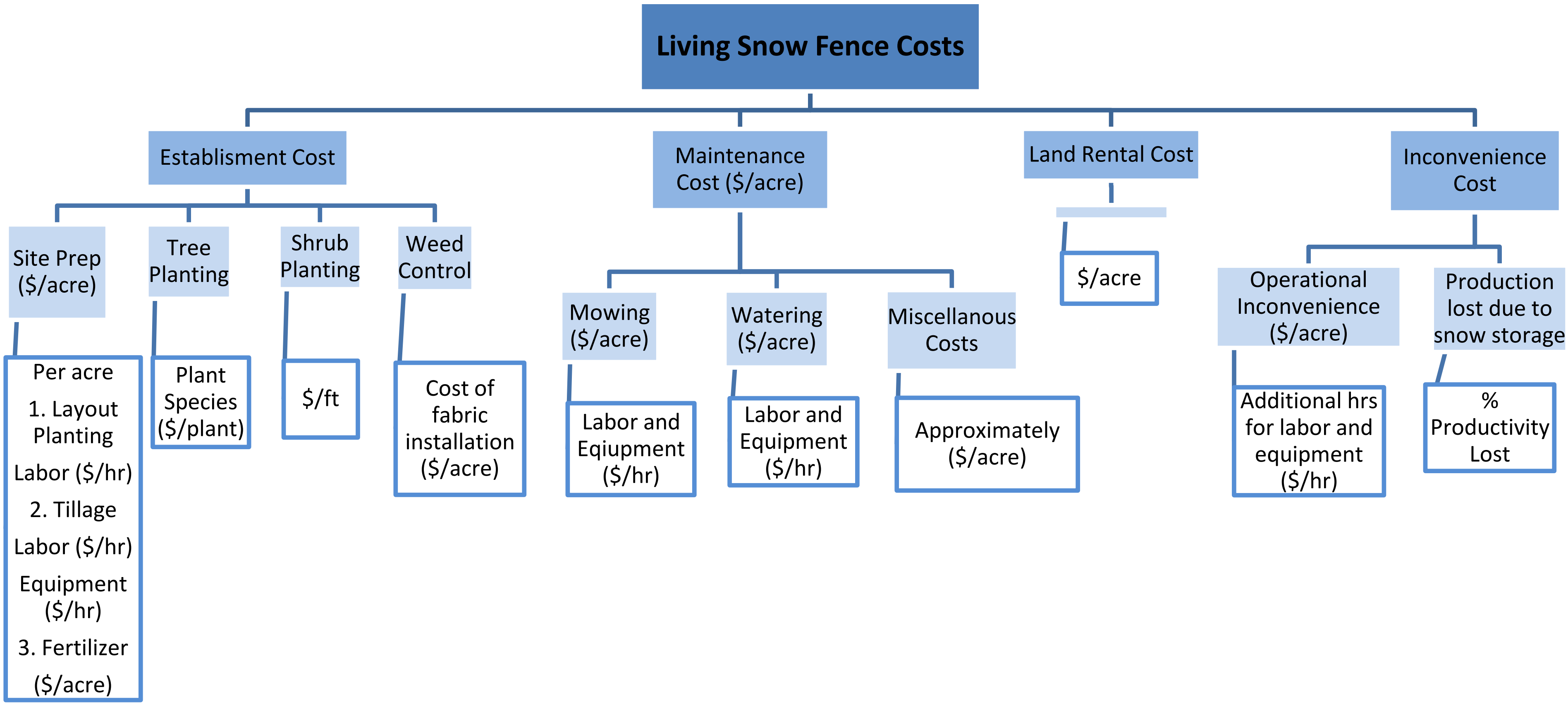

Figure 70: Cost elements for LSF cost-benefit framework recreated from (72).

4.9.3.4 Lifecycle Cost Framework

A life cycle cost framework has been developed that considers each mitigation strategy, costs associated with construction and maintenance, land or easement lease fees, crop reimbursement (where applicable), and the lifecycle.

Step 1: Select Relevant Blowing Snow Mitigation Strategies

For a specific blowing snow problem area from the top 100 list, first select your preferred treatments. Then, review the data needs below indicated by an (X) for each blowing snow mitigation strategy in Table 29.

Table 29: Data needs for lifecycle cost framework for each blowing snow treatment.

Data Needs	Structural Snow Fence	Temporary Snow Fence	Living Snow Fence	Standing Corn Rows	Earthwork Grading	Snow Ridging, Berming
Contracted Amount or Loaded Build Cost Per Foot	x		x		x	
Personnel Rate (per hour)	x	x	x		x	x
Equipment Rate (per hour)	x	x	x		x	x
Temporary Snow Fence Material		x				
Seasonal Maintenance Material Costs (ex: nails, rebar, weed cloth, etc.)	x	x	x			
Watering			x			
Land Lease/Easement ($/year)	x	x	x	x		x
Crop Reimbursement Rate (per acre, bushel)				x		
Round Trip Distance to Site (miles)	x	x	x	x	x	x
Length of Blowing Snow Treatment (ft or acres)	x	x	x	x	x	x

Step 2: Data Entry

The following information is needed to populate the Excel form with specific cost information, including:

Set Costs

- Round Trip Distance to Site (miles)
- Length of Blowing Snow Treatment (feet or acres)
- Land Lease/Easement ($/year)

Structural Snow Fence Costs (per unit)

- Set up Costs – Cost per foot
- Seasonal Snow Fence Maintenance – Personnel
- Seasonal Snow Fence Maintenance – Equipment
- Maintenance Material Costs Per Season (ex: lumber, nails, screws, rebar, u-clips, etc.)

Temporary Snow Fence Costs (per unit)

- Snow Fence Set up – Personnel
- Snow Fence Set up – Equipment
- Snow Fence Maintenance – Personnel
- Snow Fence Maintenance – Equipment
- Fence Material (ex: wood lattice or plastic sheeting, posts, ties, nails, etc.)
- Other material costs (ex: nails, screws, rebar, etc.)

Living Snow Fence (per unit)

- Set up Costs – Cost per foot
- Seasonal Snow Fence Maintenance – Personnel
- Seasonal Snow Fence Maintenance – Equipment
- Watering
- Seasonal Maintenance Material Costs (ex: replacement plants, etc.)

Standing Corn Rows (per unit)

- Crop Reimbursement Rate (per acre, bushel)

Earthwork Grading (per unit)

- Set up Costs – Cost per foot

Snow Ridging, Berming

- Ridging Set Up – Personnel

- Ridging Set Up – Equipment
- Ridging Maintenance – Personnel
- Ridging Maintenance - Equipment

Once the Excel form is populated with cost information, the lifecycle cost for building (blue) and maintenance (orange) for each blowing snow treatment strategy can be compared (Table 30).

The example provided in Table 31 is the 1 ranked blowing snow problem area located in Rapids City, SD Hwy 42, MRM 48. This site has a length of 0.101 miles (or 533 ft), is located adjacent to crop, pastureland, or hay and therefore LSF, structural snow fence, and temporary snow fence were considered as feasible options. Table 31 provides the output of the lifecycle cost framework showing that LSF is the most cost-effective option followed by structural snow fence, and then temporary snow fence. Note that this is only an example using estimated cost information and hours required.

The lifecycle cost framework has been provided to SDDOT and additional guidance on how to use this tool is provided in Appendix G: Lifecycle Cost Framework.

Items not included in the Lifecycle cost framework but are relevant include the difference in costs of materials when purchased in bulk. In the planning process, supplies (including but not limited to wood boards, lath or lattice, or plastic sheeting) can be purchased in large enough quantities to get a bulk discount rate, which can reduce upfront costs significantly. This applies to both materials and plants. Important considerations are storage of materials and care for plants. Other considerations include changeable reimbursement/land use rates. Historical agreements may need to be updated, and new cost information should be considered; new landowner agreements will need to include fair and competitive rates that represent market value, or all agreements should match new rates.

Table 30: Lifecycle cost framework for blowing snow treatment options. Costs for building (blue), maintenance (orange).

Blowing Snow Treatment	Contract Cost/Build (material, personnel, equipment costs)	Maintenance (Life Cycle)	Land Lease/Easement or Reimbursement Cost	Crop Reimbursement	Total Cost	Life Cycle (Yrs)	Cost Per Year of Service
Structural Snow Fence	$0.00	$0.00	$0.00		$0.00	20	$0.00
Temporary Snow Fence	$0.00	$0.00	$0.00		$0.00	3	$0.00
Living Snow Fence	$0.00	$0.00	$0.00		$0.00	50	$0.00
Standing Corn Rows				$0.00	$0.00	1	$0.00
Earthwork Grading	$0.00				$0.00	100	$0.00
Snow Ridging, Berming	$0.00	$0.00	$0.00		$0.00	1	$0.00

Table 31: Lifecycle cost estimate for example blowing snow problem location.

Blowing Snow Treatment	Contract Cost/Build (material, personnel, equipment costs)	Maintenance (Life Cycle)	Land Lease/Easement or Reimbursement Cost	Crop Reimbursement	Total Cost	Life Cycle (Yrs)	Cost Per Year of Service
Structural Snow Fence	$8,000.00	$11,244.80	$850.00		$20,094.80	20	$1,004.74
Temporary Snow Fence	$9,273.20	$1,873.44	$850.00		$11,996.64	3	$3,998.88
Living Snow Fence	$15,000.00	$16,112.00	$850.00		$31,962.00	50	$639.24

4.9.4 Conclusions

There are many blowing snow mitigation strategies that can be used on rural roadways. To identify the most appropriate mitigation strategy the research team used the developed top 100 list of blowing snow problem areas, feedback from SDDOT maintenance staff on existing snow fence types used, and feedback from SDDOT Maintenance Areas on mitigation strategy to develop a framework to support SDDOT in the decision-making process. Additionally, the research team developed a lifecycle cost framework to allow for comparison of various blowing snow mitigation strategies at each blowing snow problem area.

This guidance document was designed to support SDDOT in determining feasible blowing snow mitigation options for the top 100 blowing snow problem areas. Additional site analysis work will need to be completed for each chosen location, including design, orientation, and placement, for the selected blowing snow mitigation strategy.

4.10 Present Guidance Document to Technical Panel

Prepare and present for approval of the project's technical panel a technical memorandum summarizing the findings of Tasks 8 and 9.

The Guidance Document was presented to SDDOT on Monday, July 21, 2025.

4.11 Develop Final Report

In conformance with the Guidelines for Performing Research for the South Dakota Department of Transportation, prepare a final report summarizing the research methodology, findings, conclusions, and recommendations.

This document constitutes the final report for the project.

4.12 Present Guidance Document to SDDOT Research Review Board

Make an executive presentation to the South Dakota Department of Transportation Research Review Board at the conclusion of the project.

The project was presented to the SDDOT Research Review Board on Wednesday, October 29, 2025.

5.0 FINDINGS AND CONCLUSIONS

5.1 Literature Review of Blowing Snow Mitigation Strategies

Extensive research was conducted on snow transport in the 1960s, particularly by Tabler, and while research is still ongoing, the number of projects on the topic has since dwindled. Many of the outcomes from this research are still in use today. However, as much of the research conducted by Tabler was centered in the mountain west, interviews with state departments of transportation that were further east, particularly WisDOT, suggested, through practice, a modification of the recommendations which reflect climatic variations. One of the more contemporary trends post-Tabler's work was centered on using LSFs, including standing corn rows.

5.2 Interviews with Surrounding States

Almost all state DOTs suggested that there was limited funding available for the installation of snow fences. Most often, snow fences are funded on a project basis or via operating funds. However, interviewees also noted that in some cases, while a snow fence was initially integrated into a project, it was later removed to reduce the overall cost of the project. A few decades ago, it seemed that the USDA provided a funding source for snow fences that do not seem to be used much today. With recent changes to federal funding, this source may no longer be an option. There are some creative ways in which state DOTs have funded snow fences both at the federal (e.g., PROJECT) and state (e.g., Environmental and Natural Resources Trust Fund) levels.

5.3 Interviews with SDDOT Personnel

SDDOT maintenance area approaches to snow fences range from little knowledge on the topic to innovative approaches (e.g., wooden board fence). The need also seems to vary based on climatic conditions across the state. West river (west of the Missouri River), there seems to be a preference for structural snow fences, reflecting the more challenging growing conditions. East river (east of the Missouri River), where land is more fertile, there is the potential for LSFs, including standing corn rows or temporary snow fences, yet the value of the land results in landowners being generally less open to part with any amount of land for blowing snow mitigation strategies. The use of standing corn rows presents an opportunity, even with the challenges of bi-annual rotation of crops (e.g., soybeans one year, corn the next, then repeat). The Iowa DOT, who extensively uses standing corn rows, faces a similar challenge. They utilize more frequent conversations with landowners, including initiating a discussion with landowners about standing corn rows for the next year when they follow-up the previous year. Furthermore, the orientation of some of the corn rows in South Dakota was suggested as non-compatible with the use of standing corn rows – the rows are not orientated perpendicular to the winds (or close to it) carrying the snow. Finally, while some efforts have been made to engage landowners (e.g., while branding cattle), particularly farmers, outreach takes time. All of the SDDOT maintenance areas suggested that they do not have time available for this purpose. These factors serve as hurdles for SDDOT staff to overcome if standing corn rows are to be used in the state.

5.4 Identification of Blowing Snow Problem Locations

The number of rural, non-interstate blowing snow problem locations ranged from as few as two (Winner Area) to as many as 277 (Aberdeen Area). The length of these sections also ranged from as short as 0.09 miles to as long as 72.94 miles. Most of the areas identified these locations through practice, some even developing figures to describe the problem that were shared with the researchers (see Appendix B: SDDOT Interviews). The Aberdeen Area was unique in that blowing and drifting snow areas were surveyed and a KMZ file was developed and shared with the researchers. Therefore, there may be a bias regarding the number of locations identified. For this project, maintenance areas were asked to identify rural, non-interstate blowing snow locations, yet many maintenance areas reported issues along interstates within their area, highlighting the need for additional consideration of potential blowing snow treatments for these roadways as well.

5.5 Prioritization of the Top 100 Blowing Snow Problem Locations

The maintenance areas were asked to prioritize their blowing snow problem areas. Aberdeen prioritized their top 53 locations (out of 277), resulting in a list of 181 blowing snow problem locations on rural highways in South Dakota. Of the 181 blowing snow problem areas identified by the maintenance areas, the prioritization process winnowed the count down to the top 100. To do this, data was used that best describes these locations and shows the most pressing need to mitigate the impacts of blowing snow. Blowing snow problem areas identified in the top 100 list were more likely to have been selected by the maintenance areas as problem locations, have higher crash rates, and/or were located further away from a maintenance garage. The distribution of blowing snow problem areas identified in the top 100 list differed across SDDOT maintenance areas, with the number of locations and length varying significantly.

5.6 Blowing Snow Mitigation Strategy Guidance

There are many blowing snow mitigation strategies that can be used on rural roadways. To identify the most appropriate mitigation strategy, the research team used the developed top 100 list of blowing snow problem areas, feedback from SDDOT maintenance staff on existing snow fence types used, and feedback from SDDOT Maintenance Areas on mitigation strategies to develop a framework to support SDDOT in the decision-making process. The guidance document identifies blowing snow mitigation strategies, potentially feasible blowing snow mitigation strategies for the top 100 locations based on adjacent land ownership and use and maintenance area preferences. Additionally, the research team developed a lifecycle cost framework to allow for comparison of various blowing snow mitigation strategies at each blowing snow problem area.

The guidance document was designed to support SDDOT in determining feasible blowing snow mitigation options for the top 100 blowing snow problem areas. Additional site analysis work will need to be completed for each chosen location, including design, orientation, and placement, for the selected blowing snow mitigation strategy. A well placed snow fence not only helps reduce work for the DOT, but it also improves safety, keeps roads passable, and provides intangible benefits like supporting goodwill from the traveling public.

There are some key aspects to highlight when considering design. As identified by interviews with SDDOT maintenance staff, not all storms cause blowing snow problems. Different storms may have different wind directions. SDDOT maintenance staff expressed knowing which wind directions caused issues for them. Therefore, the design should reflect the wind directions that cause problems.

The “best” snow fence for a site, is one specifically designed for that location, is well-constructed, and well-maintained. SDDOT should not merely install a snow fence and leave it. A plan should be made regarding the snow fence’s long-term maintenance, including an anticipated replacement timeline. If the lifespan of the snow fence is longer than anticipated, maintenance should continue until it is replaced. Collecting performance data for each snow fence is recommended, as it can better inform future South Dakota-specific snow fence lifespans. A challenge to doing this, however, is that the lifespan of some of these structures may exceed the career length of employees, so it is important that there is a plan that enables passing this institutional knowledge to the next generation of employees. Well-maintained snow fences will ensure that landowners will be supportive of these treatments. While snow fences that begin to deteriorate can continue to address some blowing snow, their poor appearance could give pause to other landowners that may consider working with SDDOT to address blowing snow problems through snow fences.

5.7 Future Research

Through this research process, three potential future research needs were identified, one related to safety impacts, a second related to the impact of snow fences on wildlife behavior, and a third related benefit-cost analysis of the use of grading. The following provide additional details about these topics.

5.7.1 Safety Impacts of Snow Fences

At the beginning of the project, there was interest in conducting a safety analysis to quantify the impacts of snow fences on safety. Existing snow fences along rural South Dakota roadways were provided, but the installation dates were not known with certainty. Furthermore, crash data before and after the installation date of the snow fences was not always available, as many of the installations were from the 1980s. As South Dakota installs snow fences or uses grading, even if temporary, recording the location and timing of these efforts could be used to analyze the safety impacts of these efforts going forward. For example, anecdotally, the snow fence installed along the right-of-way is believed to provide significant safety benefits (Figure 8). If similar snow fences were installed in other narrow rural corridors, the date of installation should be recorded and an analysis of before and after impacts could be conducted (using control groups).

5.7.2 Effects of Snow Fences on Wildlife Behavior and Wildlife-Vehicle Collisions

Structural and LSFs have been implemented to control snow drifts and enhance road safety during winter. However, these snow fences may inadvertently influence wildlife behavior and contribute to the frequency of wildlife-vehicle collisions (WVCs). During surrounding state interviews, MnDOT identified an internal ongoing study related to this topic. However, results were not available prior to the conclusion of this project. While few scientific studies directly address these effects, existing theories suggest several potential impacts that warrant further investigation.

Snow fences can act as physical barriers, altering wildlife movement patterns and potentially fragmenting habitats. Large mammals such as deer, elk, and pronghorn may respond differently to snow fences based on their species-specific behaviors. For instance, structural snow fences may obstruct migration routes or guide wildlife toward hazardous road crossings. In contrast, LSFs might attract deer and elk due to the availability of forage or cover, while pronghorn, which rely on unobstructed sightlines for safety, may avoid these vegetative barriers. Small mammals and birds (e.g., pheasants) might experience additional, varied effects, such as benefiting from cover or encountering barriers to movement.

The placement of snow fences relative to wildlife corridors and high-risk WVC zones is critical for maintaining habitat connectivity. Poorly located snow fences may increase collision risks by funneling animals into traffic-heavy areas or restricting access to natural habitats. Conversely, strategically placed snow fences could mitigate WVCs by guiding wildlife toward safe crossing zones or reducing roadside snow accumulations for easier animal movement. Potential research opportunities both with the existing data in South Dakota and for broader studies to improve our understanding of the effects of snow fences on wildlife behavior and WVCs exist.

5.7.3 Best Practices Regarding Grading to Address Blowing Snow

SDDOT expressed an interest in understanding the costs and benefits of changes to grading to address blowing snow problems. Unfortunately, a limited understanding was available to date. Interviews with SDDOT maintenance areas suggested that projects were conducted, in part, to address blowing snow issues. However, the impact of these projects on addressing blowing snow were not quantified. Therefore, if SDDOT conducts projects that include components specific to addressing blowing snow, these impacts should be quantified by collecting before and after data.

Maintenance areas reported conducting temporary grading to address blowing snow. To the researchers' knowledge, the safety benefits of these efforts have not been quantified. A research project could be conducted to analyze the impact of temporary grading.

6.0 RECOMMENDATIONS

The researchers offer the following nine recommendations for SDDOT to consider:

1) In-depth crash analysis to determine additional blowing snow areas
2) Collaborate with DTN to improve their blowing snow model for South Dakota
3) Improve cost estimates by incorporating snowplow routes
4) Develop communication guidance for adjacent landowners about blowing snow challenges and treatment options
5) Set snow fence program metrics – collect data
6) Add blowing snow strategies as a topic at SDDOT's annual maintenance meeting
7) Disseminate the findings of this project
8) Develop a memorandum of understanding for critical routes.
9) Review Existing LSFs for Present Day Functionality

6.1 In-Depth Crash Analysis to Determine Additional Blowing Snow Areas

An in-depth crash analysis should be conducted to determine if additional blowing snow areas should be considered for blowing snow mitigation strategies. In addition, there are several other opportunities for micro-level crash analyses that South Dakota could consider.

The analysis of crashes and slide-in data are centered on the blowing snow problem locations which were identified by SDDOT Maintenance Areas. A review of the crash and slide-in data suggests that crash and slide-in clusters exist outside of the locations identified by SDDOT Maintenance Areas. These additional locations could be where solutions like grading and snow fences are already programmed in by projects. The locations could also be undetected by SDDOT Maintenance Areas (an analysis could identify why) or they may reflect lower priorities for SDDOT Maintenance Areas.

While the above is a macro-level crash analysis, additional opportunities could be identified to mitigate blowing snow crashes by conducting a micro-level crash analysis. This analysis would review the narrative, types, conditions present, roadway geometry, and potential presence of wildlife specific to crashes identified as "blowing snow" crashes in the data. Such an analysis could also instead consider several randomly selected rural South Dakota corridors and review how crashes specifically identified as "blowing snow" differed from those associated with other winter crashes to understand if there is a bias in the data or those specific to "blowing snow" tend to more precisely relate to the impacts of blowing snow. Finally, a more detailed crash analysis could include collaborating with South Dakota Highway Patrol to better determine the location of the first harmful event of the crash as compared with the end resting place of a vehicle, to determine if there are gaps regarding crash location identified and the cause behind the crash.

6.2 Collaborate with DTN to Improve Their Blowing Snow Model for South Dakota

SDDOT should consider working with DTN (their MDSS provider), to define at a higher resolution, sheltered, semi-sheltered, and unsheltered routes which will help to improve the MDSS blowing snow model.

In MDSS, a blowing snow model has been developed which allows for each route to be defined as sheltered, semi-sheltered and unsheltered. Yet, the length of some of the routes does not well capture the variation that can be experienced along the route regarding blowing snow impacts. Therefore, SDDOT should consider coordinating with DTN regarding opportunities to provide a more disaggregated understanding of the blowing snow impacts experienced along the route.

6.3 Improve Cost Estimates by Incorporating Snowplow Routes

SDDOT can improve cost estimates by incorporating snowplow routes to determine the distance from the maintenance garage to each blowing snow problem area.

SDDOT should work with each maintenance garage to map out snowplow routes to better determine specific costs of treating the identified blowing snow problem areas to allow for better cost-benefit analysis. As described in Distance from Maintenance Shop, the analysis presented herein used estimates.

6.4 Develop Communication Guidance for Adjacent Landowners About Blowing Snow Challenges and Treatment Options

SDDOT should develop guidance to improve communication with landowners about the snow fence program and the benefits of participation.

SDDOT should develop communication guidance which includes efforts to improve communication with landowners, participation in community meetings, providing training, and leveraging support from conservation districts, farm bureaus and Co-ops, and State Forestry to help encourage buy-in from landowners. One document that can assist with the development of communication guidance is MnDOT's *Promoting the Adoption of Snow Fences through Landowner Engagement* (https://mdl.mndot.gov/index.php/items/202214) (2). Early and often communication is suggested to support SDDOT in creating working relationships and maintaining these partnerships. Landowner involvement is critical to the success of these programs.

A part of this effort may include the development of communication materials which include information on safety, cost, benefits, reimbursement rates, and landowner expectations (e.g., access for snow fence installation and maintenance), and testimonials. It is recommended that the existing knowledge of maintenance crews be integrated into materials, as they will know the land, the road, the weather, and most likely the landowners.

A tool that could be used to communicate this information is a short pamphlet that can be shared. The South Dakota Department of Agriculture and Natural Resources created, *The Living Snow Fence Program in South Dakota*, (https://danr.sd.gov/Conservation/docs/InfoPubs/LSF-Brochure.pdf) (3) in 2010. This document could be updated to more recent times using information gathered from this effort.

These efforts could include increasing public awareness of why snow fences are important. SDDOT could develop a Public Service Announcement (PSA) about snow fences to aid in buy-in. SDDOT communication folks could work with local news organizations to help disseminate the benefits of snow fences, like this example from Minnesota: https://www.keyc.com/video/2023/01/09/mndot-farmers-join-forces-combat-snow-fences/. The video highlights the landowner and maintenance supervisor and provides overarching benefits of snow fences. Photos could be captured by SDDOT central office staff or by maintenance staff.

6.5 Set Snow Fence Program Metrics – Collect Data

When implementing blowing snow mitigation strategies, SDDOT should collect program data to better understand the benefits and costs.

SDDOT should prioritize resolving a select number of blowing snow problems annually. As these issues are addressed, SDDOT should collect data to better understand the challenges and the benefits of the solutions. Over time, SDDOT will better understand how locations that might be deemed as "tricky," could be addressed with an appropriate treatment. To support programmatic decisions and to show effectiveness of installations, collecting data on all aspects of blowing snow treatments is recommended. Recommended data fields include but are not limited to the following: the reasoning for the selection of a blowing snow treatment; the installation date; all costs to design, build, and maintain; and detailing communication efforts with landowners. This will help develop a detailed cost-benefit analysis of the treatments applied. Furthermore, SDDOT should ensure that a group of staff members are trained on the process and results, to ensure that as staffing changes over time, the institutional knowledge is retained.

6.6 Add Blowing Snow Strategies as a Topic at SDDOT's Annual Maintenance Meeting

SDDOT should consider conducting peer exchanges on blowing snow mitigation strategies so maintenance crews can learn from each other and their peers.

SDDOT should consider including snow fencing and other blowing snow strategies as a topic at the Annual SDDOT Maintenance Meeting. This could include having maintenance staff present on successful implementation of snow fences and potential pitfalls to avoid. This could also include potentially bringing in people from other states to present on their snow fence implementations. The presentations should represent potential solutions and examples from both east and west river.

6.7 Disseminate the Findings of This Project

SDDOT should consider sharing the findings of this project with others within SDDOT and with peer organizations at conferences, trainings, and workshops.

As mentioned in the literature review section, there are few recent research efforts occurring related to snow fences. Disseminating the results of this research effort could help other state DOTs as they look to implement snow fences. Generally, snow fences were popular around the time of research conducted by Tabler. However, in more recent years, with a focus on cost savings, efficiencies in practices (e.g., using less salt), there is a need to reconsider solutions like snow fences and grading.

6.8 Develop a Memorandum of Understanding for Critical Routes

SDDOT should consider developing or revising an MOU for landowners, schools, and emergency services to prioritize critical routes.

SDDOT should consider developing memorandums of understanding (MOUs) for critical routes. As landownership changes may result in the new owner not understanding existing agreements regarding snow fences, developing a written MOU ensures the transferability of agreements. In rural areas, highways are critical routes for residents to obtain medical care and access and receive goods and services. Routes closed as a result of drifting snow can prevent access for school buses to pick up and drop off students and impair the travel of emergency vehicles. While it can be impractical to keep all local routes open, specific routes should be identified that emergency vehicles can depend on to remain open in case of an emergency. MOUs should address what SDDOT is prepared to do to keep critical routes open during severe winter weather. These actions can be as commonplace as plowing school bus routes before the beginning and ending of the school day.

6.9 Review Existing LSFs for Present Day Functionality

SDDOT should review the present day functionality of existing LSFs.

SDDOT provided information to the researchers about existing snow fences, including LSFs. Early LSF designs included tree species that grew too large over their more than 20-year life span, such that they no longer trap snow as intended. Adding or replacing trees with other species, like juniper, will allow the LSF to continue to function as originally intended. Therefore, the researchers recommend that SDDOT review LSFs identified in the file shared to confirm that they are functioning as intended.

7.0 RESEARCH BENEFITS

The research team developed and implemented a methodology to identify the top 100 rural, non-interstate highway locations with blowing snow issues to support SDDOT in making more informed decisions for resource allocation. Through this approach, a Guidance Document was developed to help SDDOT identify blowing snow treatment strategies. The research team also developed a lifecycle framework to assist SDDOT in making more informed decisions for resource allocation. The following research benefits were achieved as a result of the approach:

1. A better understanding of the causes of blowing snow problems on roadways.
2. Identification of rural, non-interstate highways with blowing snow issues in South Dakoka.
3. A better understanding of blowing snow treatment methods, pros and cons of each, requirements, costs, lifespan, etc.
4. Identified areas for data collection improvement needed to develop a cost-benefit analysis of SDDOT blowing snow treatment program.

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Appendix A: Neighboring State Interviews

ADDRESSING BLOWING SNOW STRATEGIES

1. Does your agency employ other blowing snow mitigation measures besides the implementation of snow fences and grading?
2. Does your agency consider, in the design or redesign of roadway cross-sections, snow storage? If it does, could you refer us to the design standards, or are they site-specific?
3. Has your agency made grading improvements specifically to address blowing snow concerns?

SNOW FENCES

4. What types of snow fences does your agency use (living, structural, other)? Why?
5. If your agency uses various types of snow fences, how does your agency decide what type of snow fence to use for each application?
6. If your agency uses living snow fences (LSFs) (*skip this question otherwise*):
    a. Does your agency have a living snow fence coordinator? If so, what are their responsibilities for this role?
    b. Who pays for the installation of a living snow fence?
    c. Who is responsible for replacing trees and shrubs if they die off?
    d. Who is responsible for maintaining the trees and shrubs over time?
    e. What is your agency's experience with using standing corn rows?
7. How does your agency prioritize where to install snow fences?
8. Do you know the <u>average life expectancy</u> of your agency's snow fences (living, structural, other)?
9. How frequently and what type of inspection and <u>maintenance</u> does your agency perform on its snow fences?
10. Have you had any challenges with your existing snow fences (e.g., maintenance needs are too frequent; snow is not being captured as designed; other)?
11. Has your agency conducted a traffic safety evaluation of existing snow fence installations?
    a. Yes; do you have any associated reports/outcomes that you can share?
12. Have you documented or considered wildlife migration impacts or habitat benefits as a result of snow fence installations?
    a. Yes; please describe.
13. How do you fund snow fence materials and installation?
14. How do you fund snow fence inspection and maintenance?

15. If you put snow fences on private land adjacent to the road, how long are your contracts with landowners (e.g., 1 year, 3 years, 10 years, 15 years, handshake agreement)?
    a. Do you have any best practices regarding engaging with private landowners?
16. Does your agency have any research reports, benefit/cost analyses or the like on snow fences that you can share?
17. Does your agency have a snow fence design, installation, inspection, and/or maintenance team? Please explain.
18. Does your agency conduct trainings regarding snow fences? Please explain.

LESSONS LEARNED/FOLLOW-UP

19. Can you provide any lessons learned and/or best practices with regard to use of snow fences or other blowing snow mitigation strategies by your agency?
20. If we have additional questions, may we follow up? If so, please provide your name and contact information.
21. Are there others involved in the planning design, construction, and maintenance of snow fences within your state that you might recommend that we speak with? If so, please provide their name and contact information.

Iowa

Interview 1: July 3, 2024

ADDRESSING BLOWING SNOW STRATEGIES

1. Does your agency employ other blowing snow mitigation measures besides the implementation of snow fences and grading?

We use multiple types of snow fence. To delineate living snow fence (trees, shrubs), anything related to a living snow fence, is managed, developed, implemented by our design office. They have the funding; they do all of that part of the program. As a part of design. When they go to expand lanes. In the office of maintenance, we don't have anything to do with that portion of the program. Within the office of maintenance, our program is multi-type fence. We use a combination of standing corn, standing round bales and temporary fence. Typically, all of those different types, and a permarail type fence. All of those that I just described, for the most part, are going to be outside of the right-of-way, that they get agreements with the landowner to leave standing corn, standing round bales on their property.

It's a centralized program, meaning he manages the budget, pay for the agreements that they have in place. It's more of a decentralized place in that locations are identified, and people are signed up by maintenance staff. They know their areas much better than him. Where they've seen incidents and accidents in the crash. I give them the authority and responsibility to sign up people. I don't say know at all. Having said that, we have had a handful of incidents where landowners have said that they're interested in signing up, but the field says that they appreciate the willingness and with the topography the way it is, they prefer for the snow to blow across the road. That's very infrequent. Centralized control from the budget standpoint, processing payments. Decentralized in the responsibility for staff to talk to landowners to get people signed up. Maintenance garages, as they're finalizing agreements last fall, they're already talking to the landowners for next year. They have repeat customers. They follow back up with the landowners in the spring time. When they talk to new potential landowners in the spring time, not just an informational standpoint, but they also talk to the landowner, the plant a hybrid that has good stock strength that can be left out there as a standing corn row. Hybrid with excellent stalk strength.

2. Does your agency consider, in the design or redesign of roadway cross-sections, snow storage? If it does, could you refer us to the design standards, or are they site-specific?

It will depend on how much right-of-way. They do consider it.

3. Has your agency made grading improvements specifically to address blowing snow concerns?

I'm not really sure that we have. When I first started 10 years ago in the role, they had probably about 100 agreements and about 20 to 30 miles of standing corn temporary snow fence and permanent snow fence. The last 3-4 years, they've averaged between 55-56 miles of that combination of snow fence. 72 miles a couple of years ago. Combination of permanent, temporary standing…we mapped it all out via GIS so we can kind of see where the agreements are located across the state. A lot of them are in the north/north-central Iowa. We get a lot in the eastern part of the state. We compete with ethanol plants. They have cash corn. We struggle with farmers to participate where ethanol plants are.

Closing the market is August 1st. I pull 50 grain elevators from the State of Iowa, randomly. New crop corn. I use that information to determine the statewide average price that day. Let's say it's $5. We add $2 for that price. So, we pay $7 per bushel for the farmers that leave standing corn. For the other information, as a part of the agreement that they sign each year, the garage staff records length/width, number of rows, it records the yield, we either use that from the farmer (yield monitor in combine) or what they report for their crop insurance (average yield/acre) and we use that, 1.3 acres. For standing round bales, temporary and permanent snow fence. We pay them $1 per linear foot for fence that they install or round bales that they leave. We've had those prices in place for a number of years. We've had comments and questions asking about raising them. At this point, we haven't done that, but we'll be looking into the future. Temporary snow fence, we obtain their permission to go on the property. In many cases, our staff install the fences and take them out in the spring. Our agreements are written as such, farmers are required to leave them in place until March 15; then they harvest the corn, take out the temporary fence or remove the round bales. Many of the farmers use the standing corn as a fundraising donation type of opportunity. They'll allow a local 4H club to hand pick the corn. They donate it to the chapter/club and sell it as a fundraiser. The farmer doesn't have to harvest the corn. They knock down the stocks that are remaining. 2 or 3 farmers, they rotate and work together so one does it one year and the other another year. You can really see, when you look at the photos, you can see the delineation where the corn starts on stops. There's nothing on the road. Keeping that corn off the road, saves them a significant amount of time and effort.

SNOW FENCES

4. What types of snow fences does your agency use (living, structural, other)? Why?

Those various types are the ones used (see initial info). From a budget stand point, he has $415,000 budgeted to pay for the agreement. Last year, he spent just over $400,000. It's very important that management understands. That's a lot of money to spend on standing corn. When you look at events like last January, I don't know how many comments I got back from garages, if we didn't have standing corn there, who knows what that road would have looked like. That standing corn prevented the road from closing.

5. If your agency uses various types of snow fences, how does your agency decide what type of snow fence to use for each application?

It's the decision of the local forces and the farmer. We'd like to help you out, but we don't want to pull back out the combine in the spring. Livestock guys – I have round bales; they have to store their bales somewhere. It's pretty easy to line them up in the area where they would leave standing corn. It's been amazing to see how effective the round bale fences have been. We're not following the 50% porosity, but you're gaining the benefit of having it in place, preventing the snow from landing on the pavement.

6. If your agency uses living snow fences (LSFs) (*skip this question otherwise*):
    a. Does your agency have a living snow fence coordinator? If so, what are their responsibilities in this role?

From a living snow fence perspective, that's on the design side. They have the agreements. They manage that program. Standing corn, temporary snow fence, yes, I'm "Winter Operations Administrator." I am not going to sit in Aimes, Iowa, where they should put it and if they should put it there. The guys ask what he thinks about it, he says that he can't try to claim them, if they think it's going to be beneficial, they support. It's a very effective way to manage a program.

    b. Who pays for the installation of a living snow fence?
    c. Who is responsible for replacing trees and shrubs if they die off?
    d. Who is responsible for maintaining the trees and shrubs over time?
    e. What is your agency's experience with using standing corn rows?

It's operational dollars that pays for the $415,000.

7. How does your agency prioritize <u>where</u> to install snow fences?

Identified by the maintenance garages. He accepts what they recommend. Management sometimes looks at the amount of money that he spends. He looks in his cost center to see if they can shift anything around. It's a first come/first serve. The garage staff are dealing with so many things. Trying to pin down the farmers during harvest is sometimes difficult. If the agreement isn't signed and sent in. They usually want all agreements in by December 31st. There are a few occasions where things trickle into January. He's not going to penalize the garage.

8. Do you know the average life expectancy of your agency's snow fences (living, structural, other)?

Permarail that they utilize. It's a 20-year life before they have to replace it. It does require some annual maintenance and repair, but it's pretty minimal. They have to tighten up the straps. They may have to replace a section hit by tillage equipment.

9. How frequently and what type of inspection and maintenance does your agency perform on its snow fences?

They inspect them in the fall right before winter to make sure that they are functioning properly.

Corn rows and bale, they meet with the farmers a couple times a year. In the fall, they take the measurements of what was left to get the paperwork signed.

Living snow fence – they're monitoring and working with design folks. I-35, north of Aimes, they had living snow fence trees that had been in place for so long no one knows how long. Old enough, tall enough outgrown their usefulness and turned into a situation that was making things worse. Living snow fence on both sides of the interstate. It was creating a wind tunnel, churning. Instead of catching snow, it was coming over the top and churning where the trees were and dropping it on the highway. Portions of the tree were dead and dying. We had to work with design and do a cut and grubbing out project to remove all of the trees and shrubs in that area. They went back to the drawing board to replant new living snow fence in that area. It's all coordinated between the garages and the Office of Design.

10. Have you had any challenges with your existing snow fences (e.g., maintenance needs are too frequent; snow is not being captured as designed; other)?

It's captured by design. They have to put forward a project to have a contractor come in and remove the trees. Get it into the program for replanting.

11. Has your agency conducted a traffic safety evaluation of existing snow fence installations?
    a. Yes; do you have any associated reports/outcomes that you can share? [upload here, insert link here]
    b. No.

Not to his knowledge.

12. Have you documented or considered wildlife migration impacts or habitat benefits as a result of snow fence installations?
    a. Yes; please describe.
    b. No.

Not really to that extent. We do list it as a benefit for leaving snow fence. It does create a habitat for pheasants and deer during the winter. We haven't studied or have had a lot of feedback that it's increased the number of accidents with deer. It hasn't been brought to his attention.

13. How do you fund snow fence materials and installation?

Operations budget.

14. How do you fund snow fence inspection and maintenance?

Operations budget.

15. If you put snow fences on private land adjacent to the road, how long are your contracts with landowners (e.g., 1 year, 3 years, 10 years, 15 years, handshake agreement)?
    a. Do you have any best practices regarding engaging with private land owners?

Standing corn, round bales, temporary – 1 year agreements. Permarail – we sign a minimum of 5 year agreement. Where we install permarail. We get the agreement to install it. We do the installation. It wouldn't be cost-effective to get the money, install for only a year's worth of use. In a few instances, they signed a 10 year agreement right off the bat.

16. Does your agency have any research reports, benefit/cost analyses or the like on snow fences that you can share?

We have a pamphlet that we give out that lists some of the benefits. Strictly a report – I don't have that. It's a tough one to really get your arms wrapped around. There's some NCHRP data, MnDOT has done some research recently that we've referred to as well. Iowa, c/b research we haven't done. We're an army of two. I have my hand in a lot of different things. You have to prioritize where you're going to spend your time and effort.

17. Does your agency have a snow fence design, installation, inspection, and/or maintenance team? Please explain.

We don't. The inspection and verification is left up to the field staff. For standing corn, I ask that they do a "lookie see" after they have signed the agreement to make sure that the farmer has left the corn. We have had the instance where they signed an agreement, and the corn was gone then after. It was a simple mistake where dad signed the agreement the farmer's hired hand, "why did they leave those rows up there," they didn't know about the signed agreement. They had to cancel the agreement. They ask the field staff as a verification.

He knows the highway, the milepost, the exact length in feet. That's the information that their GIS folks used to plot it on a map. He knows the county. He's just shy of 11 years in the chair. We've been managing it since he started it. It started before his predecessors. They've gotten to the point where they have done more promotion and stressed the importance and the benefit that they've seen from doing it. They have had a large turnover in garage supervisors in the last 4 years. Previously, maybe where garage supervisors saw it as an extra; the new supervisors are more open and willing to give it a try. Once they try it and see the benefit, they're promoting the program to more and more people. Especially in those areas known as trouble spots. Areas prone to more drifting and blowing. When you had an event like last January, they had a significant number of roads that were blown shut/blocked. Blowers/graders, once they had to use them to open the roads, then they see the benefit of the program. We've placed more of an emphasis on it. We've secured more money to put to the program. He had two different times last year, he had a new supervisor, who hadn't been in the position too long, we just did a round table of coffee, where they brought in the farmers, he spent $10 on donuts and coffee and sat around the table and had a discussion with them about the program, how it works, the benefits, from the farmers and DOTs. They always tie into that kind of a presentation. They're getting a benefit, it's increasing the safety for their friends, neighbors and families traveling the roadways. Traverse the highways and being able to see in those times when you have blowing and drifting snow. He's done that a couple of times. That area had half a dozen new sign-ups since they were able to ask questions and discuss. Farmers are an interesting group of folks to deal with. I got a scathing letter from a guy who thought they were absolutely nuts in spending the money on this. He had been at the coffee shop and heard about another guy participating in the program and shared what they were paying to participate in the program. They suggested that they were wasting money. There's nothing that I can do to change that person's thought. Thank you for your comments.

The new guys, younger guys coming in, try new things and new technology to help them do their job.

18. Does your agency conduct trainings regarding snow fences? Please explain.

Each year in early October, we bring in leadership from field garages. 200-220 folks. It's a day and a half long conference, we have a series of presentations and update them on operations and maintenance. I always do an update on some of the changes and some of the research going on. We talk about snow fence and talk about prices for the year. We review how they go about signing folks up. Some of the guidelines they use for setbacks. We can't always achieve the setback that they want. Allowing the field staff to use their best judgement. Setback from the edge of the road. It's not a formalized training session. Every year we review the program and answer any questions. That conference is one of his responsibilities. He's the keeper of the agenda. I'm a bit ruthless in managing the agenda. We had some pie in the sky, fairy engineers that wanted to present. He wanted to know what they were going to present that would make the maintenance engineer to make his job more efficient or do it better.

LESSONS LEARNED/FOLLOW-UP

19. Can you provide any lessons learned and or best practices with regard to use of snow fences or other blowing snow mitigation strategies by your agency?

The biggest lesson learned, as I mentioned, is decentralizing the control of where we place these agreements. Allowing the field staff to do their job. They know their areas better than I do. Supporting them in their decisions. I'm not going to dictate them yes or no. I think it's allowed our program to be effective. Especially promoting and supporting the field, particularly the new supervisor and getting the word out and helping them communicate with the farmers, it has helped them to be successful as well.

20. If we have additional questions, may we follow-up? If so, please provide your name and contact information.

Yes.

21. Are there others involved in the planning, design, construction, and maintenance of snow fences within your state that you might recommend that we speak with? If so, please provide their name and contact information.

Myself and one other person on the design side consist of the winter operations team. We kind of divide things up. I take care of snow fence, snow fence agreement. My colleague handles the weather, with a master's in meteorology. AVL data, she manages the data and dashboards behind the scene.

This is a program that you need to make sure that you have management buy-in. In his case, there were a few people in management positions that were questioning the expenses. Guy management buy-in and keeping them in the loop is critical.

When we do our pre-winter brief to management, telling them information that's new, this is part of what we brief. The last couple of years, we've been grilled on the amount of money spent on the program. Are we getting the bang for the buck. It's it cost/benefit. I've used NCHRP research and some of the data that Minnesota had put together recently.

Interview 2: July 3, 2024

ADDRESSING BLOWING SNOW STRATEGIES

1. Does your agency employ other blowing snow mitigation measures besides the implementation of snow fences and grading?

Yes. Snow fences, it depends on how you describe them. We have a number of snow fences that aren't structural. Standing bale. Standing corn. LSF. We're strategic with our mowing to keep snow from drifting across. Depending on your definition, yes or no. Standing bale and standing corn may be the most unusual.

Grading. I'm glad that you've mentioned. We've had to do remedial corrections. We try to reshape the right-of-way to make it less blow prone. It works. As long as, when they're doing the grading, they're doing it for the purpose of blowing snow. It doesn't remove it completely in a lot of cases. It could be the difference between a road being passable.

2. Does your agency consider, in the design or redesign of roadway cross-sections, snow storage? If it does, could you refer us to the design standards, or are they site-specific?

I don't think that snow storage has a humongous design consideration outside of an urban area. Most of the right-of-way, they're more thinking about safety and runoff. At highway speeds, they're more looking at, are they going to hit a berm or the backside of a ditch, is the right-of-way too short for an errant car. That's a bigger deal than the snow storage. Normal plowing and the like, we can accommodate a lot of storms within the right-of-way that we have. In blizzards and so forth, our ditches fill up. The road would fill in with a relatively light breeze when the ditches fill up. Snow storage is less of a deal maybe than whether the right-of-way is big enough to accommodate a snow fence on our property. Typically, interstates, major four lanes, have enough right-of-way to put a snow fence. Otherwise, we have to pick up agreements with the landowners. I'm unsure if they have the appetite to buy the right-of-way to accommodate snow storage issues. I don't think that's going to happen.

3. Has your agency made grading improvements specifically to address blowing snow concerns?

Yes. We've done it. I don't really have more to add. Our design folks have become more cognizant about that. We've gone back. There's not that much of a process. It's based on complaints. If there's a road that always has closures. It's not really crashes. The district will be sick of a road closing all of the time. They start asking for money to address it then after.

SNOW FENCES

4. What types of snow fences does your agency use (living, structural, other)? Why?

The one that we have the most mileage of is standing corn. Somewhere in about 50 to 70 miles, annual accumulate length of snow fence of standing corn. The second most common, it's a bit harder to track, are the 4' woven plastic, wood lathe fences, where a garage can get permission to put up. Or they attach it to right-of-way on an interstate our four-way. Less common is the bales, essentially a giant wall. It's a payment to the farmer to do that. After the winter is done, they can move the bales. They just started doing that several years ago. Then there's permanent snow fence, which can be on their right-of-way or a long-term agreement with the farmer. 6' or 8' foot fences. Taller, wood, with plastic mesh. Then we have some permarail fences. It's horse fence. High tensil vinyl-covered fence that has very thick horizontal bars that are held tight by tension. They're really nice because they last a long time. They require concrete footings on the end posts because they're under tension. They don't sag. Install is pretty expensive. Snow traps – managing the mowing practices so that they don't have a bald ditch. They tend to keep a lot of native grasses off the immediate shoulder area where the snow can settle in and stay there. It's not really a fence. It's not going to accumulate a drift. It keeps the snow that lands there. Sometimes farmers leave the stocks standing, that tends to be more informal. It's a snow trap strategy. It gives a surface roughness. It's not an official program. No money is offered. Someone knows someone. Do you mind doing this. It's not an official mitigation strategy. Community connections. If they use that road and it serves the community. If they agree to do the standing stocks, it's their own good will.

5. If your agency uses various types of snow fences, how does your agency decide what type of snow fence to use for each application?

A lot of times, it's the one that we can use. Standing corn is the most common. That's often the only one a farmer agrees to use, if at all. There are other roads that people would love to see a snow fence on, but if a farmer doesn't agree to it, they can't put it on there. We start with the easy idea. A structural snow fence we can't put on the majority of the roads, we'd have to put it on our right-of-way, unless they can get a long-term agreement with the farmer who may not be interested in locking in for 10-30 years. The permanent fences, we can't often put them in. Is the farmer willing to do bales, standing corn, then that's what we'll do. It often comes down to what we're able to do and often times it comes down to, we can't. Corn and bales are great, but they aren't around every year. If it's a bean year, nothing about soy beans is useful for blowing snow. It's an inconsistent practice.

6. If your agency uses living snow fences (LSFs) (*skip this question otherwise*):
    a. Does your agency have a living snow fence coordinator? If so, what are their responsibilities in this role?

No. We do have a number of people who have various parts of it. Our office, Maintenance Bureau, we manage the contracts with the farmer and things like that. If we are going to put in the LSF along the ROW, that's usually managed by the design folks or someone in road design and location environment bureau. A LSF may pop up in a new line in a four lane; we have nothing to do with it.

    b. Who pays for the installation of a living snow fence?

I think they try to include it within the project budget whenever they can. Or a maintenance project. Or a reconstruction project regarding that road.

    c. Who is responsible for replacing trees and shrubs if they die off?

That's a good question. I'm not sure if it passes to the District at that point.

    d. Who is responsible for maintaining the trees and shrubs over time?

That usually falls on the local garage, like grubbing and clearing out the dead stuff. Sometimes we have contracts for people to come in and do it. She's not sure who pays for such efforts. Pushing back something overgrown would be the local maintenance garage's responsibility.

    e. What is your agency's experience with using standing corn rows?

That is our office. My colleague has the responsibility for entering the payments. The local garages are responsible for working with the farmers to see who's available and interested. Getting the documents signed and the approximate value set. They send in the paperwork. Her co-worker will enter the farmer into the system and set them up with payment information (tax document). That initializes the payment for that farmer. It also keeps track of where the fence is, how long it is, and so forth. Our experience using standing corn is long. Standing corn is a very effective snow fence. Like I mentioned earlier, it's not a guarantee from year to year. The land may be sold. The crops rotate. It's not corn every year. If it's not the corn rotation year, you're not going to have a fence there. Using bales in place of corn. Bales are usually corn stocks. They use it as bedding and feed. Farmers are not necessarily going to use all of their bales at once. Instead of storing them by their farm, we ask that they are lined up in the field. They might be willing to put them in the soy bean field, but it has to be convenient enough for them to transport them in and do that. In a cornfield where the bales themselves were harvested, it's a matter of picking them up and arranging them. It's not as much of a transport as compared with arranging and harvesting them. A possibility, but not a cure all.

There's another benefit where someone might choose to do the bales instead of the standing corn. Someone has to get the combine out of storage and fire it up and harvest the corn then in the spring. That's a pain. If they're going to do some fertilizer and tilling, they have a role of standing corn. They have to go around it. It's an annoyance. The bales, for those who are interested in doing something, but don't want to farm around 8 rows of corn, it can be more attractive. They can still do their soil preparation and still line up the bales before the snow comes. It accommodates the farm work that has to happen after the crop is harvested. Standing corn is in their way for spring planting. We have options. There's a lot of farmers that don't bale. If you don't have livestock, there's no reason to do that.

7. How does your agency prioritize where to install snow fences?

We rely on local expertise. It's up to the area to say if a location is a good spot for any kind of snow fence. It's too difficult for us to come up with some formula, based on right-of-way distance, slope. Blowing snow is really tricky to predict where it's going to be an issue. It's usually local experience that tells you it's a problem. We rely on that. Generally, we would like snow fences in a lot more places than what we can get. We're usually limited by what the farmers in the area are willing to do. Usually, we think a snow fence can go here, is the farmer willing? More often: we'd like a snow fence here. Too bad, they're not interested.

8. Do you know the average life expectancy of your agency's snow fences (living, structural, other)?

Our permarails are a 20 or 30 year. Standing corn is just one season. Standing bales, one season. Living snow fences – they use 20 years on those. You also don't get much out of them for the first five, so an operating life of the first 15. As far as structural fences, like the black plastic stuff strapped to a post, we can't get more than a few years out of it before it gets "ratty." They're taken down every year. Re-use the post, re-use the plastic. After a while, the plastic starts to degrade. A black plastic fence is doing good if it gets more than 5 years.

9. How frequently and what type of inspection and maintenance does your agency perform on its snow fences?

The permarails just need to be checked for tightness. The rails are held up by tension. Maybe annually or every other year to see if something is getting floppy.

The higher maintenance fences are likely the living snow fences because those have sometimes, especially, the red dogwoods, yellow dogwoods tend to be more preferred, the red dogwoods, if you don't keep them pushed back, they take over pretty quick. They're usually in there every ten years. A lot of things grow pretty well down here in Iowa, so we choose native species when we do living fences. Species designed to live in Iowa. Keeping up with making sure they don't get too overgrown is a thing. If a couple of rows of plant that has died, I'm not sure who's responsible. They're probably maintaining the living snow fences about every 5 years and major upgrade, about 10-15 years. The more you can mow down instead of chainsaw down. It may turn into we'll deal with it when we have to rather than preventative maintenance. They're a great tool, but not maintenance free.

Temporary man-made fences that go up and down every year. They're touched every year. Does it look too bad to reinstall? If it starts flapping in the wind in the middle of the year, they may or may not be able to get to it. If it's just sagging a bit, it probably won't be touched, sagging a lot they'll address.

10. Have you had any challenges with your existing snow fences (e.g., maintenance needs are too frequent; snow is not being captured as designed; other)?

Yes. Some areas on I-35, the living snow fence got too big. It's starting to cause the drifts and the snow to settle on the road rather than go on past. If you get a big blizzard, it will start to fill up, and the drift can form over the road. A tall fence close to the road, you're playing your odds. Most won't be big enough to result in a drift on the road. In those cases, it may have been better if it wasn't there in the first place. The general rule of thumb is that you have enough space, 35x height of the fence. If you have tall shrubs, that's a big distance. A really tall fence, its potential drift area can be really big. We just hope that we don't get events to cause that much accumulation of snow. Sometimes we lose that gamble.

We have some fences that have fallen over from lack of maintenance.

More infrequently, issues where the standing corn doesn't stand up to the snow load very well. It's falling over and ratty looking. Less common. Can happen if crops haven't been rotated recently.

I don't think we've ever been let down, as in "snow is not being captured as designed," hasn't been an issue.

11. Has your agency conducted a traffic safety evaluation of existing snow fence installations?
    a. Yes; do you have any associated reports/outcomes that you can share? [upload here, insert link here]
    b. No.

No. We have some pictures of what it looks like.

12. Have you documented or considered wildlife migration impacts or habitat benefits as a result of snow fence installations?
    a. Yes; please describe.
    b. No.

There was a program about 20 years ago in partnership with their DNR. They were trying to market living snow fences as a dual-purpose habitat and snow control. Shelter and food for pheasants and other animals attractive for hunting to try to drum up some interest.

There's been some interest in our native species and wildflowers, like butterflies. It's not a big driving force, as we have had our native species.

We get questions if standing corn increases deer hits. We haven't found any significant correlations between road kill and standing corn row fences. Especially on social media, it can flare up, suggesting that they can attract deer. As far as we know, it's not an actual concern.

13. How do you fund snow fence materials and installation?

Our standing bale/standing corn/ is managed out of our maintenance bureau, operating funds. I think that a lot of our living snow fences are project related.

As far as materials for temporary fences and things like that, that might be put up by the garage facility, it's a district garage expense. It's all over the place depending on the type of snow fence.

14. How do you fund snow fence inspection and maintenance?

Most of the inspection and maintenance is district-level/garage-level time. They're doing most of the leg work regarding finding the landowners. All of the time that they spend doing that is basically taken up by their garage/district pay.

15. If you put snow fences on private land adjacent to the road, how long are your contracts with landowners (e.g., 1 year, 3 years, 10 years, 15 years, handshake agreement)?
    a. Do you have any best practices regarding engaging with private land owners?

Permanent snow fences, like the wooden fences, permarail fences. At least 5 years. It's a contract with signature. It's not just a handshake kind of thing. If it's standing corn/standing bales/temporary fence, like the metal fence, that's a one-year. Each year, it's up for renewal.

16. Does your agency have any research reports, benefit/cost analyses or the like on snow fences that you can share?

We have a lot of anecdotal studies of our own. Pictures and stuff like that. We don't have a lot of our own research. There has been a lot of research done by the University of Minnesota, Wisconsin and Illinois, have done extensive studies with their universities as well.

17. Does your agency have a snow fence design, installation, inspection, and/or maintenance team? Please explain.

We have a fair amount; we've also had some research done on the typical snow fence designs. Tweaking the porosity and bottom gap. We have a little bit of that, otherwise our snow fence design. It falls along Tabler stuff, Wyoming DOT.

Our minimum is 8 rows; 12 rows is what they usually do. Older research on standing corn versus various man-made fences. In the end, they're pretty similar. For their practices, it comes down to what they can do, instead of what is the most ideal.

At least what our guidelines are. We can share what we consider our minimums. I'll drag out some of the old reports on some of the research that we've done.

This is done in addition to other duties.

18. Does your agency conduct trainings regarding snow fences? Please explain.

We don't really do trainings, we have guidelines. Where to place them. It's very simple. We don't do any…we had a training video. I can send you a link. It's part of our new operator training. Snow fences. How they work.

It's a snow fence, they're not new. They've been around for centuries. Small changes. We'll keep it simple approach. I've seen it on private driveways; they put it right by the driveway. Have enough distance between the road and the fence. As long as you can adhere to the guidelines that Tabler put forward in his many publications, you'll be good.

Cliff notes: bottom gap. 50% porosity. 35x height. If you play with the bottom gap and the porosity, you'll get different profiles and extend or shrink the 35x.

LESSONS LEARNED/FOLLOW-UP

19. Can you provide any lessons learned and or best practices with regard to use of snow fences or other blowing snow mitigation strategies by your agency?

I would say, yes, we do. You can tweak designs a little bit. There's an ability to do that. I would say in the past, I think pines or conifer species were thought of as, they have dense foliage all year round, their branches are close to the ground. A lot of the conifer species don't thrive real naturally in Iowa. They tended to die. If you drove through Iowa. They're deciduous shrub type species. There's nothing wrong with conifers, but they're out of place here. Using plants native to our land. A snow fence is not going to babied. It's not going to be taken care of. It's going to be abused out there. Pick a species that can do it just fine without human intervention. Something that's hardy. Something that's not nearly as aggressive. Is my problem that these would die or take over. A species that's very aggressive, like the red twig dogwoods, they've taken over the ditch. They'll interfere with the drifts that they're intended to help form. Around here, honeysuckle is invasive. It was very popular for wind breaks. They have taken over. A county and state park. They ask you to clean off your shoes so you don't track their seeds. They're a nuisance and a danger to the rest of the habitat. We may have a bunch of honeysuckle in our older stands. Talk with your plant person. Roadside vegetation guru. Don't pick something that's a menace, but it has to be healthy. Holes in a living snow fence. A different growth cycle. You definitely want something that lives.

Agricultural stuff. Working with farmers. Making sure they understand it's a benefit. It's not all about the money. We try to sweeten the pot a little bit. Farmers have their own priorities and their own time constraints in the fall. Sometimes, they're not willing to deal with it. If it's about just making the money, it's not worth it. If it's about helping the community, you may get more interest. That's a local thing we found. Some supervisors tend to find better interest than others. Some areas they have better luck. If it's the approach or farmer friends, she's not really sure. We leave it up to them to do the outreach and ultimately get the contract signed. Your supervisor has to have some time invested in it too. If they don't invest in outreach, it's not going to happen.

20. If we have additional questions, may we follow-up? If so, please provide your name and contact information.

Yes, that would be fine.

21. Are there others involved in the planning, design, construction, and maintenance of snow fences within your state that you might recommend that we speak with? If so, please provide their name and contact information.

I don't think so. I'm not sure who the plant person would be.

If South Dakota wants to talk to a supervisor, just let us know, we'll hook them up with someone in northwest Iowa that can give them their advice, some of their experience.

A supervisor talking to another supervisor, putting it in that context. Figure out how it's done

Resources Shared:

https://www.youtube.com/watch?v=bDIEnOZV1FY

https://publications.iowa.gov/33824/1/TR-760_Final%20Report_Reducing%20Uncertainties%20in%20Snow%20Fence%20Design.pdf

https://files01.core.ac.uk/download/pdf/11347911.pdf

https://rosap.ntl.bts.gov/view/dot/66876/dot_66876_DS1.pdf

https://iowadot.gov/maintenance/winter-operations/snow-fence

Minnesota Department of Transportation (MnDOT)

Interview: July 18, 2024

ADDRESSING BLOWING SNOW STRATEGIES

1. Does your agency employ other blowing snow mitigation measures besides the implementation of snow fences and grading?

When we look at blowing snow control measures. We use structural, flexible rail composite type system. Living snow fence, shrubs, wind break, shelter belt. It can take different shapes and forms. The other types of treatments, standing corn rows. We may even put up the seasonal snow fencing, 4' in height. We put it up in the fall and take it down in the spring. 5 tons or less. That's where the temporary work.

West, 15 tons, a 4' is not tall enough. To contain that amount of snow. We do have areas where the 4' fence will work just fine. The designers will assist with assessing how many tons per linear snow.

Wind rowing snow. They take a motor grader, dozers, big plows, they wind row snow in the farm fields to create trip points. They have to go back in and clean those up to reclaim them. Wind rowing snow happens quite frequently.

The winter that you referred to a few years ago, wind rowing of snow is quite frequently.

We also stack bales.

Granite Falls, Minnesota – they use round bales.

2. Does your agency consider, in the design or redesign of roadway cross-sections, snow storage? If it does, could you refer us to the design standards, or are they site-specific?

We do. Our designers will look at the cross sections, ditch width. Ditch depth. We used to have a tool that we would use. A Wyoming prediction tool. Geopak. We lost that tool as we migrated into Open Roads Designer. We are looking to see if we can get a new version that would be compatible with Open Roads Designer. Geopak, a Microstation Tool, which was in existence for 20 years or more.

We have a facility design guide. It will be found in the iHub page. Facility Design Guide is a useful tool for looking at storage. To design for drift-free roads. In looking at our design standard, we utilize a tool that was birthed out of previous research projects with the University of Minnesota looking at our Winter Climate Database. Based on lat./long., estimate of how much snow, relocation coefficient, so we know how prone it is to be blown by wind, the snow/water equipment. End shelter fetch distance that's reaching the road and it self-reports how much tons per linear foot. The attack angle of how it's striking the road. 90 degree is the worst-case scenario. Prevailing wind direction.

In terms of consistency, there are more wind events. We need to have wind speeds of about 13 mph to start to move the snow. We're starting to see that we're having more wind events greater than 15 mph out there. So, there's more of a need for snow fencing. Snow fencing is a powerful event for managing the wind.

Our prevailing winds tend to be more out of the North/Northwest.

Winds coming out of the South/Southwest/Southeast, which can be problematic. You typically won't have big snow drifts from that.

With RWIS, there is now a lot of wind data being collected. That didn't exist when doing the initial research. That could really add and validate when it's occurring.

3. Has your agency made grading improvements specifically to address blowing snow concerns?

We have. When there's grading on a road project, it's got to be scoped in the scope of work. We raise the profile of the road, widen the ditches, steepen the backslope to try to reduce the back slope. They work to prevent the snow drift. We still have problems with blow ice. Sunny day, usually in late winter/early spring, the winds are blowing the snow across during a sunny day. It melts and freezes the snow on the roadway. Grading is not effective. Snow fence is effective against blow ice.

SNOW FENCES

4. What types of snow fences does your agency use (living, structural, other)? Why?

As we look at the type of snow fence that we're deploying, we have about 132 miles of highway that are being protected by long-term snow fence practices. Long-term snow fence practices, roots in the ground or a flexible composite rail snow fence. Sleeves driven into the ground, 6' to 12' feet. It's not something that you're going to pick up and move. 132 miles of those long-term. 96 miles in the living snow fence. 36 miles in the structural snow fence category. Standing corn rows, putting up seasonal snow fencing, about 45 miles of those each year.

Snow berm. The grading with the berm. Along with the ditch. We grade the berm to make it longer, wider. Like a ridge.

Temporary ones can change from year to year. Corn/soy bean crop rotation. We might have a year without the benefit of the standing corn rows. We work with them to leave standing corn rows. Maybe in about two/three years down the road, they may want to do something long-term, like a structural or living snow fence. It's a gateway to a longer-term fix. It's a cooperation. It's a prove-it type concept.

5. If your agency uses various types of snow fences, how does your agency decide what type of snow fence to use for each application?

The color of the money or type of funding. The other thing is, working with our design team, as they're looking for designing and looking at things that are, are there constraints for utilizes, overhead power lines. Flexible composite rail system. They also look at soils. Is the soil too wet? Too droughty to support the survival of an LSF. We're also, in our analytical work, where are the deer collisions happening? It could also drive the style of fencing to deter deer collisions with our transportation system. We're just starting to look at that. GIS, we're able to see it spatially. It could become a valuable tool for us. Tile lines. Agricultural tile lines that are draining the farm fields. A living snow fence could plug up the tile lines and interrupt that drainage. Non-perforated tile to not let roots grow into it. Or use a structural snow fence. 6 to 12 feet into the ground, need to make sure that we don't puncture.

There's also the element of what the landowner is interested in. They may be more interested in wildlife and song birds that's more soft living. That's the LSF. There could be that level of interest. The landscape, the context, and the ultimate objectives for MnDOT and the adjacent landowners.

6. If your agency uses living snow fences (LSFs) (*skip this question otherwise*):
    a. Does your agency have a living snow fence coordinator? If so, what are their responsibilities in this role?

I used to be the living snow fence coordinator for the department. In 2016, we started the process of elevating the blowing fence control, from LSF to all tools out there. Working with maintenance as well as program delivery. In 2019, our shared service was birthed. The beauty of our shared service, not every district has the expertise of estimating the number of tons that are hitting the roadway. Designers that are regionally based can work with the districts and can become part of the community and get more effective at getting projects designed and built and having better contact with our partners.

Having someone regionally located, creating a team that has a team lead. Neighbors like to talk with neighbors. People who understand the area are more likely to have a conversation about the needs of the agency rather than someone coming from central office. I think that's the biggest piece, someone part of the community that's the spokesperson of the agency.

    b. Who pays for the installation of a living snow fence?

Looking at the cost of doing snow fence. We use federal funds, transportation dollars, like a PROTECT Grant, a road safety project that can be used for snow fencing. Federal Funds. Federal funds, not in the form of transportation dollars, USDA through the Farmer Bill, Farm Service Agency, both federal agencies. When we partner with those types of federal funds, we have to use state dollars.

A lion share of what we've done in the past has been state funded, Trunk Highway Fund. State dollars allocated towards that. The standing corn row program, it's been funded out of the districts, snow, and ice. The same fund that buys salt and chemicals.

We have partnering opportunities, like Soil & Water Conservation Districts (SWCD). Soil and Water.

It's variable based on how the districts respond. The districts have provided us with funding from their budgets. Blowing snow control of all different types. Funding from grants. Appropriated by the legislature for LSF.

$200,000 from the Environmental and Natural Resources Trust Fund, which is funded by the Minnesota State Lottery. The Loon Symbol. We didn't solicit the appropriation. They wanted to see us jump-start the program. We have done two demonstration projects along I-90 near Austin, Minnesota. It's using native plant material to the area. We're trying to reduce chlorides. If we can reduce the amount of wind-blown snow on the roadway. It improves water quality. It will have benefits for song birds, pollinators and others. We're helping to reduce chlorides.

The other funding source from the legislature, a project we're installing this fall. $1.5 million. LSF using plant material that are adaptable to climate change. We're using a diverse set of plant species. If we happen to get wetter or dryer to ensure success. Diversity in plant pallet, a single disease doesn't wipe things out. Dutch elm disease. Emerald ash borer. Diversity in our pallets.

HSIP funds are road safety.

c. Who is responsible for replacing trees and shrubs if they die off?

If you want to make sure that they get replaced, MnDOT has to lead the way. Working with the landowner, we can provide cost-shared to cost the initial cost of the plant material. They may help with some of the watering, care, and upkeep. We're finding that a lot of the landowners are getting up in age and may not have the physical capabilities of watering and maintaining a project a quarter mile long. You're talking hundreds and hundreds of plants. They may not have time even if they have the physical capability. They're working on crops to ensure that they have an income.

d. Who is responsible for maintaining the trees and shrubs over time?

We're starting a campaign: Good Fences Make Good Neighbors. We having living snow fences, going back with shrubs in there and rejuvenating. Compass pruning. Mowing them to the grown in the dormant season. All new wood, you have an established root system. You can get 4-6' of growth after compass pruning. We've made an investment in a piece of equipment, a mower device with really sharp blades to mow them down. We're going to clean up sites to bring plants back that have dead wood.

e. What is your agency's experience with using standing corn rows?

There could be the headlands. It's easier for a farmer to have the headlands to be parallel to the highway. If they don't have the headlands parallel to the highway, they have to combine across the grain. It's not as clean as a picking operation for a combine. It's a little messy.

We worked with the University of Minnesota Extension, to line up 4H, the volleyball team, the football team. The farmer would donate it as a local fundraiser. The fact of the matter is that it doesn't happen that often. It's very, very labor intensive. It's really not happening anymore. It's a novel idea. The hand operation is difficult.

7. How does your agency prioritize where to install snow fences?

I think we're still trying to figure it out. First and foremost, scoping a future road project, a roundabout project, in an area that's wind swept, unsheltered fetch distance greater than a quarter mile, those are sites to be looked at. Scoping.

We're also developing, with Iqra's help, developing a **vulnerability index**. Where are we most prone to snow traps. Which ones rank higher in terms of severity and frequency of wind events. Higher crashes. Vehicles going off road.

Daily traffic count. Use of chloride along that route. Higher maintenance costs. It's a tool that we've been working on over the past year, and we're starting to see some pattern. We're starting to see some transportation corridors. Not just removing one or two areas along the plow route. Did we make a difference? We're going to start to see miles of corridor.

Trent can be part of a design team expanding from 2-lane to 4-lane. We incorporated several miles of structural snow fence along with grading. It doesn't happen that often any more. Where are the problems due to blowing snow? Our current inventory of snow traps are in the neighborhood of 5,000 snow traps. The length of the snow traps are about 2,581 miles. Some are going to be more cost-effective to plow our way out. As we look at the vulnerability index, we can whittle down, based on the index. Where is the corridor that's going to give us the best return on the investment.

Mid America Association of State Transportation Officials (MAASTO) Conference. Hearing python and analytics. Safer pedestrian crossing. We have to first have a snow trap identified by maintenance. Additional maintenance beyond routine snow plowing. More call-outs by state patrol. Maintenance identifies these locations and Iqra looks at all of the data tied to the corridor. These are the type of things not dictated by an individual. It's a 5-year average. It's a tool to help to see where the corridor is.

More of a written type of process. I would point to the PPTs right now as our best communication.

8. Do you know the average life expectancy of your agency's snow fences (living, structural, other)?

Structural, flexible composite rail. First one went in 2001. It does not have galvanized sleeves in the ground. Every post is embedded in concrete. We need to look at doing restoration work after 20 years. Now we're doing galvanization and improvements in the design, he thinks they'll get 30 years.

LSF, if you include the rejuvenation pruning, 50-100 years. If you miss that time, and let it go too long, we might have missed the chance to salvage.

We're shooting for 30 years.

9. How frequently and what type of inspection and maintenance does your agency perform on its snow fences?

It's evolving. Good Fences Make Good Neighbors campaign. Those installed 20 years ago or more, we're re-looking at snow fences.

Transportation Asset Management System, Agile Assets, we are going to start tracking all of these assets. All of our snow fence assets, living, structural, grading. Where have they occurred on the landscape. Work orders to conduct maintenance and inspections. We need to inspect more frequently. A lot were put I the ground and haven't been looked at since they were first to put in them. It's a valuable tool for them to track. We'll be able to run reports to say whether or not they were inspected. This is what was spent to care for them. That system is getting built right now. It will be a valuable tool to help maintain and care for the assets.

10. Have you had any challenges with your existing snow fences (e.g., maintenance needs are too frequent; snow is not being captured as designed; other)?

Landowner, finding an agreeable landowner. Allow us to put our fence on their property. We start conversation with the maintenance folks in that area that either know people or relatives know people. To get the ball rolling. Rather than some guy behind the desk, from St. Paul. That won't work. Getting foot in the door.

Based on the University of Minnesota researchers, early adopters, their comment was, we need to have someone sit down with us and help us understand what it would look like on the farm or their land. You can start to break down those barriers. It's not every day that they work with the DOT and snow fencing. Why does it need to be so far back? Why does it need to be so tall? It also helps in establishing construction limits to start the compensation right-of-way process. Knowing what that acreage is.

The local MnDOT. The guy plowing the road. The kids are going to school as the same place as the farmer's kids.

Getting the communication out there. We want them to be able to get between the fence. We want to ensure that they can farm around it. We try to work with them. If the land isn't squared off, and it's hard to farm. Sometimes it's good, we square the field off for them. It can be more productive to farm.

District people are a familiar face. It takes a lot of people to get farmers or landowners to buy-in.

We're not asking them to do it for nothing. We do compensate them. We compensate them either in the form of a lump sum payment of buying an easement or we lease the snow fence for the winter (e.g., standing corn rows) or a long-term lease for LSF or structural. You need to compensate the landowners.

We're not just putting fences up, we're solving problems. Safety and mobility problem on the highway. Start by talking about the problem, the reason why we're here. Have the data. How many crashes have been occurring due to snow and ice. How much are we spending on labor and materials. We spend over $100 million annual on snow and ice in Minnesota. That's to reactively manage the snow. Blowing snow control can enable preventing the wind from being a problem. We can manage the wind.

And reducing emissions by reducing trips.

CRP. A landowner can get a payment from CRP and from the state. He's making more money than trying to farm. Conservation Reserve Program (CRP).

There's a CP17A Living Snow Fence practice administered by the USDA. It's a federal program that could be eligible. First you have to have land that's in the land program. Pastureland is not eligible. You have to have a cropping history that's eligible.

11. Has your agency conducted a traffic safety evaluation of existing snow fence installations?
    a. Yes; do you have any associated reports/outcomes that you can share? [upload here, insert link here]
    b. No.
12. Have you documented or considered wildlife migration impacts or habitat benefits as a result of snow fence installations?
    a. Yes; please describe.
    b. No.

When we look at Minnesota, we don't have grizzly bears that need animal bridge corridors. We don't have migratory pathways that you might see in western states. White tailed deer. Song birds. White tailed deer don't have a strong migratory pathway. They may have areas where they winter up. It's hit or miss. Some of our deer/vehicle collisions are happening in the Metro area. There's a lot of deer in heavily populated areas.

In the western states, you'll have strong corridors that they'll follow. We don't have those here.

13. How do you fund snow fence materials and installation?
14. How do you fund snow fence inspection and maintenance?

About $500,000 a year, for the design team to be working with districts.

Maintenance and inspection is happening to a certain degree. Contracts, less than $250,000, specialized work or work not able to get done. Volunteer trees that are quite large. To cut them down, we might hire a commercial arborist firm to drop the trees. Volunteer trees can be detrimental to the success of our LSF and structural, if they're not in the correct place.

15. If you put snow fences on private land adjacent to the road, how long are your contracts with landowners (e.g., 1 year, 3 years, 10 years, 15 years, handshake agreement)?
    a. Do you have any best practices regarding engaging with private land owners?
16. Does your agency have any research reports, benefit/cost analyses or the like on snow fences that you can share?

It was a tool that was really intended to help us understand to help us understand if it is helpful to spend $100/linear foot to do a snow fence. Over 30 years, what that's going to cost, that can pay for itself three times over in a 30 year life. The paradigm, we can afford to make this investment, it's a good investment. Do we run the tool on every project that we do? We don't.

Vulnerability index. That might be a much faster tool to see which sites rise to the top. It's labor intensive. It's a bit arbitrary and judgmental. How often were you out there with the dozer and so forth? If we search for perfection, we're not going to make any progress. We can use if we question a specific site.

17. Does your agency have a snow fence design, installation, inspection, and/or maintenance team? Please explain.
18. Does your agency conduct trainings regarding snow fences? Please explain.

We have done training. Before we formed our shared service. We did training with district staff. We as project managers/designers in the district. We're not going to do this enough to be proficient. That led to the formation of shared service. Hire regional designers. This is what they do 40 hours a week. They communicate with the district staff. As a result of having the shared service, we haven't been doing intensive training. We have trained consultants. We may have a pre-approved list of contractors, engineering firms we can call upon.

LESSONS LEARNED/FOLLOW-UP

19. Can you provide any lessons learned and or best practices with regard to use of snow fences or other blowing snow mitigation strategies by your agency?

I'd like to put a plug in for, does SDDOT use Open Roads? We need to not only get this in the maintenance community but also in the design community. If they're using Open Roads Designer. Are they interested in seeing a collaborative push to get that software so it can predict the snow drift? It can be a powerful tool in their design community. Predict and address current problems. Right now, that software doesn't exist. We're seeing if we can get it built in as an application. Are there other snow belt states that may be interested?

Clear Roads is more focused on maintenance as compared with design. Get into the design community.

20. If we have additional questions, may we follow-up? If so, please provide your name and contact information.

21. Are there others involved in the planning, design, construction, and maintenance of snow fences within your state that you might recommend that we speak with? If so, please provide their name and contact information.

Montana Department of Transportation (MDT)

Interview #1: July 15, 2024

ADDRESSING BLOWING SNOW STRATEGIES

1. Does your agency employ other blowing snow mitigation measures besides the implementation of snow fences and grading?

Guardrail selection. Box beam rail or cable rail for blowing snow concerns.

Snow capture, snow traps. As needed, typically during a bigger winter. Parallel snow traps for the highway.

2. Does your agency consider, in the design or redesign of roadway cross-sections, snow storage? If it does, could you refer us to the design standards, or are they site-specific?

Yes. Site-specific. For a while we had adopted snow slopes, from 11:1, it was a huge amount of grading. We were doing our backslopes on private property. We've abandoned that process. In areas with snow drifting issues, predominately western slope, northern sides of the roadway, in some locations, we extended the ditch section and steepen up the backslope to provide more area for storage.

To the extent that we're changing the road profile. If we're reconstructing them, roads that are 100 years old, they were side borrow jobs. We introduce deeper cuts or more cuts, having a conversation with maintenance earlier in design.

We look for intermediate cut heights – 15 or 20 feet. A trap, snow fence or wider ditches. When it gets much deeper than that, you have a canyon effect.

Excavating materials and not paying royalties. We weren't compensating landowners. For a deep cut, at an 11:1, it can be pretty extensive. Projects with snow slopes, only for about 4 or 5 years. It's been 15 years since we've done it.

3. Has your agency made grading improvements specifically to address blowing snow concerns?

See above.

SNOW FENCES

4. What types of snow fences does your agency use (living, structural, other)? Why?

In most cases structural. I think we have, for the leaning slope fences.

8 and 12 are the most typical.

We have some snow fence installed with vertical post and guardrail section space. We've used just the fabric, but most often just used by maintenance.

Old concrete guardrail posts. We've salvaged to maintenance, built snow fence out of it.

Living snow fence – I know of one location. I'm not sure when it was installed or how effective it is.

Montana 200 – Circle and Glendive. Not much in the state.

5. If your agency uses various types of snow fences, how does your agency decide what type of snow fence to use for each application?

Our standard is usually the 8 or 12 foot, Wyoming. We've used concrete guardrail posts.

The height, that's a factor of how far off the roadway we can place it. Our placement and orientation to get easement.

Both on interstates and rural roadways.

A bunch by Livingston, a historically windy area next to the interstate. We have it along primary highways, snow fences.

One stretch, what's remaining or now is fairly new. When we constructed it in the 40's, we had a mile of snow fence on the west side and on the east side. We've been using snow fence historically for a long time.

For secondary highways, we typically don't have them on those highways.

We have some out on Whitetail by the Canadian corridor. It was on private property. It has since been removed. It may not have been us putting it up.

That could be the trigger, if it was our maintenance.

It's case-by-case with maintenance.

6. If your agency uses living snow fences (LSFs) (*skip this question otherwise*):
    a. Does your agency have a living snow fence coordinator? If so, what are their responsibilities in this role?
    b. Who pays for the installation of a living snow fence?
    c. Who is responsible for replacing trees and shrubs if they die off?
    d. Who is responsible for maintaining the trees and shrubs over time?
    e. What is your agency's experience with using standing corn rows?

It's not standard practice. It doesn't work particularly well.

We don't have any maintenance associated with it. Some scrubby little trees.

We haven't seen a lot of success with a living snow fence. We don't want to do the same thing that doesn't work so well. When maintenance is at a preliminary field review, they request a structural snow fence ahead of time.

7. How does your agency prioritize where to install snow fences?

Maintenance usually identifies them.

Case-by-case.

8. Do you know the average life expectancy of your agency's snow fences (living, structural, other)?

Indefinitely. We've set-up contracts, where people come and harvest the boards. They'll maintain the fences for us. We don't maintain very many of them. They last a good long time. As elements fail, we replace them.

We had one installation of a composite material, by Livingston, it's been around for 20 years now. I'm not sure if it'll last any longer.

9. How frequently and what type of inspection and maintenance does your agency perform on its snow fences?

As needed. Our guys will drive the road daily. If they see something going on, they'll replace it. No maintenance or inspection schedule.

10. Have you had any challenges with your existing snow fences (e.g., maintenance needs are too frequent; snow is not being captured as designed; other)?

We had a few constructability issues; the contractor fixed it. The Jack Leg, concrete fences that we put in, there's no maintenance to them. No real constructability issues.

11. Has your agency conducted a traffic safety evaluation of existing snow fence installations?
    a. Yes; do you have any associated reports/outcomes that you can share? [upload here, insert link here]
    b. No.

Not that I'm aware of.

We did one safety project on Montana 7, north eagle….

Slope flattening.

That was the only safety project intended to address snow drifting. In the area of doing snow slopes.

12. Have you documented or considered wildlife migration impacts or habitat benefits as a result of snow fence installations?
    a. Yes; please describe.
    b. No.

No. He checked with environmental.

They're usually staggered. There's no blockage at all. Animals can get around them pretty easily. Unless they're bulls.

13. How do you fund snow fence materials and installation?

Normal budget. We don't have a budget for snow fence. We don't even have a winter budget. They'll fund it, each individual area out of their original budget.

Most of the roadway improvement projects are federal aid projects. So, they'll be funded through the federal aid projects. I don't know if we have any stand-alone. They come from a regular highway maintenance through design.

14. How do you fund snow fence inspection and maintenance?

The whole scope was the installation of snow fence. I don't recall if those were federal aid.

I think they were.

Through our normal budget operation.

State maintenance budget.

15. If you put snow fences on private land adjacent to the road, how long are your contracts with landowners (e.g., 1 year, 3 years, 10 years, 15 years, handshake agreement)?
    a. Do you have any best practices regarding engaging with private land owners?

Contracts in perpetuity. Ether party can cancel the agreement for basically any reason. They have to give 30 days. Farmers and ranchers, they like the snow fences because it puts more water in the fields and it's not taking up the land. I haven't had an issue of where we're putting them where we want to.

Stand-alone snow fence project, we did buy easements.

Our state law dictates in to perpetuity to be 99 years.

Dry land farmers would like it.

Cultivated or irrigated, not so much.

16. Does your agency have any research reports, benefit/cost analyses or the like on snow fences that you can share?

Something we didn't publish. Wyoming did the study.

We borrow most of our stuff from Wyoming. They're pretty much the snow drifting gurus.

17. Does your agency have a snow fence design, installation, inspection, and/or maintenance team? Please explain.

It's handled in construction through the normal EPMs.

Every team should involve maintenance.

In terms of grading, the one thing where we do have drifting potential that's outside the highway, when we're reconstructing the roadway, we make sure that we're not creating an issue that did not exist. They're often shallow cuts.

18. Does your agency conduct trainings regarding snow fences? Please explain.

We don't conduct trainings.

Even for design, Transportation Learning Network (TLN) offered training in 2017.

LESSONS LEARNED/FOLLOW-UP

19. Can you provide any lessons learned and or best practices with regard to use of snow fences or other blowing snow mitigation strategies by your agency?

Not anything beyond what we talked about already. Snow slopes weren't a great fit. It was such an impact from right-of-way and grading. The cost of the grading and the ROW impacts. Landowners were never excited about it.

20. If we have additional questions, may we follow-up? If so, please provide your name and contact information.

Sure.

21. Are there others involved in the planning, design, construction, and maintenance of snow fences within your state that you might recommend that we speak with? If so, please provide their name and contact information.

One thing that he mentioned is, when you provide living snow fences, upland habitat for game. They're not that great from a maintenance perspective. They don't seem to address the drifting as well as the wooden snow fence.

Wyoming is the greatest resource for snow drifting mitigation. We borrow a lot from them.

Interview #2: July 24, 2024

In his 30-year tenure, they did not put in any snow fences. MSU Co-Op, out of Bozeman. Circle and One Dive. That was an MSU-Extension Project.

He had attempted a living snow fence effort, for funding and maintenance; it was torpedoed.

His friend said they're very labor intensive for the first 3-5 years. If a dry environment, you're maintaining them with water with a static drift line. Established and self-sustaining then after.

From personal experience, having driven I-94, they have a number of shelter belts. You might refer to them as living snow fences. They may not utilize them or not. They have a terrible drifting problem at their underpasses and overpasses on I-94.

Height and set-back from roadways, man-made or LSF, they're very important components.

One of the things that he's heard of most recently, a zipper fence, a zig zag of logs. You stack them so there is some spacing between them. If you get them up to that 8 foot height, and the angles are correct. A zipper fence constructed with severe angles doesn't work very well. They need to have a flatter surface, so the wind brushes up against it and deposits its snow load. They're a developing alternative to an engineering fenced. He's read about it in the literature.

These living snow fences, I don't believe are onerous on the landscape, like a Wyoming snow fence, the wildlife can move through them easily. You have to be cautious about where you put them up. The big game will suck into those areas for shelter if there's limited shelter within the area. I urge caution in their placement. We have mule deer, white tailed deer, that the MSU unit put up. One had a flock of turkeys in it.

If you put in silver buffalo berry, you'll pull in the pheasants and the hunters too. From I-90, Rapid to Sioux Falls. It's not a good condition to have.

We've moving away from the significant right-of-way ask from landowners by not asking for longer slopes. It does allow the drift to develop further away from the road surface.

He's unaware of any new applications. It's fenced to keep the livestock out of it. They'll go in and rough things up and browse it. Ask the MSU Co-Op unit.

Living snow fence have never been hinderances. Wyoming snow fences are hinderances. Keeping reaches short so animals can walk around the ends of them. He hasn't spoken to any wildlife biologists that have suggested that they are blocking pathways. They should put openings in the application so there is some movement in that corridor.

Traffic volumes and fences are biggest impact, woven fences.

A living snow fence had a fence around the outside of it to keep livestock from rubbing the trees/bushes to death.

They shade around the Wyoming snow fence. They need to be good, heavy timbers.

Livestock may come where the grass is growing from the snow that has contributed to its growth.

All of the snow fences are on private land.

It's a very real issue. If the habitat is limited, these things will attract large game. They will move into them. As evidence of this face in northeastern Montana. They have shelter belt/trees built around them. In the winter time, the deer are attracted into them. As a result, we get animal/vehicle collisions in the roadway adjacent to these areas. If there's lots of habitat on the landscape, it's not as much of an issue. West River South Dakota, mule deer, are going to find the islands of shelter and pull into them. East river South Dakota, the Big Sioux, James River Corridor, there's plenty of habitat down this reach, I don't see it as much of a problem. It's a consideration to fully vet.

Shelter belts. If you want to discourage use, alter species that's planted. Silver buffalo berry, juniper berries, those sorts of trees. They're going to attract upland game birds. If that's a goal, then select those species.

Most of what we discussed was engineering. Snow slopes. The concrete tethered together – they're very ineffective. Need taller applications. He hasn't seen the concrete to be overly effective. It took more labor and time to put it up than what it was a solution for it. They're so short, so they needed to put them closer to the roadway. They're going to live forever, since they're concrete, but it's not a long-term solution.

Attempted to fund through maintenance. Maintenance is persnickety about their budget. Time and manpower. These things (LSF) take maintenance and upkeep in 3-5 years to make them effective.

He hasn't seen any research on the existing snow fences in MT. The lessons learned from him to me is the concrete walls. He hasn't seen them to be more than 4-5' tall. Their usage is limited and success is limited.

They would evaluate any new ones going up to make sure that wildlife impacts don't occur once they're up.

The Wyoming snow fences, they've been up for years, and they might replace a board every once and a while. Tearing down, he hasn't seen that. They're pretty sturdy and longevity is pretty good.

He would encourage me to reach out and speak with folks on I-94. Overpasses and interchanges. Those close to I-94. Dickinson Office in Western North Dakota. Bismark and the west. That's where they have the biggest issues. They don't have the drifting problem that western North Dakota has.

Nebraska Department of Transportation

Email #1: Thursday, July 25, 2024

ADDRESSING BLOWING SNOW STRATEGIES

1. Does your agency employ other blowing snow mitigation measures besides the implementation

of snow fences and grading? No

2. Does your agency consider, in the design or redesign of roadway cross-sections, snow storage?

If it does, could you refer us to the design standards, or are they site-specific? Talk with Design

3. Has your agency made grading improvements specifically to address blowing snow concerns?

Yes

SNOW FENCES

4. What types of snow fences does your agency use (living, structural, other)? Why?

Structural/Due to budget and what landowners will allow us to use on their property.

5. If your agency uses various types of snow fences, how does your agency decide what type of

snow fence to use for each application? Lay of the land, history of wind areas, history of closures, consistency of area affected(is this an area that has problems all the time), what is the best fence for the area it is in.

6. If your agency uses living snow fences (LSFs) (*skip this question otherwise*): No

a. Does your agency have a living snow fence coordinator? If so, what are them responsibilities in this role?

b. Who pays for the installation of a living snow fence?

c. Who is responsible for replacing trees and shrubs if they die off?

d. Who is responsible for maintaining the trees and shrubs over time?

e. What is your agency's experience with using standing corn rows?

7. How does your agency prioritize where to install snow fences? History of closures, consistency

of problem areas, ease of installation, landowner preference.

8. Do you know the average life expectancy of your agency's snow fences (living, structural,

other)? Structural – 7-10 yrs./ 4' roll fence. Unlimited with the 12' guardrail fence.

9. How frequently and what type of inspection and maintenance does your agency perform on its

snow fences? Yearly inspection and repair or replacement. D5 has very little fence that remains

up year-round.

10. Have you had any challenges with your existing snow fences (e.g., maintenance needs are too

frequent; snow is not being captured as designed; other)? The 4' fence that we typically use fills

up after 1 or 2 storms and doesn't do the job. The 4' fence requires too much maintenance.

Fence needs to be removed before winter is over. Requirements are to install in October and

remove in April, removal is a major problem most years.

11. Has your agency conducted a traffic safety evaluation of existing snow fence installations?

a. Yes; do you have any associated reports/outcomes that you can share? [upload here,

insert link here]

b. No.

12. Have you documented or considered wildlife migration impacts or habitat benefits as a result of

snow fence installations?

a. Yes; please describe.

b. No.

13. How do you fund snow fence materials and installation? Yearly District Maintenance budget

14. How do you fund snow fence inspection and maintenance? District Maintenance budget

15. If you put snow fences on private land adjacent to the road, how long are your contracts with

landowners (e.g., 1 year, 3 years, 10 years, 15 years, handshake agreement)? Unwritten

agreement in the past. Some has been left up for years in a few areas. Mostly up in October and

down in April. We have one location with 12' guardrail fence that has been there for over 10

years.

a. Do you have any best practices regarding engaging with private landowners? We explain

the benefits and disadvantages of having snow fence on their property. Always tell them

the truth about how the fence works and what they can expect after winter. Let the

landowner know that if we come in and put-up fence and take it down, the damage that

we can do to their property. Explain to them how we will fix their property and how we will

pay them for damages so they can have an educated decision if they want it on their

property or if they would prefer not to have us put up the fence.

16. Does your agency have any research reports, benefit/cost analyses or the like on snow fences

that you can share? No

17. Does your agency have a snow fence design, installation, inspection, and/or maintenance

team? Please explain. District Maintenance crews

18. Does your agency conduct trainings regarding snow fences? Please explain. When we know we

are putting up new fence.

LESSONS LEARNED/FOLLOW-UP

19. Can you provide any lessons learned and or best practices with regard to use of snow fences or

other blowing snow mitigation strategies by your agency? Snow fence needs to be the right type for the situation you are trying to control. There are many different types of snow fence, and everyone works a little different. Know what you need to use for every application. Know where you want the snow to end up, so your footages are correct. Look at your history of areas that require fences to see what type of fence would be the best fit, and if the landowner will agree with having it up year-round. Look at laying back hills for a sweep effect. Give warning to drivers in severe wind areas, such as signs or message boards, to help with rerouting.

20. If we have additional questions, may we follow-up? If so, please provide your name and contact

information.

21. Are there others involved in the planning, design, construction, and maintenance of snow fences within your state that you might recommend that we speak with? If so, please provide their name and contact information.

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5. SNOW CONTROL

Snow drifting may be a problem when the prevailing winds are from the north or west. Snowdrifts on roadways can be minimized by several different methods, including:

- Cross-section modification
- Structural snow fencing, both temporary and permanent
- Living snow fencing

The **District's** input regarding the location of existing snow fences will help to identify locations susceptible to drifting snow. If aerial photos were taken in late fall or early winter they may show the location of existing snow fence. Designers are responsible for contacting the **District Engineer** to see if snow shots are desired for the plan-in-hand inspection. Snow shots are cut stations where the top of the backslope is less than 60 feet from the roadway centerline and the backslope elevation is greater than the centerline elevation.

Allowing a greater ditch area for the accumulation of snow at locations susceptible to drifting can minimize snowdrifts on roadways. Normally snowdrifts on a roadway occur at the ends of cut sections. Ditches may be widened to provide more area for snow accumulation. The backslope, especially at the ends of high cuts, should be laid back from its normal 1:3 slope (See Chapter Six: The Typical Roadway Cross-Section, Section 10.H, of this manual).

Structural snow fencing is often used to reduce snow drifting. Annually, maintenance units will place temporary snow fence along the right-of-way in areas of known snow drifting. Along roadways with limited right-of-way, temporary snow fencing may be placed on private property. Permanent snow fencing panels may be needed where a cut section becomes a fill section. Living snow fencing may also be used to reduce snow drifting. If the right-of-way is sufficient, shrubs and trees can be planted along right-of-way or fence lines. Contact **RDC** for the possibility of using living snow fence at the right-of-way line.

Email #2: Thursday, July 17, 2024

Our Roadway Design Engineer said we modify slope and grade during reconstruction or 3R (Resurfacing, Restoration, and Rehabilitation) projects at the request of districts to address specific blowing snow concerns.

https://dot.nebraska.gov/media/nlgjyme0/m-chapter-10-misc-design-issues.pdf

Page 20 has the information on snow control.

https://dot.nebraska.gov/media/f5ffhjyt/t-chapter-17-3r.pdf

This chapter provides a definition of 3R and the standards and guidelines.

North Dakota Department of Transportation (NDDOT)

Emailed: July 25, 2024

ADDRESSING BLOWING SNOW STRATEGIES

1. Does your agency employ other blowing snow mitigation measures besides the implementation of snow fences and grading? No

2. Does your agency consider, in the design or redesign of roadway cross-sections, snow storage? If it does, could you refer us to the design standards, or are they site-specific? Yes, it is site-specific. We make an effort to provide a distance of 105’ instead of 84’ between centerlines on 4 lane highways for extra snow storage.

3. Has your agency made grading improvements specifically to address blowing snow concerns? In areas identified with blowing snow concerns, we have cut back slopes down.

SNOW FENCES

4. What types of snow fences does your agency use (living, structural, other)? Why? Living fence, structural fence, mechanical windrows, and temporary fence. Living snow fence is dependent on an agreement with the adjacent landowner. If an agreement cannot be met with the landowner, a structural snow fence is placed along the right-of-way. During winters with heavier snowfall, mechanical wind rowing in adjacent landowner fields has been performed. Temporary snow fence using orange safety/snow fence has been

placed along the right-of-way.

5. If your agency uses various types of snow fences, how does your agency decide what type of snow fence to use for each application? Please see question 4.

6. If your agency uses living snow fences (LSFs) (*skip this question otherwise*):

a. Does your agency have a living snow fence coordinator? If so, what are their responsibilities in this role? Currently this role is within the operations team leader. We have a position request for a blowing snow mitigation coordinator. In the past, a temporary position in coordination with the Forest Service has been utilized. The time allotted to it currently is minimal and requires a full time position.

b. Who pays for the installation of a living snow fence? We pay for a living snow fence and provide a 10 year easement to maintain it.

c. Who is responsible for replacing trees and shrubs if they die off? Typically they have not been replaced since they still seem to function properly.

d. Who is responsible for maintaining the trees and shrubs over time? There is a cost share with the landowner for 10 years. It is then left in the possession of the landowner to do as they wish.

e. What is your agency's experience with using standing corn rows? Several years ago, a one-time experiment at a location was done, but no other experience with standing corn rows.

7. How does your agency prioritize where to install snow fences? Due to funding constraints for living snow fence, a prioritized list was created. Rest of the snow fences are on a project by project basis and if a district brings up an area of concern.

8. Do you know the average life expectancy of your agency's snow fences (living, structural, other)? Life expectancy of living snow fences is the life of shrubs and trees that are used. Existing structural snow fences have been up for 30 plus years.

9. How frequently and what type of inspection and maintenance does your agency perform on its snow fences? Structural fences are inspected and tightened in fall before winter. Living snow fences have no inspection and maintenance.

10. Have you had any challenges with your existing snow fences (e.g., maintenance needs are too frequent; snow is not being captured as designed; other)? Challenges have been funding, the snow fences cannot be too close to the roadway and finding willing adjacent landowners. So, challenges are created if we can't come to agreement with landowner. Several landowners have been approached that are unwilling to put up a living snow fence because they do not want to fence the trees to keep cattle out.

11. Has your agency conducted a traffic safety evaluation of existing snow fence installations? No, only use observations with no formal study.

a. Yes; do you have any associated reports/outcomes that you can share? [upload here, insert link here]

b. No.

12. Have you documented or considered wildlife migration impacts or habitat benefits as a result of snow fence installations? Installations are very short (1,000' feet or less), so there is not much impact to wildlife travels.

a. Yes; please describe.

b. No.

13. How do you fund snow fence materials and installation? Very minimal funding is available for snow fences. In the past, hazard mitigation and transportation enhancement funding was used. Now, district and project by project funding is used.

14. How do you fund snow fence inspection and maintenance? A minimal amount is available and it comes from the district operations budget.

15. If you put snow fences on private land adjacent to the road, how long are your contracts with landowners (e.g., 1 year, 3 years, 10 years, 15 years, handshake agreement)? 10

years for living snow fence. The other fences are within the right-of-way.

a. Do you have any best practices regarding engaging with private land owners? Face to face meetings to discuss the issues. Snow drift issues usually impact the landowner as well.

16. Does your agency have any research reports, benefit/cost analyses or the like on snow fences that you can share? No

17. Does your agency have a snow fence design, installation, inspection, and/or maintenance team? Please explain. We have a design for height and fetch distance, plans for fences, and no formal inspection but the snow fences are checked out each fall before winter to see if they are operational.

18. Does your agency conduct trainings regarding snow fences? Please explain. No formal training. New innovations are brought up like MnDOT and their solar snow fence through North Dakota State University (NDSU).

LESSONS LEARNED/FOLLOW-UP

19. Can you provide any lessons learned and or best practices with regard to use of snow fences or other blowing snow mitigation strategies by your agency? Prior use of hazard mitigation funding. Applied for a grant to investigate additional snow mitigation strategies. Everything with our snow fences is observational and it is seen that they are effective and needed. We just need a way to get them in place.

20. If we have additional questions, may we follow-up? If so, please provide your name and contact information.

21. Are there others involved in the planning, design, construction, and maintenance of snow fences within your state that you might recommend that we speak with? If so, please provide their name and contact information. No recommendations at this time.

Wisconsin Department of Transportation (WisDOT)

Interview: July 2, 2024

ADDRESSING BLOWING SNOW STRATEGIES

1. Does your agency employ other blowing snow mitigation measures besides the implementation of snow fences and grading? WisDOT uses temporary fence like wood lathe or mesh plastic, Living Snow Fence, manufactured snow fence (like Perma-Rail), Standing Corn Rows, and grading walls from existing snow in the fields.
2. Does your agency consider, in the design or redesign of roadway cross-sections, snow storage? If it does, could you refer us to the design standards, or are they site-specific? No, that is not a practice WisDOT implements at this time. I would refer to MnDOT for this.
3. Has your agency made grading improvements specifically to address blowing snow concerns? No.

SNOW FENCES

4. What types of snow fences does your agency use (living, structural, other)? Why? WisDOT's first choice is Living Snow Fence where room allows. This is for several reasons: pollinators, carbon capture, water transpiration, aesthetics, and cost. If room does not allow, then we opt for a man made option that can be designed to store up wind.
5. If your agency uses various types of snow fences, how does your agency decide what type of snow fence to use for each application? See above. In addition, funding source. For example, HSIP funds tend to want more immediate results which push for a man made option.
6. If your agency uses living snow fences (LSFs) (*skip this question otherwise*):
    a. Does your agency have a living snow fence coordinator? If so, what are their responsibilities in this role? I'm the statewide drift control program manager. I collect data from the regions and counties where drifting is known to occur. I organize projects with the limited funding I have available. (This is not an annual budget, but derived from fees collected by businesses charged for removing vegetation on our right of way.) I work with regional safety engineers and project development teams when known drifting locations exist inside project limits. I put designs together for them and am the subject matter expert for them.
    b. Who pays for the installation of a living snow fence? My projects are from the funding source mentioned above. If the counties perform the install it comes from their state allotted maintenance budget. If it is project development, then it comes from the improvement budget.
    c. Who is responsible for replacing trees and shrubs if they die off? There is a two year establishment for any plantings installed, this includes two spring replacement plantings during that two year period. If it is from long

established LSF, then a project through the counties or me is planned to address this.

d. Who is responsible for maintaining the trees and shrubs over time? Beyond the two year establishment, no one. Unless we see an issue that needs to be addressed.
e. What is your agency's experience with using standing corn rows? We have a standing corn row program. The few places it is implemented, it yields positive results. It is being overhauled to make it easier to administer and encourage more participation from property owners.

Their system for a long time was based on the bushel rate. What they pay over that rate to try to encourage property owners to leave corn rows up. It's led to problems. It's based on what they signed the document. If they sat and the paperwork and sent it a month later but the signature was a month earlier they would have to go back and find the rate. Per station cost is their new approach. Effective cost to have them put wood lathe/temporary fence up in the fields versus encouraging property owners to put the corn rows. How high of an amount can they pay. It's supposed to be a cost savings. Encourage more participation, about double of now, with even higher bushel rates because they're using the new unit rate. It's a win for WisDOT in participation and overall cost savings. For every 100 feet, $150 is what will be paid. It's easy on the property owners to understand and regional staff. The bushel rates are pretty volatile. Whatever day they sign it, that's the payment rate. Flood of corn on the market, the price drops down. Supply and demand. Events in Ukraine really impacted them; they were a lot higher than normal. It's trending back down again. Simplification. Their production rate varies depending upon where they're in the state. Yield per acre changes where they are in Wisconsin. Property owner being honest about their crop yield. I don't call them out on it, but some seem to be doing "amazing" based on their yields. A flat rate. It's about $11/bushel, on average for them. A huge win for them. It's one flat rate across the state. It's the average cost of installing the fencing. A nice round number that's a clear benefit to them. $10/bushell. It's a flat $150. The state is still benefitting too.

There are only two living snow fences on private property. The only ones on private property are corn rows.

One off property. They had a large pond and a house. The highway was exposed to a pocket. It was narrow right-of-way. They approached the property owner and offered to plant trees on the property. They wanted to put it on their side of the property. It became a visual screen for the property owners, so they didn't have to see the property.

I-39 in "sand country." It's the dead zone of a field. The irrigation system; it's circular. These dead corners. They asked if they could continue the wind break that they had built.

They don't do anything like MnDOT, where there are 15-year leases. It takes a while for it to be established and be effective. You lose 5 of the 15 years. At any point the farmer can come back and say that they're not going to renew the lease. It's hard to justify a massive investment being taken away. There's a potential for overspray when the roundup is being sprayed. A 2-year endeavor is what he'd be interested in. Most of what they do is on state right-of-way. It can become a real issue on a two-lane roadway.

I-43. 57 and 43 split. Permarail…looks like cattle fence. He can see putting that out in the field – minimal impact to the farmer. 1 foot wide. 5 foot buffer on either side. They can farm almost up against it. No overspray. Effective immediately. If the lease was up, you can install it somewhere else.

Doing everything in state right-of-way. Manmade fence. There's never a guarantee regarding living snow fence. With a manmade one, we know how it's going to act. His manmade fences within 18 feet of the traveled way. It will stop all of the snow from reaching the roadway. He just had one put in the last year. He heard that it did amazing, where three major storms came through in one week. It did exactly what it was designed to do.

7. How does your agency prioritize where to install snow fences? The region maintenance coordinators ask property owners along corridors where they know they have blowing/drifting issues. This mainly involves our two-lane highway system. Participation is voluntary.
8. Do you know the average life expectancy of your agency's snow fences (living, structural, other)? Living snow fence, some has been around for well over 30yrs. This is mainly evergreens. Shrub plantings are 20+years. Structural, we have fences installed in 2012 that are still here. From the manufacturer, their fences have been installed out west and have been standing for over 30yrs.

Living snow fences, they install a lot. 25,000 feet a year, on average. They tend to use shrubs. Native shrub species. Depending on how much right-of-way is available is the number of rows that they have. If there's an embankment where there is a benefit from taller evergreens, then they'll use. Evergreens don't really do a lot for the pollinators. Shrubs also grow faster. Things can be where they're performing more immediately. Evergreens, the benefits may not come until 10 years. We also try to match some of the surroundings. If there's a subdivision, we try to mimic what's found in the subdivision. We will also plant the shrubs that will be fast growing. They see the trees similar to their subdivision on their side and the DOT has the shrubs that help address the need for controlling snow more immediately. They take a lot of technique from MnDOT. They take information from New York. They develop their own processes. They have some adaptations for their climate. MnDOT has five zones. They're more where he'd like to be, but they've pushed forward at other aspects for WisDOT.

Living snow fence study that was done in New York. Use that to try to back-calculate what the area is for the fence. The biggest take-away. You have to design it for being mature. While it's growing, it's not going to be as effective or deposit snow where you completely want it to be.

Best practice. They're moving from a retroactive approach to a proactive approach. Guardrails are a problem. Creating steeper slopes where they're using the guardrail. They've created an issue by putting things into place. It can be mitigated by planting shrubs at the base of the embankment. If there's major accidents or a history, that's when he gets phone calls. For safety reasons. Occasionally from a project development side, they'll put it in. As a part of the project, they installed control all the way up to Green Bay.

Regional maintenance/county highway departments. They will point areas out. He asks them twice a year if they're having any problems. Every winter is different. Every year can have different wind patterns. They're the experts in their areas for what's going on with their roadways. He asks them to prioritize. They also work on things that's corridor based. MnDOT, found similar to him, if you address a field that's bad, then the field next to it shows itself the next year. If they tell him the one location is bad, instead of just addressing that, they look more as a corridor. WisDOT has seen the benefit as has MnDOT of creating a consistent corridor so that the conditions are the same. They start marching down the highway in 2 mile clumps to close the entire way off.

One thing he wants to do, he took a corridor of when exactly it was planted. Found the paperwork of when exactly it went in. He has an official start date. He got all of the traffic data. All of the accidents that took place in winter. He also used "winter related." It was back in 2015. He was able to take the 8 years prior and the 12 years after. It showed a 69% reduction in accidents. In 8 years, there was 84% reduction in accidents. Some reports don't show that they're winter related. There will be a description that says a car hits a drift. If they don't check a box that's winter related. A deep dive into winter accidents. Dial into when the storms happen. Trailing days. Dig through the data. It doesn't say winter related, but then you read and it says that it struck a snow drift and went off the highway. Create hot spots. Where the regions have said drifting issues. We have some areas that are hot spots for overturning trucks from wind. Taller shrubs that can slow wind speeds down to prevent trucks from overturning. They know corridors and benefits. They have the cost/benefit tool. They've (MnDOT) put a lot of money into studying that state-wide.

Knowing when the storm happened. The perception of what a drift is by people believe. Heavy winds within an hour of an event. A 3 foot snow drift on a highway is pretty rare.

It would be on a sunny day. Where the accident is reported isn't necessarily where the accident occurred. 300 or 500 feet on a side. If you hit an ice patch when driving down the road, you do some swerving and lose control, you travel some distance before you go off the roadway.

50/50. Using HSIP funds. They tend to prefer the manmade because it's immediate, rather than estimating the improvement in the future. Two-lane highways are the hardest one to address because they have limited right-of-way. He gets an email of why did you stop here, you could have extended it further. They don't want to chase spots. What you did…snow forms in two ways. Off the ground, fluid. On the ground, coastal engineering. You have to think of both at the same time. Fluid, you plug up one spot, it's like a weir, you put that pressure elsewhere. One of our best practices, is to tie into the existing tree line. When you stop, you're not creating a further issue that it can go around.

MnDOT has redone many of their studies. They redid a bunch of studies from Tabler. They got the same results. Willow shrub study. It's what New York did. Maximum storage. Wisconsin winters are not as dry. We can get a lot of the winds, maybe not as strong. Our snow is different. I couldn't put an a-frame and expect to get what they have in Wyoming. You're not going to see that in Wisconsin. They also don't have the same melt-offs. We may get a few big storms and then a few months where it compacts. Storage capacity is never full. They've never seen any exceed a Stage 1 in Wisconsin, but all of our designs are designed as if they're going to get to Stage 7, as if they're full. 8 foot minimum that they go for to protect the bulk of the windshields for people driving. Narrow right-of-way. They're trying to get it close to the fence. It really changes their design. We have 30 feet to work with, what can we get done with in that 30 feet. How does it affect our design? Some of the vegetation plays to their benefit. I know they're talking about putting it perpendicular to the wind. At a slightly different angle, I view it as to our benefit. 2" at the perpendicular, versus the slope. 2.5 to 3" thick. The same for the living snow fence, it makes it that much more dense. Increasing its porosity. It's more likely to deposit internally or upwind of the fence itself. It benefits them in increasing protection. Using the tools from the various studies and apply it to their approach.

So much depends on topography and what's present. The install is the same. The design, approach, and species can be totally different based on-site. MnDOT has 5 different zones. Wisconsin has 4 different zones based on the type of snow in Wisconsin. Avg. 180" a year. At what point do you walk outside and there's 6 feet out your door. North, more two-lane roads, but heavily wooded. You might have a pocket where there's a settlement along the roadway. It's not deep, but they've cut into the existing woods and can result in a massive issue. Fluid-wise, it'll flow down and speed up and grab the snow in the open plot and deposit on the road. It really depends on conditions that they're dealing with.

How they mow along the highway. There has been a big drive to rid of the right-of-way of trees, then it's exposing a highway. They've performed those removals because of grading and because of project removal, and then they have an exposed spot. Utilities come through and remove a bunch of vegetation and then have crashes. Let's protect what we have here, the result of removing it. Is it performing as a living snow fence? If they remove it and then problems are seen, it's too late.

They have a certain thickness of a trunk that they don't want, but then they allow a post. A right-of-way fence. There's no design standard. Western side of the roadways, why not make the right-of-way fence as a drift control fence. Absorb the cost that way.

They got the safety improvement numbers from one of the studies. From that, it was one of the biggest changes in their team being able to incorporate it into the projects. Safety engineers were arguing for that.

As websites have been revamped, links were broken. He's glad that he's saved PDFs of the studies.

9. How frequently and what type of inspection and maintenance does your agency perform on its snow fences? No true inspections, unless addressing an issue. Regional maintenance staff and county staff during surveillance may notice a problem and then we work it into maintenance to address.
10. Have you had any challenges with your existing snow fences (e.g., maintenance needs are too frequent; snow is not being captured as designed; other)? If the manufactured fence is hit, it can be a challenge to get it repaired due to funding and/or availability of parts. LSF can have issues with requested vegetation removals or later planned roadway expansions.
11. Has your agency conducted a traffic safety evaluation of existing snow fence installations?
    a. Yes; do you have any associated reports/outcomes that you can share? [upload here, insert link here] I have one study and a naïve study I performed on an LSF site. These are studies I'm pushing for more of, but limited by funds to get them performed.
    b. No.
12. Have you documented or considered wildlife migration impacts or habitat benefits as a result of snow fence installations?
    a. Yes; please describe. Mainly pollinator habitat. Shade and shelter. By having a variety of species that bloom at different times, an early food source is available for longer periods.
    b. No.
13. How do you fund snow fence materials and installation? Mentioned above.
14. How do you fund snow fence inspection and maintenance? Mentioned above.
15. If you put snow fences on private land adjacent to the road, how long are your contracts with landowners (e.g., 1 year, 3 years, 10 years, 15 years, handshake agreement)? WisDOT does not install on private land.
    a. Do you have any best practices regarding engaging with private land owners?

16. Does your agency have any research reports, benefit/cost analyses or the like on snow fences that you can share? I had one planned and after covid it fell apart and the researchers retired.
17. Does your agency have a snow fence design, installation, inspection, and/or maintenance team? Please explain. Mentioned above.
18. Does your agency conduct trainings regarding snow fences? Please explain. No.

LESSONS LEARNED/FOLLOW-UP

19. Can you provide any lessons learned and or best practices with regard to use of snow fences or other blowing snow mitigation strategies by your agency? I have plenty that could be considered future best practices but am restricted by budget and policy to have implemented. We address where we can, trying to target worse locations first based on feedback from county/region staff.
20. If we have additional questions, may we follow-up? If so, please provide your name and contact information. Yes, you can follow up with me.
21. Are there others involved in the planning, design, construction, and maintenance of snow fences within your state that you might recommend that we speak with? If so, please provide their name and contact information. It's just me.

Wyoming Department of Transportation (WYDOT)

Interview: July 17, 2024

ADDRESSING BLOWING SNOW STRATEGIES

1. Does your agency employ other blowing snow mitigation measures besides the implementation of snow fences and grading?

We've had some pretty bad winters in the last couple of years. SW part of the state. Snow fence is very limited. Due to landowner usage and funding issues, we have been using snow cats to create snow traps in the prairie. Those seem to work pretty well. They would fill in and they could come back out and dig more snow traps.

Anemometer. We have some Vaisala. Scientific instruments on the truck. We'll go out and find out where these problem areas are and collect data. It helps in the design process. The snow traps seem to be the most common.

2. Does your agency consider, in the design or redesign of roadway cross-sections, snow storage? If it does, could you refer us to the design standards, or are they site-specific?

If we can. That's part of the grading. We ask them to make a 3' ditch at the bottom. Go out from 10-20' if we have room. It depends on the ROW. It stores in the flat-bottomed ditch. Project development is trying to balance the earthwork as well. They don't like to create a waste station as well. They listen, but don't necessarily take their advice.

The former thought was to try to make it shallower. Flatter so it would blow on through. He later said to make the back slope steeper, but you needed to be able to store.

That's correct. Part of that is for plow storage. Ditches are storing snow from two separate directions. Plowed off the road and blowing off the prairie. Safety concerns as well. There's so many places where that's not an option.

3. Has your agency made grading improvements specifically to address blowing snow concerns?

We haven't done anything special like that.

On 430? Or did we make the ditches bigger.

We never went out and remeasured. If they did the flat-bottomed ditches, we never measured how the depths are working. Start with 3' dept from the edge of pavement.

SNOW FENCES

4. What types of snow fences does your agency use (living, structural, other)? Why?

We use living snow fence when we can. The woven wire, cribbing fence when storage space is limited. Maintenance personnel put it up. Right-of-way fence that we can own. We can do that without prior permission from landowners. Vertical wood snow fence. It's different than the Wyoming. A couple of sections with the vinyl polymer.

Our living snow fences are trees and shrubs. A lot of places call corn rows living snow fences. Minnesota, for example. When we talk about it, we're talking about trees and shrubs.

Agricultural areas can grow corn for two seasons, but then they plant alfalfa, so we can't establish that practice.

5. If your agency uses various types of snow fences, how does your agency decide what type of snow fence to use for each application?

We go with a structural snow fence first. Wyoming A-frame. If the landowner is going to be picky and not want us in there very often, we can go with the vertical snow fence and don't have to come back as often with maintenance due to the anchor system. If the landowner says absolutely no, they don't want something obtrusive, then they try to convince them of a living snow fence. Trees and bushes. The last resort would be for the maintenance forces to put up 4' lathe. 4' lathe more than likely fills up and then it's not effective. We have snow fence up, why isn't our road protected. When you really should have a 12' fence. We don't double up lathe. Game fence, we don't do that.

We don't do that anymore.

The additional layers fall out and fall out of the webbing.

6. If your agency uses living snow fences (LSFs) (*skip this question otherwise*):
    a. Does your agency have a living snow fence coordinator? If so, what are their responsibilities in this role?
    b. Who pays for the installation of a living snow fence?
    c. Who is responsible for replacing trees and shrubs if they die off?
    d. Who is responsible for maintaining the trees and shrubs over time?
    e. What is your agency's experience with using standing corn rows?

The coordinator is our team. I have been mostly involved. I sit on the selection committee for the living snow fences. At WYDOT, we provide $100,000 to the state forestry division to administer the LSF. They deal with the County conservations districts. They're the ones who put in the plantings. They don't select them. They work with the WYDOT foreman to find out what areas need protection. If the landowner is agreeable to planting trees, then the conservation district gets a contract with them. We provide the design. Length, width, angle and offset. We get maximized snow storage. A lot of times it's usually in 2/10 of a mile distances. It often gets too expensive. We try to spread around the $100000.

$100,000 out of state maintenance funds.

No federal funding.

If enough die or the planting gets burnt out, the conservation district will ask for repair money to put in a new planting or repair or replant new trees. It's a 2 year process to get a process done. The first year is approval, then we get the contract ready, they put up the boundary fence around the planting, break ground on the rows, sit for a year, during that year, they send off to the greenhouse who plants the trees and get them growing, they are 5 gallon bucket trees that are ready to be planted. The second year is when the planting takes place along with a moisture barrier.

4’ cribbing on the upwind side to provide snow storage to water the plants and protect them from the wind. That stays there for 3 years after the planting. That fence can come down and can be potentially used for a new planting. It should save us money on future projects.

Every third rib on the snow fence is removed to keep from having too much snow stored on top of the trees.

In the long run, the landowner is supposed to maintain the trees and shrubs. The landowner donates the land. Usually, our maintenance forces go out and repair the boundary fence.

Don’t they also get a conservation easement?

We try to get it in the court house. They can get out of taxes if they want to. If they sell the property. So, the next person that owns it, doesn’t see the trees as their Christmas trees. In 30 years, they’re big enough so they don’t fit in people’s yards. We have found that they’re not followed through very well.

We know exactly what we have with structural. Living snow fence takes 20 years to get the full benefit. We start receiving some benefit around the 10 year mark.

It can vary. That’s why we use the state forestry division. They know what trees go in in certain locations along with the conservation districts, as they know what trees/bushes grow in their county. In one county, we did grow willows as the foot print was moist all of the time. It would kill a pine tree. We got away from pine trees. We’re heading more towards junipers and cedars. We have a huge bottom gap that can’t be covered by bushes.

Arid conditions, water amounts, altitude. State forest will help make it a successful planting.

The pine trees have evolved to not grow branches on the bottom for 4-5 feet. They’ve modified themselves for predation. They’re growing tall enough that they’re drifting their roads.

WYDOT does not use standing corn rows or any type of agricultural barriers.

We used hay bales?

We thought about it.

It drifted so much behind the bales, the farmer couldn’t get in to plant.

The farmer wants to get in as early as they possibly can. We have snow season until mid-April. He wants to get in at the beginning of April. We have more winter left than when the farmers want to get in. Extra moisture not anticipated by the farmer makes the tractor sink.

7. How does your agency prioritize <u>where</u> to install snow fences?

We usually look at some of the data. The increased cost of drift maintenance, traffic incident data, wind polished ice and visibility issues. Highly trafficked areas. I-80. It's got a pretty good AADT. Mainly we coordinate with our maintenance foreman. They know where we're spending a lot of time. They'll contact the weather maintenance team. We'll get out there and do some studies and get some data on paper to identify why we need a fence there. Anything to slow down the negative effect of the blowing snow.

Also, our districts. The funding for a project would come from the districts. Our construction budget is broken into 5 pieces. 5 districts across the state. $25 million to construct roads and anything else that they're going to be doing. Unfortunately, snow fence is anything else. But it's also low-hanging fruit. If we have a project, if we like to add snow fence, it might be $200,000. When they start looking at other aspects in design. It's going to cost $200,000. They cut the snow fence. Trying to get the funding from the districts is very difficult. WYDOT breaks their budget out so that it's similar. They get to control how it's spent. Districts prioritize where they spend their money. Our winter research doesn't have any money. We've asked, they say no.

8. Do you know the average life expectancy of your agency's snow fences (living, structural, other)?

Structural fences, 40+ years old. It comes down to basic maintenance. Some living snow fences, 25+ years. Some are in pretty good condition. Some need help. We try to schedule horizontal slate with our contractor. They try that every 8-10 years. They do some minor repairs on the structural part of the fence, the anchor system. As far as a definitely life expectancy, it's dependent upon maintenance.

Older structural fences are Swedish fences. They're earlier designed fences.

The anchor system. On a Swedish fence, they may be piles of rock to rebar put in on the cross member. It's also possible because they're a different height that they don't blow over as much. Some of the 12 to 14' high fences don't take the same abuse. But the storage is also less.

They're neglected. No one wants to fix them.

The wind will thin as a result of sand being thrown at them.

The piece of wood had been chewed away by weather and elements. It was still standing.

A contractor has a corner the market in weathered wood. They pay costs for materials and labor. They get the rights to the wood. They take it to their facility and mill it out. They took the wood out through maintenance and try to sell. It wasn't worth the cost to try to do it. Man hours and equipment costs and materials. Still using a contractor, 25-30 years.

We still have problems with not getting boards nailed back on properly. A lot of it is corrected because Duard is following them around doing their job right. Sometimes we lost our bottom gap on these fences.

One thing we've been noticing coming up on the life cycle, they've been refaced. 3 nails per board. 3 or 4 times. It takes a lot of the structural integrity. New boards can be put on 3 times. They eventually need to start replacing the vertical boards that the horizontal boards are attached to. Those verticals are degrading. Within the next 5-10 years, we're going to have to find a different way to award the contract so they replace the vertical board. They also adjust the bottom gap. 21 nails would be going through it at the certain part, so they move it up an inch or 2 inch. In a 12' fence, it messes with the gap.

We hope to have a study on next summer.

We have two different contracts. We divide them up into districts. We try to stay along the corridor I-80. District 1 and 3. Northeastern part of the state. District 2 and 4. District 5 doesn't have a lot of snow fence out there.

We haven't had that type of number. If they're only paying us $3.50 per panel, it's going to cost us equal amount to go out and inspect and check what they're doing. As long as we're getting paid above it, we're making some money. We're not making some money in the sense that we're using. It goes into financial services of WYDOT and we never see it again. Executive Staff and Finance seem to know where it is. We were hoping that it could be earmarked for snow fence. If they have to pay a claim. If they have a cost overrun. They use that money.

9. How frequently and what type of inspection and maintenance does your agency perform on its snow fences?

They're supposed to be going out every year. It's a WYDOT asset that needs to be inspected like other assets. Yearly when they go out and walk the fence. People with a lot of snow fences are good about that. They go out and fix minor details. They let "winter maintenance" know what repairs are needed to be completed. I as the inspector before any projects and do preliminary inspections.

10. Have you had any challenges with your existing snow fences (e.g., maintenance needs are too frequent; snow is not being captured as designed; other)?

A lot. Obviously, the wind. They're designed to take the brunt of the wind. If we have really bad soil where it was put in. The anchor system can fail. If the landowner has live stock, having a rebar sticking up is not good. Poor construction, normal degradation, wind, livestock and all impact the longevity of the snow fence.

Deer can get in to the living snow fence, so the perimeter fence is important.

Easements. Contractors want to cut a road right through it or tear down the trees to build a house.

In the Cheyenne area, the developer, they contact them and they ask if they can do that, but they've often already cut them down and they know there isn't an easement to keep the LSF.

Landowners say get off the land.

Sometimes, a landowner is very conservative. When some roads were put through in the 1950's, a great grandfather was wronged by the State of Wyoming and they remember that. So, they hold it against us any time that they can. If we don't have that easement, they try to kick us off.

11. Has your agency conducted a traffic safety evaluation of existing snow fence installations?
    a. Yes; do you have any associated reports/outcomes that you can share? [upload here, insert link here]
    b. No.

NCHRP 20-7. We're still following that. We haven't had the time to restudy.

I've had issues with both of the papers that I've seen. We're doing a study on blowing snow in the road. Wind snow condition that will cause that. Vertical fences are filling faster than the other fences. Study on two sets of fences. One set got kicked out. Two vertical fences and two Wyoming fences. Vertical fences hold about 40% less snow. Snow fence protects from prevailing winds, not snow storm winds. We're going to throw on a bottom board to pull the snow closer to the fence and store more snow with that.

12. Have you documented or considered wildlife migration impacts or habitat benefits as a result of snow fence installations?
    a. Yes; please describe.
    b. No.

That's a rough issue. The game and fish will tell us not to put any snow fence in the way of wildlife. When you listen to our mentor. What else do they have to do all day but to walk. They can walk around the snow fences. Snow fences aren't too long so they can walk around them. If they might block their migration, they don't put them up.

We do put in the gaps.

1200 is the max to go before a gap.

13. How do you fund snow fence materials and installation?
14. How do you fund snow fence inspection and maintenance?

The maintenance foreman has to decide what to spend their money on. They have to walk the fences every year. They might drive and use their binoculars to look at snow fence. They do walk a right-of-way fence. They may claim that they shake a panel or two. There are only so many hours in a day.

15. If you put snow fences on private land adjacent to the road, how long are your contracts with landowners (e.g., 1 year, 3 years, 10 years, 15 years, handshake agreement)?
    a. Do you have any best practices regarding engaging with private land owners?

If we put it on a construction project, we get the easement, and it's ours forever or until we release it under good justification. Cheyenne – we are selling off ranchettes, 10 acre plots. We do have structural snow fence. They will ask us: do you want to release it. We can release the easement and let them in.

16. Does your agency have any research reports, benefit/cost analyses or the like on snow fences that you can share?
17. Does your agency have a snow fence design, installation, inspection, and/or maintenance team? Please explain.
18. Does your agency conduct trainings regarding snow fences? Please explain.

I've done some training with some of the maintenance foreman. Some of the newer guys. Why it's important to keep the snow fences in good shape. How it can help them throughout the winter. Let them know what to look for with what can potentially fail. Signs to look for on the road or up at the fence. Tell-tale signs during a storm when a fence isn't doing what it's supposed to do. He's more than happy to train people. Snow fences are your friend. A lot of them blame snow fences for the lack of overtime. Keep the traveling public safe.

LESSONS LEARNED/FOLLOW-UP

19. Can you provide any lessons learned and or best practices with regard to use of snow fences or other blowing snow mitigation strategies by your agency?

Best practices are to be able to get it installed any time that you can. Know what your snow accumulation is. Follow Tabler's NCHRP report. Design it appropriately. Not just throw it up. We had quite a few, before our team was formed, they put living snow fence, just 250' off the right-of-way. They didn't take into account he prevailing wind. Whether structural or living, maximize the storage of the devices.

If they understand how it works, the details, the mathematics. People have built snow fences or planted trees right along their driveway – they have problems with their driveway. If you want to put this lathe fence up on your right-of-way, make sure that you have the 35x. If you don't, you're going to cause yourself more of a problem. Educating people. Understand exactly how a snow fence works so that you're not causing problems in the future.

Know how the drift builds. Depending on what you're expecting. Do you get melt-out? Can you put it closer than 35h. H is the critical part. Know your area, how it snows. It's not just throwing up a fence. You're not stopping the wind or snow, the snow is dropping out. We took the plan for the Wyoming fence and stood it upright. We don't need the bottom gap. Pushing the snow up further from the fence. We're not storing as much. We're learning things as we go along. There is a lot more to it. Tabler did a lot of work with pencil and paper.

She’s not that into computational fluid dynamics. Tabler nailed it. We’ve done presentations to multiple states, including South Dakota.

Quad-state…training. Computer zoom meetings.

TLN. Transportation Learning Network. There’s also a four-state thing. SD, ND, WY, MT.

20. If we have additional questions, may we follow-up? If so, please provide your name and contact information.
21. Are there others involved in the planning, design, construction, and maintenance of snow fences within your state that you might recommend that we speak with? If so, please provide their name and contact information.

There’s an art to snow fence design.

That was something that Tabler had to drill in to me. We can get numbers so that it’s helpful to justify. The actual location, there is where you’re supposed to put, 12’, 150’. We’re going to have to change that location. Maybe it had to double. We need to make it fit the terrain. That’s the art form. Rather than science tells us, that’s the numbers.

Emailed: July 17, 2024

ADDRESSING BLOWING SNOW STRATEGIES

Does your agency employ other blowing snow mitigation measures besides the implementation of snow fences and grading?

Use of Snow cats to create Snow traps

Deployment of Weather instrumentation (anemometers, snow depth sensors and specialized traction measurement instruments on a blowing snow research truck to help with the design process

We will use all available measures if the Landowner will agree. Please see NCHRP 20-7(147) dated August 2003

Does your agency consider, in the design or redesign of roadway cross-sections, snow storage? If it does, could you refer us to the design standards, or are they site-specific?

No design standard in place. From the NCHRP report it is recommended to have a ditch depth of 3’ measured from the edge of pavement. Then a 12:1 flat bottom ditch for as long as possible. Usually the blade with of a grader for ease of construction.

Has your agency made grading improvements specifically to address blowing snow concerns?

We make recommendations to the Design Team. Then it is up to them to incorporate the recommendations into the design. There may be other factors that keeps these recommendation out of the design.

SNOW FENCES

What types of snow fences does your agency use (living, structural, other)?

Living, Slat\Woven Wire (cribbing) Vertical structural with wood and vinyl polymer.

Why?

Cost benefits, functionality concerns, overall maintenance costs, storage capacity concerns. Sometimes it is site specific

Also we take into account what the Landowner will allow on his property.

If your agency uses various types of snow fences, how does your agency decide what type of snow fence to use for each application?

Cost benefits, functionality concerns, overall maintenance costs, storage capacity concerns. Available funding, Maintenance Burden, and soil quality

Above is all true, but a big factor is what will the Landowner allow on their property.

If your agency uses living snow fences (LSFs) (*skip this question otherwise*):

Does your agency have a living snow fence coordinator? If so, what are their responsibilities in this role?

Yes, they provide data and justification for funding issues, currently is $100,000.00 per year

Who pays for the installation of a living snow fence?

WYDOT pays the WY State Forestry Division, who in turn contracts with the conservation district to get soil samples, plant and maintain the growth cycle

Who is responsible for replacing trees and shrubs if they die off?

Nobody is in place to do this task to my knowledge

The conservation districts love these fences. They take great pride in seeing them grow. When trees die, they take notice. If enough die then they set up a replacement project through the WY State Forestry Division. WYDOT is a voting member of the co

Who is responsible for maintaining the trees and shrubs over time?

After the first 3 years the Landowner is to take responsibility for the planting. However, time has proven that this is not true. WYDOT Maintenance has had to come back in and rebuild the boundary fences. If they can get help they will also cut the fabric to keep the tree from being choked off at the base.

What is your agency's experience with using standing corn rows?

We have considered it but to this date none have been implemented, due to limited suitable soil and, or landowner cooperation

How does your agency prioritize where to install snow fences?

Corridors that have increased costs of drift maintenance, decreased visibility, High traffic incident data due to drifting, wind polished ice, and visibility issues. Main thoroughfares with High ADT and increased closure instances

We also coordinate with the local WYDOT maintenance foreperson. They know their roads the best and what areas are trouble spots.

Do you know the average life expectancy of your agency's snow fences (living, structural, other)?

Some structures have been in place for 40+ years and some living fences have been growing for 20+years. Horizontal slat replacement on structural fences takes place every 8-10 years on average.

How frequently and what type of inspection and maintenance does your agency perform on its snow fences?

Fences should be inspected yearly by maintenance crews and minor repairs performed yearly or as needed.

Have you had any challenges with your existing snow fences (e.g., maintenance needs are too frequent; snow is not being captured as designed; other)?

Fences have worked loose due to our unique geography, geology and climate. With higher than average winds, most notably the cross winds in orientation to the roadway, paired with some less desirable soils, fences tend to rock loose from the anchoring and lose structural integrity. This can cause premature failure. This will happen with the Wyoming A-Frame fence structure. Wildlife and Livestock can cause damage as well to all fences including living and structural. The Vertical structural fences have shown the most resilience to the above mentioned challenges.

Has your agency conducted a traffic safety evaluation of existing snow fence installations?

Have you documented or considered wildlife migration impacts or habitat benefits as a result of snow fence installations?

Not really, we know that structural snow fences act as a wind break for all animals. Snow drifts act as insolation for rodent populations. Rodents are a food supply for predators. The cycle of life.

Living snow fences provide more protects for other animals such as birds. We try to keep deer or pronghorn out of the area to protect the trees. It seems that only the domestic animals are prevented from entering the area.

How do you fund snow fence materials and installation?

All materials, labor and insurance is paid by the contractor. This is achieved through contractual obligations in which the contractor will maintain and repair fences via a NetZero contract, or a payment to the agency for the rights to the reclaimed weathered and marketable wood. Which they turn around and process to sell for a profit on their end.

New Construction is bid out through a contract. The funds are allocated by the District which is desiring the snow fences. We have worked with a Private Coal Mine that will fund the snow fences on a road realignment project. This is rare.

WYDOT has a Living Snow Fence Program in which we work with the WY State Forestry Division to administer $100,000. They in turn contract out with County Conservation Districts to propose, plant and maintain for the first 3 years.

How do you fund snow fence inspection and maintenance?

This is State funded maintenance work. The Districts will allocate equipment, materials and labor to maintain and inspect snow fences.

If you put snow fences on private land adjacent to the road, how long are your contracts with landowners (e.g., 1 year, 3 years, 10 years, 15 years, handshake agreement)?

We have found out there was some handshake agreements. When WYDOT Right-of-Way secures the property the agreement is for life of WYDOT with a one-time payment to that current landowner.

Do you have any best practices regarding engaging with private land owners?

Develop a working relationship with the landowner based on trust, and integrity. Assuring them that the land will be taken care of during ingress and egress. Maintaining their assets as if they were our own. Being transparent with plans and timelines. We have found that it works best if maintenance foreman that live and operate in the area of construction or maintenance be the primary line of contact with landowners, as there is a sense of community and rapport with them

Does your agency have any research reports, benefit/cost analyses or the like on snow fences that you can share?

See NCHRP 20-7(147)

Does your agency have a snow fence design, installation, inspection, and/or maintenance team? Please explain.

Yes, we go to an area of concern with specialized weather data recording equipment and survey the road surface and ambient conditions. (This usually happens during and or post storm) This includes average wind speeds, prevailing wind direction, geographical profile of the corridor, and any obstacles that may be causing drifts. We also have a state of the art surface monitoring system on the vehicle that measures road temperature, ambient temperature, dew point and humidity as well as the state of friction of the road surface and how much water is in and on the road down to the millimeter. These instruments take detailed images and video of the conditions that are present. They also take detailed measurements throughout the drive and plots them on a map so we can see where these problems are occurring and if they can be solved by snow fence placement.

We will take the data from the instruments and create a map of the entire corridor with fences in place where they need to be, how long and how high they need to be and the angle set to give the road the most protection.

Installation and some maintenance is completed, by a third party contractor. All inspections are done within the agency by the local maintenance crews or by the winter research team's inspector.

Does your agency conduct trainings regarding snow fences? Please explain.

We train and inform our maintenance personnel annually at a foreman's meeting put on by the state maintenance staff. We also have brochures placed throughout the states port of entries, rest areas and select museums and tourist destinations to help inform the public as well

LESSONS LEARNED/FOLLOW-UP

Can you provide any lessons learned and or best practices with regard to use of snow fences or other blowing snow mitigation strategies by your agency?

Snow fences are a vital maintenance tool in protecting our roadway infrastructure. Proper maintenance is important to keep this asset doing its job.

If we have additional questions, may we follow-up? If so, please provide your name and contact information.

Are there others involved in the planning, design, construction, and maintenance of snow fences within your state that you might recommend that we speak with? If so, please provide their name and contact information.

Appendix B: SDDOT Interviews

Belle Fourche Area

8/15/24

1. Does your region experience challenges related to blowing snow?

Yes, we have issues with blowing snow issues.

Blow snow occurs in concentrated areas, and then depending on the wind every section can be affected. Certain locations are more prone including Hwy 34 from mm 15-17 & mm 23-25, and US 85 lots of spots. Mm 78-79, 82, 91. Hwy 79 mm 170-185. When they have 60 mph, snow is blowing everywhere. A lot of these 79, 82, 83 have some Wyoming snow fence sections and it helps. Used to have tons of lathe snow fence. There are pros and cons to each type, the lathe does not last.

In 1996 the state had a generational winter event, had road sections they needed to blow open every day with drifts growing up to a mile long.

We have a few bad spots, Hwy 79 mm 222 is an angled road, they need to check it all the time. Hwy 75 mm 220 is a really bad spot. Hwy 20 mm 213-207 constantly is a bad spot. Down south all of the Hwy is like that from 72-127.

In 1996 the state had a generational winter event, had road sections they needed to blow open every day with drifts growing up to a mile long. Last year had a massive winter, but not even close to 1996. In 1996 the highway drifted shut with 1-2 miles long, 6-8 ft high, and the snow drifts were hard enough for semis to drive on. Had to blow snow every day to get feed to people and animals, even had to snow blow out fire stations. Had to have National Guard support. Part of the issue with 1996 was it lasted the whole winter. Like the winter of 1948. Two years ago had semis stuck everywhere on Hwy 34, but the duration was not as long (max up to a few days). Have very different equipment after 1996, purchased blowers after that season. Interstates were closed so cars/trucks were rerouted to secondary roads and this caused a problem.

Have used snow fence since the 80's. Always in problem area. Hwy 212 was regraded and in the process they asked for input on problem areas, and they were able to regrade to fix some of the blowing snow problem areas and eliminate snow fences in these areas. They also worked with BLM and knocked back some of the raised cuts (at R pan turn off) and put in living snow fence. They eliminated most of wood lath snow fence along Hwy 212.

After the 1996 storm they got Wyoming snow fence. Prior to this they had miles of lath snow fence. Wyoming snow fence has been good but is high maintenance. They have changed the design of the Wyoming snow fence they use by shortening it; 8-10 ft now instead of 15 ft. This is still tall enough to serve its purpose and it can handle the wind better. They have issues with the Wyoming snow fence getting blown over, and once one goes, it is like a domino effect, and they all go. This tears the Wyoming snow fence to shreds. The Wyoming snow fence is supposed to be moveable, but it is not. This summer they had a storm blow through near Camp Creek and destroyed and an entire section of Wyoming snow fence. Would prefer to put posts in the ground and screw boards in. The Wyoming snow fence is secured to the ground with rebar at an angle, but in high winds this acts like a spring, and seems to help tip them. They also have an issue with cattle rubbing on the snow fences.

During mild snowstorms, red lath snow fences catch snow faster. Whereas Wyoming snow fence takes longer start building the snow drift and drift looks different. They also modified the Wyoming Snow fence and added a board to the bottom to help catch snow. This also helps prevent cattle from rubbing on the boards and causing damage. Used to do a of ridging, which can be very effective. A lot of ridging (Hwy 73 mm 207-177) landowners give permission to ridge back. Hwy 79 have Wyoming snow fence (have to fix a lot), and some live trees (re: living snow fence). Live trees do better than Wyoming snow fence. At Enning, they have snow fence and have no issues, but the snow fence down the road they have to fix all the time. Near Bison at mm 80 they had an S-curve in the road and blowing snow got really bad, but they took this out since 1996 and realigned the road and put trees in. Much better now.

Shelter belts (re: living snow fences) start stopping snow right where they are. One row is not enough, so they plan multiple rows (4-5 rows needed). Landowners are using the shelter belts to calve too.

Hwy 12 mm 90 on (Question Mark Hill) curve in the road causing issues. The landowner does not want trees or Wyoming snow fence, so there is nothing they can do at this site.

Have always used snow fence. Most landowners that hear the safety argument are willing to have it on their property, but there are some areas where landowners are hard to work with/don't want snow fencing; but this is the exception. Just a couple landowners that don't like government, the state.

Asked landowners in two locations that have chronic blowing snow issues if they would put snow fence on their property, but they don't want snow fence on it.

Most Wyoming snow fence in one part of the area is shorter, newer, and built differently than the other, so he does not have the same issues.

Has a few locations that he would prioritize for snow fencing, but landowners are not compliant, or the right of way is too narrow.   In the future as they go to repair Wyoming snow fence, where it gets wiped out by wind frequently, he would remove the A-frame, and instead plant posts in the ground to create a vertical snow fence. The Wyoming snow fence he has is older and taller (15 ft). The newer Wyoming snow fence that is shorter (8-10ft) is holding up well, mm 220-225. They also have issues with the cattle, so put a board down low to prevent the cattle from breaking the upper boards.

Likes tree belts (living snow fence) better than Wyoming snow fence. Living snow fence is great, but it takes a while to get going, and eventually need to go in and replant. They have a life span.

There are locations where a living snow fence could work, or replace existing snow fence, but it is all up to the landowner, what they are willing to have on their property, the amount of space it takes up, if watering is needed, etc. A lot of the current snow fences are in hay fields, and living snow fence need 4-5 rows thick, so this takes up a lot of space. On the flip side, they get snow built up in field which is water for the crops.

   a. If yes, excluding interstates, please identify (by MRM if possible) where you experience blowing snow challenges.

2. Does your unit use wind forecasts to inform maintenance operations?

They always monitor forecasts and wind. In their area, the forecasters do not forecast snow well, but they never miss on wind. Their most important weather forecast is from employees call it in, reporting the bad spots.

Prevailing wind is from N/N-W, but more now from the E. When the wind is from the E it is the worst. They, or at least parts of the state, are in a drought and that means less standing grass to catch snow in winter, so smaller snow amounts are getting blown with less wind. Normal years when it is wet enough to have grass in the pastures this is good enough to help reduce blowing snow. But for example, a farmer burned his pasture and they had drifting issues on the adjacent road the next winter. It really depends on year to year conditions and site specific conditions.

   a. If so, how?

3. Has your region ever closed a roadway as a result of the impacts of blowing snow?

They close the interstate all the time due to visibly. They used to close roads years ago, but then the state changed the law so they couldn't. Now the law has changed again so they can this coming winter. Until now have been putting up Road Blocked or Impassible signs, or No travel advised.

2 years ago a maintenance worker was out on road blowing snow to open Hwy 212, and he found a young woman stranded trying to get home for Christmas. She saw that the roads were marked impassable but did not care.

The DOT shuts down I-90 due to visibility issues from blowing snow. This last winter they put out signs on Hwy 34 near Sturgis to notify people to not go down the road. The new rule change helps.

Visibility is the big issue. Once they stop winter maintenance operations, that is when drifts form. You go from treatment (plowing around the clock) being a nuisance to when you stop blowing the road, it becomes impassable (drifted).

Main problem is bridges. He has tried snow fences. The guard rail on the sides of the bridge act like a snow fence. The worst bridge is the Red Elm bridge and every storm an ambulance gets stuck. Have tried everything there.

For one part of the area, there is a point in time, in the storm, where he will pull staff. They can't run 24/7 and it just burns fuel. The other part of the area does not feel this way; he keeps his staff out as long as they can because moving snow now means less to move later, e.g., easier clean up.

4. Where has your region observed above average snow removal costs from blowing snow?

Two years ago, had some events that created big drifts and had to use snow blowers to clear the road. Anytime you have to go from plowing and salting to bigger equipment (snow blowers), and it takes longer to open; that is going to cause above average costs. He sends folks down south to help when the drifts are tall (10ft). The storm two years ago they had issues with lack of food in stores, but this was the only winter Rick can remember where all roads in the state was closed or blocked.

They track costs by performance measures. But when a big storm hits, it is going to cost more. Never need to contract out equipment, have it all on hand.

5. Has your region experienced any pavement repair costs that are believed to be the product of blowing snow?

No can't think of an area.

6. Has your region considered implementing snow fences to address blowing snow problems?
    a. If no, what are barriers to implementing them?
7. Do you have a preferred snow fence type?

Post in ground with boards. Living snow fence where doable.

a. If so, why?

8. Have you encountered any challenges in leveraging snow fences?

Done well getting snow fence in the past. Wyoming snow fence is a good tool but would prefer planting posts if the landowners are willing. Likely same cost in the long run. The new, smaller Wyoming snow fence is not blowing over, they just need to replace boards mostly from cattle. At Enning, worked with landowner to put posts in the side of the snow fence and this eliminated the issue of cattle pulling the boards off, they rub on the post instead of the snow fence boards.

Where they have snow fence it works. One part of the area has long stretches of snow fence, but the other doesn't. Near "Whitehour" they have snow fence up on hill and that one needs maintenance, replace boards, etc. just board replacement mostly from cattle. Wyoming snow fence in one area doesn't tip like the other.

a. If so, have you had any success in overcoming such challenges that you can share?

9. What type of annual maintenance do you conduct on snow fences if there are any in your unit?

Replace boards as needed. Annually, site lead go out once year and check fix the snow fences as is needed, have lumber on site. Wyoming snow fence has a lot of nuts and bolts that need to be tightened up, have rebar that needs to be checked it is in place and bolts holding the rebar in place that need to be tightened /checked. A mile long section of Wyoming snow fence is a lot of bolts. (The older/taller Wyoming snow fence is a maintenance headache)

We pick a day in the fall when the cattle are gone and fix all of the snow fences in one go.

It will take weeks this year because of the snow fence that was destroyed at Camp Creek. But normally it will take days to for all of the snow fence repairs/maintenance.

10. How does your agency train or pass on knowledge of snow fences to other employees?

Lead workers see the effectiveness of snow fences in the field and see the maintenance required. Once they have worked on the snow fence (fix, tighten), they become well aware of what is needed and what they do. There is training out there, but they rely more on on-the-ground experience.

Have experienced folks train the younger ones.

Are there any reimbursements for land use? Yes, the DOT started doing a financial incentive with the agreement for land use, it is not a lot, several hundred dollars a year. None get paid in Joel's area (e.g., they do it because it benefits everyone including themselves on the road).

Rapid City Area

7/22/24

1. Does your region experience challenges related to blowing snow?

(Deadwood/Sturgis) – Hwy 34 mm 48 (worst one for deep snow caused by a shelter belt that runs perpendicular to the road up to about 40 yards from the fence line, with open flat ground outside of this. Hwy 473 (Leed) to the ski lodge on top of mountain have wood lath snow fence up there and it works, but even with that it is hard to keep snow from blowing. Hwy 385 mm 116, do not have a lot of right-of-way up there, a high point on the road (mountain crossing). Hwy 85 mm 32-35 flat open stretch N-S, some shelter trees, in worst spots have wood lath about 40 ft off the road but still have problems.

[Hwy 14A mm 46-48 highwall canyon on the map should not be due to blowing snow.]

Mm 108 bare creek bottom that funnels wind, have wood lath. Will add shoulders to that road. Can more be done than to put a fence up at this location?

In Spearfish up near airport – 2 x 12 wooden board fence, two wooden boards on the fence, mm 14.5 – 15.5, runs into an overpass. Would like to run all way to exit 17. Knew would work in that area because of the previous wood lath fencing in the right of way that worked. When the airport changed the road, they put a wildlife crossing in so they had to change snow fence to what it is now. Works better than expected.

Work with Wyoming DOT on ideas, design, etc. Whenever they have an issue, they talk to them.

Hwy 16 mm 56-57 get blowing snow on the flats, rest of the route is well sheltered. Hwy 44 east mm 85-88, depends on wind. Hwy 79 mm 69 (Spring Creek). Hwy 16B at mm 65, 67-69, 72 at the bottom. Interstate I-90 mm 88-90 is the worst spot (landowner won’t allow shelter belt), used wood lath in the barbed wire, helps until the snow builds up higher than the fence. Have a shelter belt on I-90 mm 84 put in the by the landowner, works well.

Have few places. Hwy 14 mm 113-115, mm 121 near Big Foot Road. Hwy 240 near Sage Road and Golf Course Road. Interstate I-90 mm 90-92, mm 129.1 near Prairie Dog town get blowing snow at a hill. Do not have any wood lath on the fence. Could be an option here.

Use wood lath in fences (stand up better to nature), have used plastic snow fence. Do not use any standing corn rows due a lack of corn. Have Wyoming snow fence on the highway near Tilford.

   a. If yes, excluding interstates, please identify (by MRM if possible) where you experience blowing snow challenges.

2. Does your unit use wind forecasts to inform maintenance operations?

Use wind forecast to determine if they are going to use deicers, or if they will just push back finger drifts. Wind speed issues vary by location, interstate can be very different. Usually wind speeds of 15 mph or higher starts to cause problems. Majority of time winds from North/northwest. If the wind is from the south, they are usually okay.

a. If so, how?

3. Has your region ever closed a roadway as a result of the impacts of blowing snow?

No not really.

Would probably close Hwy 34 if needed. If the interstate opens, then Hwy 34 may not be cleared yet so get a backup.

Where has your region observed above average snow removal costs from blowing snow?

Majority of snow removal from Hwy 34 from Sturges out is from blowing snow, do not get much snow fall out there. Spent 2-3 week on I-90 mm 88 to get rid of a drift (double normal effort, partially operator error – dumped too much mag). Blowing snow got so bad it built up over the ditches. Needed to clear out the shoulder so brought in blowers. This is always a bad spot. I-90 mm 88-92 normally see blowing snow.

Could look at MDSS data to see if more work was needed than expected in the after action reports. This could give cost numbers to work associated with snow drift clean up.

If they use blowers, it is on Hwy 34 mm 48.

4. Has your region experienced any pavement repair costs that are believed to be the product of blowing snow?

No issues

5. Has your region considered implementing snow fences to address blowing snow problems?

Yes, whenever possible. Living, temporary. Start with temporary to see if it works, then see about a more permanent solution. Put some hay bales up on Hwy 14A, had an elk issue so had to take down. Many areas cannot put up snow fence due to landowners.

Have used snow ridging in the past if they can, near the airport area; typically on private property.

Once they get snow it builds up so quick and they don't always have time to ridge. He has had a few landowners offer to do snow ridging on their property, but they don't always have the time to do it. Hwy 14A by the helipad, the landowner does snow ridging on his own (Kangaroo farm).

    a. If no, what are barriers to implementing them?

7. Do you have a preferred snow fence type?

Prefer wood lath (temporary 4 ft fences) over plastic. Have used steel post, but these can cause issues in the right of way. Whereas wood lath in the right of way fence is not a ditch obstruction and it holds up well. These fences mingle with ranchers' fence, but DOT is responsible for maintenance of it so there any have not been any issues. The wooden lath fencing has become permanent until they rot out.

A frame (Wyoming) snow fence. Up near Spearfish sunk into ground due to space issues. Very flexible using both Wyoming, sunken Wyoming style, wood lath, etc.

Likes living snow fence when it can take hold. Like as long as they are not too close to the road.

Would choose Wyoming A-frame or Wyoming sunk into the ground.

    a. If so, why?

8. Have you encountered any challenges in leveraging snow fences?

1. Getting landowners to agree and 2. some highways flow northwest and have a hard time trying figure out where to put snow fence so it is most effective.

Get warmer temperatures in their part of SD, so this helps melt or at least create a crust on the snow so it stops blowing.

    a. If so, have you had any success in overcoming such challenges that you can share?

9. What type of annual maintenance do you conduct on snow fences if there are any in your unit?

Minor – nailing a board that fell, tying up a wood lath. Chad – not really any maintenance, the wood lath holds up really well. May need to tighten up the wire on the wood lat.

Wood lath - Horizontal boards held in place by wire. (Photos of this)

10. How does your agency train or pass on knowledge of snow fences to other employees?

Comes along with snowplow training. Required to do 40 hours of training/drive time, so it is the old teaching the new.

Custer Area

7/22/24

1. Does your region experience challenges related to blowing snow?

Hwy 16 west of Custer mm 4, Hwy 16 mm 19, Hwy 385 mm 64.5, Hwy 385 mm 55.3, Hwy 16/385 mm 30-32, Hwy 40 mm 47- 47.8, scattered sections Hwy 40 mm 50 – 67.

Every road they have has blowing snow issues. Specifically, Hwy 18 mm 48-121, Hwy 385 mm 0-13. The whole thing blows. For snow fence, have quite a bit already on Hwy 385 mm 0-6 Wyoming style snow fence. Other worst areas near Edmont / Hotsprings on Hwy 18 mm 22 – 25. Down in "Orix" everything blows and every sticks. Have quite a few tree rows (living snow fences), it just takes them a while to grow.

Hwy 471 is in good shape have Wyoming snow fence, cribbing (4 ft), etc. This section is set up well with snow fence.

   a. If yes, excluding interstates, please identify (by MRM if possible) where you experience blowing snow challenges.

2. Does your unit use wind forecasts to inform maintenance operations?

Look at the wind especially when temperatures are increasing. Then tells the guys to watch the roads. The worst part of the temperatures warming is that stuff starts to stick to the roads around 10am. Use MDSS for projected areas where it is probable to see blowing snow. By 10-11am when it starts to warm up on the road the blowing snow will stick all day until the evening when the road cools down again.

Watch for wind in 20 mph range or above it, and a north/north-west wind. The wind can also blow from the southeast.

   a. If so, how?

3. Has your region ever closed a roadway as a result of the impacts of blowing snow?

Do not really close roads. Can get snow drifts up to 6 inches to 1 foot. They have common thaw-drift-stick cycle that causes the biggest issues. This happens when there isn't a storm, so people are not expecting it. Most of the road is in good condition so the drivers are moving at normal speeds, then they'll hit a drift and get caught off guard. Can get pillow drifts at night, maybe a couple feet deep, but this is rare. Not enough snow to get big drifts.

Do not close roads. Will see 6 ft drifts, but typically 3 ft. Build up pretty bad at night and will send out a v-plow or blower.

4. Where has your region observed above average snow removal costs from blowing snow?

This is the bulk of our effort. Have the equipment to handle it.

This is very small for us, have equipment on hand to handle it.

5. Has your region experienced any pavement repair costs that are believed to be the product of blowing snow?

No, not that they know of. If Wyoming or Nebraska gets hit by a big storm, then they have drainage issues, dams breaking, etc.

6. Has your region considered implementing snow fences to address blowing snow problems?

Worked in the past to prioritize snow fence locations and get them done whenever they have a chance. Got quite a bit of snow fence up in last a few years. Have had issues with landowners now wanting snow fence. They created a list of locations, then then talked with landowners, but most don't want any type of snow fence, even while acknowledging there is problem on the adjacent road. National grasslands have a lot of land, but they have a lot of red tape too.

   a. If no, what are barriers to implementing them?

7. Do you have a preferred snow fence type?

Wyoming style, have done some themselves, homemade in Edgemont, permanent. Use telespar (their own material).

Cribbing on Hwy 471, almost the whole route. (Hwy 471 also has tree rows and Wyoming snow fence). Basically, the whole 13 miles is treated with snow fence. Also have cribbing Hwy 71 mm 10. Hwy 18 mm 22 temporary cribbing (Black Hills National Forest temporary snow fence, put up in fall and take down in spring). Hwy 89 may still have some up (land has changed owners a lot so hard to track).

Snow Ridging – do this and reach out to the landowners as is needed to get permission.

Tree row, living snow fence, 3 – 5 rows deep. When the road up by Crazy Horse was built, they put some bushes that work as snow fencing, but they only took hold in one section. The landowner is not interested in filling in the areas where the bushes did not take with any type of snow fence living or otherwise. For the bushes that did take, it is really growing now, but very isolated.

Land use in their area is farmland corn and wheat, pasture, national grass lands, Black Hills National Forest.

Would prefer Wyoming snow fence, then bushes/trees (living snow fences). Wyoming may be an eye sore, whereas living snow fence is nice to look at. Would mix up both options if they could. They type of snow fence depends on the situation and where it is located.

Do have areas where a change in geometric design would help. Could make a list of these sites. Most of the roads in his area were established a long time ago, it would take a road project to address geometric issues. No real terrain changes naturally occur so it would be hard to intimate any change. Down here they worked on most of the geometric issues, using back cuts, etc. They have been lucky with construction project and have had luck with this.

Section by Sioux Falls used information from MDSS to raise one side of the interstate to prevent drifting on the other lanes of the road. Could also use MDSS to look at where trucks are working an area 6+hours after a storm on a regular basis to help ID where blowing snow clean up efforts are taking place.

   a. If so, why?

8. Have you encountered any challenges in leveraging snow fences?

Landowners are the biggest challenge. Don't think they like to see snow fence on their land. Maybe SDDOT needs to make landowners aware of the pros and cons of snow fences. They could maybe see the value in water retention.

They are aware of the SDDOT snow fence pamphlet but do not see any need for modifications.

When working with landowners, the area engineer contacts them with a proposal, talk about the snow fence areas, etc. Generally, landowners are not interested in the Custer area.

Went out and met with folks, has gone many ways. If landowners wanted snow fence, they put it in, but also had folks that did not. When they go out to ridge, they call them beforehand, or have a guy working the farm (branding, etc.) that brings it up.

Do see landowners frustrated with DOT by increased road size/loss of right of way/farmland.

   a. If so, have you had any success in overcoming such challenges that you can share?

9. What type of annual maintenance do you conduct on snow fences if there are any in your unit?

Other than mowing changes to prevent snow build up in the shoulder, do not really mess with bushes or trees, they self-manage.

Look at them every fall, cribbing – need to replace or maintain annually. Wyoming fence is good to go no issues, then the temporary fence needs to get put up and taken down seasonally.

For local roads with more constrained roadways, do you do anything differently with snow fences design, install, etc.? No

10. How does your agency train or pass on knowledge of snow fences to other employees?

Have done TLN (Transportation Learning Network) events on snow fence, usually every fall. At safety meetings in the fall, talk about each route and if there is snow fence, what it does, how to handle it, etc. No formal training on snow fencing but share information as is needed with staff.

For other interviews: Talk to folks in the North West: Spearfish – research on snow fence near the airport, Tilford – ask about all of the Wyoming snow fence they put in (likely both interstate highway projects).

Mobridge Area

7/16/24

1. Does your region experience challenges related to blowing snow?

There are a handful of drifting snow locations in each district. Part of the area's blowing snow issues are well documented (see email with map and pictures) and they are currently working toward a snow fence project west of Mobridge. Originally it was to use a Wyoming style man-made snow fence, but another group is looking to revitalize an old living snow fence at this site instead. The property owner gave permission for a living snow fence. Requirements through the conservation district include no past pesticide application, but there was so they are on a 2-year hold until they can plant trees at the Golden Hills Ranch. They have not considered a temporary snow fence for the interim 2-years. Interested in learning more about what Sioux Falls is doing with regard to temporary snow fencing. Golden Hills Ranch #1 issue site. Then Curtis/Gearing #2 issue site – both thinking of using the living snow fence.

When out plowing snow and controlling snow, drifting/blowing snow can cause issues at very specific and isolated locations.

Hwy 62 – Wyoming style

US 212 – Wyoming style, on tribal lands (Cheynne River Sioux tribe)

Will send more information after the meeting.

Sent photos, fill in maps with blowing and drift snow locations and mm (see email)

Have only seen it once where the road was completely blocked, big storm and most everything was closed.

Trail City community has a lot of trees and a house that cause the problem.

   a. If yes, excluding interstates, please identify (by MRM if possible) where you experience blowing snow challenges.

2. Does your unit use wind forecasts to inform maintenance operations?

   a. If so, how?

Use wind forecasts for treatment, but for the #1 and #2 sites whenever it snows/blows it will be blocked with 4-5 ft of snow. Wind is their primary concern.

Sites #1 and #2 both locations are in farming areas. Site #1 has an outslope with a tree belt and causes snow drifts to form. Site #2 has an outslope so snow just lays down. Both outslopes are in the right-of-way and go up to the fence line.

3. Has your region ever closed a roadway as a result of the impacts of blowing snow?

Up until this past year have not been able to close state or local roads. Had little to no snow last year, but two years ago they closed some roads, and labeled them as blocked and could not travel. Had many places with trucks and anyone with GPS be rerouted to the road blocked roads because they were not labeled as closed, so the law change allowed for a change in the verbiage used.

2018-2019 winter worst winter with a few roads blocked, but everything was blocked that winter.

4. Where has your region observed above average snow removal costs from blowing snow?

Over time yes, but in the grand scheme of things it likely gets folded into the general cost. There is more cost to it, but having the road closed is a bigger issue. At the sites identified on the maps they can punch through the snow drifts with a v-plow and with then use a blower to push it back. Once the drift starts you are stuck with them for the winter. They manage with their own crews, did not need to contract anyone. Both have 3 blowers.

5. Has your region experienced any pavement repair costs that are believed to be the product of blowing snow?

No, pavement damage. On both the east and west riverside, water can run off easily.

6. Has your region considered implementing snow fences to address blowing snow problems?

    a. If no, what are barriers to implementing them?

Ridging is used where they can when land owners allow them too. When they have pasture or winter wheat can likely ridge.

Soybeans mostly that are very flat, not much to ridge so don't ridge at all.

No snow fence in place at this time. Put temporary snow fence in the past, plastic/slats.

7. Do you have a preferred snow fence type?

    a. If so, why?

Interested in Wyoming and living snow fence (but can take up to 20 years to establish).

8. Have you encountered any challenges in leveraging snow fences?

    a. If so, have you had any success in overcoming such challenges that you can share?

Working to get a snow fence in place on US 212, they are working with the tribe. Have 2-3 years to make it happen. Folks on council get complaints near the VE ranch, can block the whole route even with 4-wheel drive.

9. What type of annual maintenance do you conduct on snow fences if there are any in your unit?

No maintenance

10. How does your agency train or pass on knowledge of snow fences to other employees?

Heard about snow fences from the operation office that is promoting it. Slat snow fence, the former supervisor used them a lot, but noted it only worked for one storm. Mostly hear about snow fences from research. Interested in snow fence training options.

The following figures were shared by SDDOT with the researchers. Pastureland is causing snow drifting issues (Figure 71).

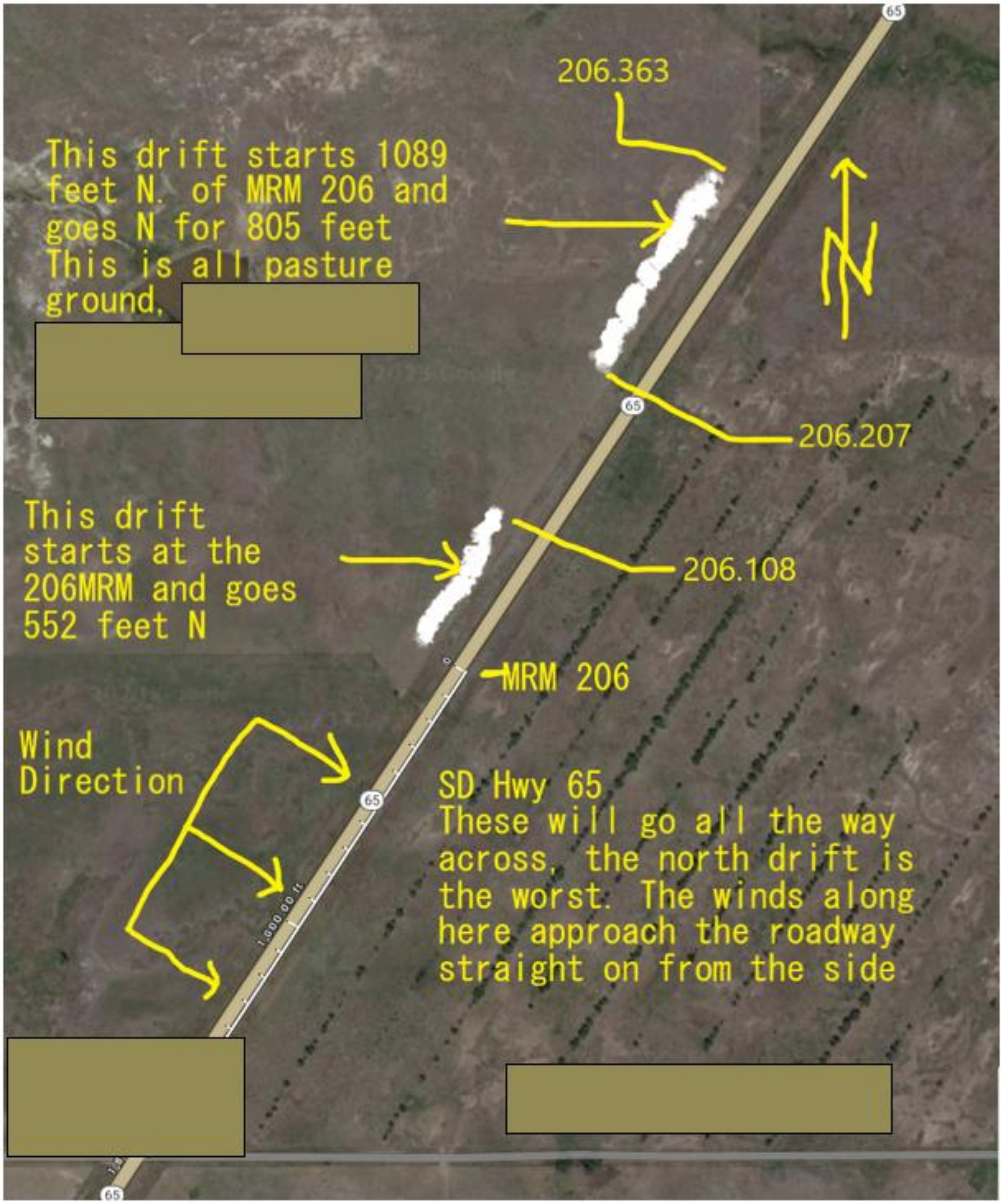


Figure 71: Blowing Snow Across Pastureland, Hwy 65 (Figure Credit: SDDOT).

The area reported a preference for man-made snow fences, like the Wyoming snow fence, in order for instant results to be obtained.

The county conservation district was working on revitalizing their LSF. In one location, they had to delay the implementation of an LSF by two years because of the existing herbicides and pesticides (Figure 72).

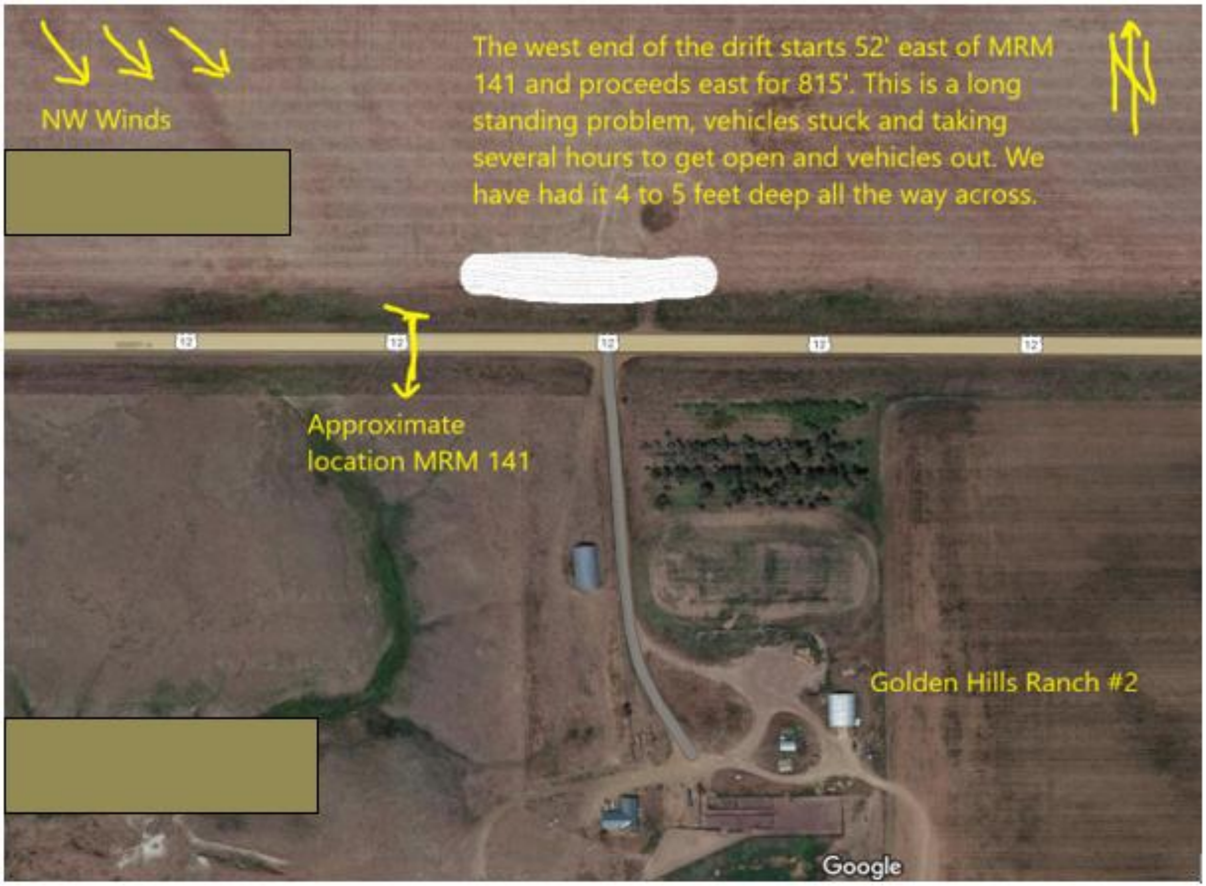


Figure 72: Hwy 12, MRM 141, Future LSF (Figure Credit: SDDOT).

This area was unique in that they discussed the need for a snow fence to address blowing snow that would be located on the Cheyenne River Sioux Tribe Reservation (Figure 73). Hence, there was an additional need for coordination with the Tribal Council. The snow drifting is restricting travel for more than 50 miles, creating "misery," and the Tribe is very interested in the implementation of a snow fence.

Figure 73: Blowing snow problems on Hwy 212, Cheyenne River Sioux Tribe Reservation (Figure Credit: SDDOT).

They described an instance where a house and a lot of trees within the Trail City community were causing a snow drift (Figure 74).

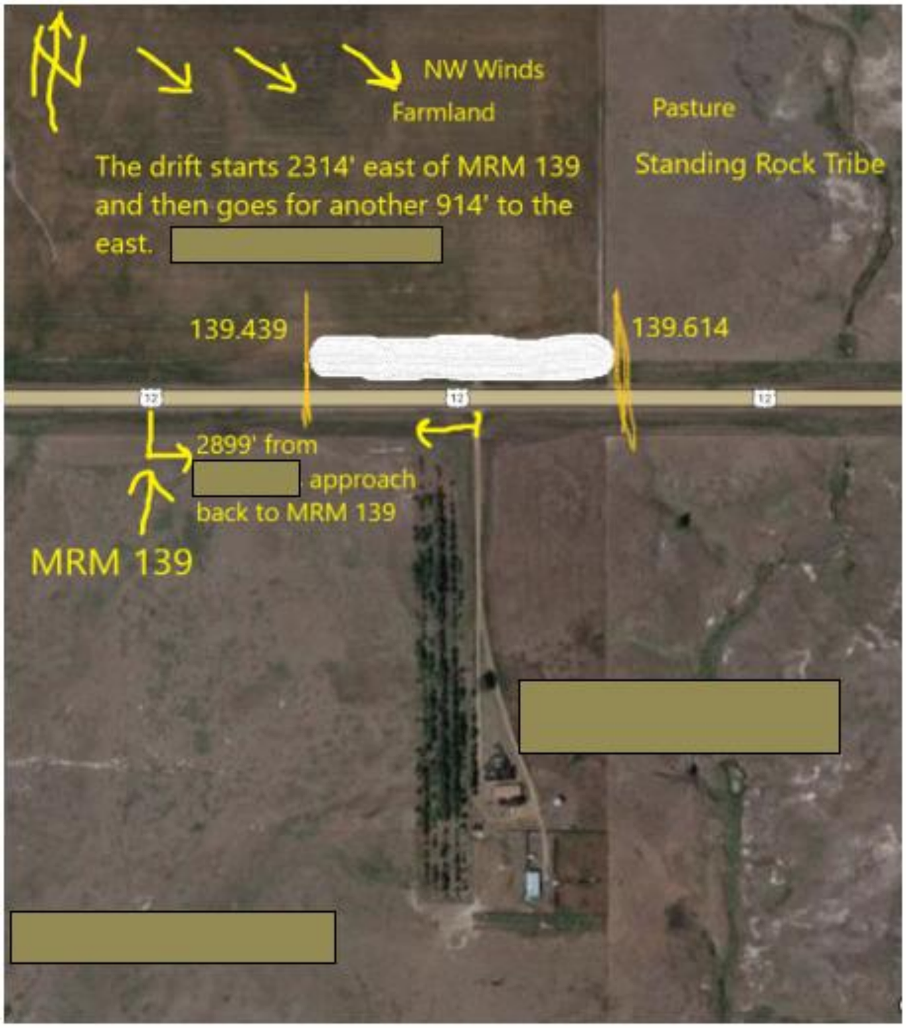


Figure 74: House and trees causing snow drift (Figure Credit: SDDOT).

Pierre Area

7/23/24

1. Does your region experience challenges related to blowing snow?

Hwy 1806 mm 138.46-139.5 (on straightaway by 273 junction), mm 149.7 - 152.0 (has a Wyoming snow fence for most of it but cannot put snow fence on the buttes, so snow builds up there. Tribe was very assertive on the need to do something. Also put a camera in there.). Hwy 1434 mm 207.7-215. Hwy 83 mm 96-98 (where the camera is, working on possible living snow fence there), mm 103-105. Hwy 14 mm 246.6 (junction of Hwy 14 and Hwy 83), mm 249. Hwy 212 mm 220-224 (from 6 mile corner to the town of Gettysburg), mm 227-229. All surrounded by fields, but blowing snow issues depend on what was planted; when soy is planted get a lot of snow on the road, but not with corn. Not necessarily always blowing snow issues, but at least sometimes.

Looking to put a living snow fence in the Grassland National Park and going through the NEPA process now. DOT has to get easement of land from National grassland, County Conservations group will plant, DOT will maintain. A lot of bureaucracy; it is long process.

Snow fences on Hwy 1806, have very alkaline soil/bluffs, so do not support vegetation. Hwy portion that runs through the bluff will not grow trees, so they need to use Wyoming snow fence there. They are not sure they can grow trees on National Grassland. Worried that a lot of maintenance may be required in terms of watering to get the plants to establish. Do have a tree shelter belt on the other side of the road, but it has cedar trees, which are considered an invasive species and cannot use now. Site was originally identified by maintenance, then communicated with support from DNR. Overall not very comfortable with this process, the federal process is so formal, not how they normally do business.

Less issues with blowing snow than the other part of the area. Hwy 14 mm 129.3-130.5. Hwy 63 mm 121.5-122.5 (north of 4 Corners by 2-3 miles). Hwy 34 mm 151-153 (west of the curve), mm 134-135 (Jetter's curve). Nothing really in the valley. Do get blowing snow that sticks to the road but does not necessarily drift.

Talked to operator on Hwy 1434 mm 207.7-215.0 (a 511 site), landowner lives in California. The idea was to try leaving standing corn, by the time they got into contact with the landowner, the corn had already harvested. They think the land is owned by an out-of-state collective that is operated by some local folks. The road gets blocked because soil is filling the ditches and gets 5-7 ft drifts on the road. A huge issue, repeatedly occurring. In fact, the road was blocked by drifts, and it prevented folks from accessing medical care during an emergency situation. Backslopes are higher than the road. MOST REPEAT OFFENDER in the area. Acknowledges that he needs to start working on standing corn row agreements in Spring/May, but that they are so busy it is hard to stay on top of this. Having a central officer winter ops snow coordinator would be helpful. He has standard agreements/pricing, etc. Would be happy to accept help from this person. Need data to show the issue to get funding to change it. DOT need to "trust" the operators when they ID bad spots. Use MDSS to get the data they need to show the amount of effort it is taking to clear drift sites.

They worked with tribes to put in a snow fence. Needed to use local funds to pay for it because the state needs data that did not exist.

They know leaving standing corn rows works because they don't have issues with blowing snow at these sites in winter. But when soy is planted, they will have issues that year. Winter wheat is fine if the farmer leaves 6 inches of stubble. For corn 10-16 rows of corn will catch a lot of snow.

Most locals are easy to work with because they see the problem and have to deal with the snow drifts. If they need to go out in a field to cut lines (ridging) most don't have a problem. Get a permit with the landowners to cut lines.

Generally, get issues with drifting snow on the roads when the backslopes are higher than road and when the crops are low lying, etc.

"Putting up a snow fence on a secondary route is like having an extra plow to do work. If resources cannot be allocated to trouble spots, they can work on other issues."

   a. If yes, excluding interstates, please identify (by MRM if possible) where you experience blowing snow challenges.

2. Does your unit use wind forecasts to inform maintenance operations?

We watch the wind, every storm hits a little different. Use the wind forecast to determine if they should put product out or not. If you put chemical down once and it causes sticking, then you'll be in a chemical cycle endlessly. [See pictures provided of road where deicers were used versus not. Jared's areas has some of the lowest deicer application rates in the state. Good at reading the road and what is needed.]

See if the wind is blowing against the normal prevailing wind. May keep road clear or keep up. Prevailing wind from Northwest. If there are heavy winds they do not need to worry about drifting because it will blow any snow off the road, but at 15 mph they will see snow drifting and build up.

Roads affects are either North-South roads or East-west depending on the prevailing wind.

   a. If so, how?

3. Has your region ever closed a roadway as a result of the impacts of blowing snow?

St Partick storm, heavy wet storm, got dumped on at the CA farm (Hwy 1434 mm 207.7-215). December storms last year got hit by 3 storms in row and had snow built up, which put them in a hole that they had to dig out of. Hwy 14, Hwy 34, Hwy 83 all roads were basically closed/blocked from the event. Could not close roads at this time, so brought message boards in and had Sheriffs/Highway Patrol telling drivers to not go through. Google was telling people to take the route that should have been labeled as closed, prior to rule change. They will recommend closing a road, but then it goes up the chain. 511 labeled the road as winter maintenance suspended or not passable, but not the same as Closed. ¼ of trucks have cameras and can see what the driving sees.

Every 3 years they have struggle with road at the CA farm. Only 1 truck without a camera.

4. Where has your region observed above average snow removal costs from blowing snow?

Do not formally track this. If they were better at tracking the data, and using the information in MDSS they could likely show they are putting a lot of time into it. The data is there, they just need to track it.

They do not have a way to track blower use, do not have MDC [Mobile Data Collectors] in them. Can track blower and personnel hours but cannot say from clearing snow drifts.

5. Has your region experienced any pavement repair costs that are believed to be the product of blowing snow?

The only example I can think of is where a permanent snow fence went in, could not punch through the snow drifts the year before. Had a contractor come out with a bulldozer and he did some damage to road. Only instance they are aware.

Areas with chip seals, chains will tear it off. Have a big hill on Hwy 34 in the Cheyenne Valley. Put in camera up there.

6. Has your region considered implementing snow fences to address blowing snow problems?

East side of Gettysburg on Hwy 212 mm 227-229, not necessarily the whole area but one curve always seems to be covered with snow. The type of fence would have to be determined by landowner – Wyoming, living snow fence. If a living snow fence is possible, they may prefer that.

    a. If no, what are barriers to implementing them?

7. Do you have a preferred snow fence type?

If they can grow it, living snow fence would be preferred, but if cannot grow it then Wyoming snow fence would be preferred.

Could ask farmers to stack hay bales to use as snow fences, need work on coordination.

Could use orange temporary fence, installation is not an issue, but removal could muck up the soil, cause water issues, not get to it in time. Temporary snow fence scares him because he worries, they won't get there in time to remove it in the Spring. And temporary snow fence requires installation and take down every year, a lot of person hours. Most length are 500-1500ft so this would be a major undertaking for temporary snow fence.

   a. If so, why?

8. Have you encountered any challenges in leveraging snow fences?

   a. If so, have you had any success in overcoming such challenges that you can share?

9. What type of annual maintenance do you conduct on snow fences if there are any in your unit?

Currently maintaining the Wyoming snow fence we just put in. The fence got pushed down into the soil and cows were rubbing on it and pushed some boards out. They need to pull it up out of the ground and cow proof it. 1500 ft of snow fence so a lot of maintenance. Used a permitter fence to keep the cows out, but the drifts were so big it overtook the permitter fence and the cows just walked right over it. The original construction was with nails, so they will repair it with screws.

No active living snow fences. Future agreements will require discing and watering. Does not want to put staff on weekly watering duty, this would be too time intensive. Ideally they would go with irrigation. Conservation district would replace trees that die.

10. How does your agency train or pass on knowledge of snow fences to other employees?

They are new to this so they are learning as they go. Wyoming snow fence has only been up 2 years.

Internal meetings of SDDOT they do talk about what works, but often times issues are so site-specific, it is hard to translate solutions from one site to another.

There are tricks and ideas that are exchanged at the Snow Roadeo, such as mowing a double pass to increase ditch capacity in snow drifting trouble areas.

White collar needs to meet the plow driver in the middle, where trust and flexibility exists when reporting issues and requesting funding for projects.

Winner Area

7/17/24

A few years ago, Doug was a part of the interstate survey on snow fences, Steve Gram was the lead on that. SDOT ICS_Blowing Snow Analysis_Final.pdf.

1. Does your region experience challenges related to blowing snow?
    a. If yes, excluding interstates, please identify (by MRM if possible) where you experience blowing snow challenges.

Yes on interstate they have numerous drifting snow locations. Just deal with it as they get it right now. Hwy 248 is a two-lane parallel with the interstate (I-90) and have snow drifting trouble with it too. Will email mile markers, there are quite a few areas. One area identified along 241 west bound along I-90 in the past study but nothing was done.

Some issues include big billboards and the rest is attributed to terrain.

Have several areas in his region. Not documented, most will be regraded in the next couple of years. He anticipates drifting issues getting fixed. Vary depending on weather conditions and site conditions. Nothing to major, unless like 2 years ago, everything was an issue. Asked to mark locations on the map, and mark where regrading will occur.

Part of the area on the secondary road 248 the backslopes are so steep the snow drifts in. There is nothing they can do about it.

Tried snow ridging, it works for one storm, but once filled in they no longer function.

Tried corn cribbing and plastic orange snow fence west of Martin; but this location will be regraded. Very narrow right of way and landowners would farm beyond the right of way line. Farmers would get upset if it was still set up in the spring, also the drifts made the soil extra wet and when they took it out it would tear up the land, etc. So quit putting it up.

2. Does your unit use wind forecasts to inform maintenance operations?
    a. If so, how?

Look at the forecast but there is not much they can do different than plowing. With the high backslopes, the road will get blocked on secondary roads, the interstate will see normal drifting.

Getting cameras put up and can use to look for drifting on roads. Trying to get cameras located in drift issue locations. Otherwise, folks will call in when drifting occurs.

All the parameters matter, amount of snow and wind speed. Can have issues with prolonged wind speeds (50 mph +) and many feet of snow. This was really bad a couple years ago, but this is not typical.

3. Has your region ever closed a roadway as a result of the impacts of blowing snow?

Yes, they have closed the interstate for many decades. But can now close state and local roads. If needed, they can close any road. Will likely not post signs on roads but will post to Safe Travel USA. This was a big issue a couple years ago during the big storm. Need to be posted as closed, otherwise Google Maps thinks side roads are open.

4. Where has your region observed above average snow removal costs from blowing snow?

They track all costs in performance measures, and they will see them fluctuate each year. It would be hard to determine what is associated with blowing snow. The after affects of a storm are where blowing snow costs really show up.

Their part of the state is warmer, so snow will blow onto and stick on the road. But they also see more warmer days and get a crust on the snow so less blowing snow.

Have all the equipment they need to manage events.

5. Has your region experienced any pavement repair costs that are believed to be the product of blowing snow?

No, but the chemical deicers could affect the pavements. Have good drainage so do not see issues from melting drifts.

6. Has your region considered implementing snow fences to address blowing snow problems?
    a. If no, what are barriers to implementing them?

Would like to put up a lot of Wyoming snow fence. Tried the living snow fence, struggled because they have rough (poor quality) soils, tough to get plants going. Would need a project to do it. Need access and right of way issues have been the challenge in the past. Need to set up easements, and this can be difficult. Would like support on this! Need a project to ID locations, work through design, set up easement, then build.

Have talked to farmers to leave corn standing the field helps, but they have had no luck with this.

7. Do you have a preferred snow fence type?
    a. If so, why?

Wyoming snow fence because it works right away. Whereas living snow fence it can take up to 20 years to establish and the right trees may not survive due to poor soil quality.

8. Have you encountered any challenges in leveraging snow fences?
    a. If so, have you had any success in overcoming such challenges that you can share?

Willing landowners, getting easements in place. Snow fences do not seem hard to get designed. Having snow fences located on farmers land needs to be profitable, they will lose crop or pasture land.

9. What type of annual maintenance do you conduct on snow fences if there are any in your unit?

There are some living snow fences mostly along I-90. For 10 years the DOT had to maintain them, now the landowner takes care of them. The living snow fences help tremendously. Most were installed in the late 90’s early 2000’s. State DOT planted, then maintained. Now some trees are 10 ft tall. Really like the living snow fence, it just takes a long time to get them big enough and the poor-quality soil can affect survival and growth rates. The DOT reached out to the Soil Conservation office in Murtle and they recommend the trees based on soil types – cedars and rocky mountain junipers.

10. How does your agency train or pass on knowledge of snow fences to other employees?

No formal training or sharing of information. There may be and SDDOT committee looking at snow fences and safety data: Dustin Whit, Safety Engineer.

Aberdeen Area

8/15/24

1. Does your region experience challenges related to blowing snow?

Maps were made where snow blows over roadway. Created maps for the area in a KMZ file.

Tried leaving row crops but did not have many takers, especially because they alternate corn and beans. The snow drifts cause too much water in the fields.

Prioritize sites that plug/block the road overnight 1. Summit along Hwy 12, just west of the interstate (could be a living snow fence option that build off an existing agreement nearby). 2. On 10 west of Leola by the golf course (281 to Eureka). For both of these sites they can plug up overnight. Both are pastures sites so snow fencing could work.

Other issue sites: West side of Groton (Hwy 12 east of Aberdeen) by the body shop, and Andover (near Groton) going up the hill. Then two bridges have issues. Langford is low traffic.

Farmers don't seem to want to have snow fencing on their property so need to factor this into the sites.

Have had trouble with hay bales being stored in the wrong spot or putting hay bales up along fence lines and wanting to get paid but they are not in a trouble spot. Then they have to worked with folks to put them in the right spot or tell them they can be in compensation program. Example, Hwy 10 a guy put bales by the road and it created an issue instead of solving one.

Even a little bit of wind shift can really change where the roads plug up.

   If yes, excluding interstates, please identify (by MRM if possible) where you experience blowing snow challenges.

2. Does your unit use wind forecasts to inform maintenance operations?

Use MDSS and it provides a forecast, used heavily. MDSS will model build up on the roads, and they work with vendor to help improve the models. Melvin – anything over 12 mph will have blowing snow. If the snow has a heavy crust it will start to break and blow at 35 mph. Prevailing wind N/N-W plow and prep accordingly, odd ball scenarios happen and cannot pin-point how to handle. NE wind will give them a lot of trouble if it comes with snow can dump a lot of snow.

   a. If so, how?

3. Has your region ever closed a roadway as a result of the impacts of blowing snow?

40-50 mph winds can cause closing of the interstate. Have not to date closed any secondary highways yet, but likely will.

US 12, 212, 281 had most of the issues, they see higher traffic from Aberdeen to I29. Had some trouble on 10 west of Leola, but this is a lower traffic location so not as high of a priority. Lake City always has wind and folks look at that camera a lot to see what is going on.

4. Where has your region observed above average snow removal costs from blowing snow?

Two winters ago, they had to go back to the legislature to get more money. In the NE part of the state, they spent a lot of money blowing out the ditches to create storage, just part of normal winter maintenance operations. If they get snow, it will stick around still Spring, so it will blow around. Can spend a day creating storage, and then have it filled in in one night.

5. Has your region experienced any pavement repair costs that are believed to be the product of blowing snow?

No but the bridge east of Leola they have trouble with scrapping off the chip seal from during snow removal in part because they use underbody plows. Have a lot of potholes but cannot attribute potholes to blowing/drifting snow. It is flat in the area and have a lot of water (Prairie Pothole land).

Don't see the blowing snow sticking as much when use salt brine as compared to Magnesium Chloride ($MgCl_2$) deicer. They have project working to move the ditches and widen/flatten approaches out to help with storage capacity and reducing snow drifting.

Experience a lot more of blowing snow because of colder temperatures. They do not use much MgCl, they use salt brine and salt.

6. Has your region considered implementing snow fences to address blowing snow problems?

They are open to Wyoming snow fence but do not have any takers yet. Have some living snow fence on Hwy 10 near Leola, 40+ years old. Farmers do not want to leave crop rows, bales, etc. so farmers would likely not want wooden structures in their fields. Would like to try the Wyoming style on Hwy 10 in the grassland area.

Have a large road grading program to widen the right of ways, cutback slopes, etc. to help alleviate some issues. Department wide grading program, statewide construction program for all the reasons. Example, Cody had a road grading project and can say it has helped reduce drifting on the road, but this winter was not a big one, so time will tell.

At another locations they widen a bridge approach and knocked down backslope which helped a lot.

If no, what are barriers to implementing them?

7. Do you have a preferred snow fence type?

Interested in trying Wyoming. Every once in while they will put in temporary snow fence – e.g., Brookings at an intersection. Mitchell region tried guardrail out the field that they take out the spring, will continue to do as long as the landowner is willing. Did a little snow ridging, but not much. Cody did a lot of snow ridging out the Faulk County, works very well, but you are dependent on the landowners allowing it.

Ethanol plant put up some plastic or nylon webbing on wood posts to address snow drifting issues on their property, works for them and does not affect/help the road.

Resigned contracts on living snow fences in 2019, 20-year agreements. The one at Summit could be extended into the other problem area.

Vertical snow fences could be viable option that farmers may be more interested in.

   a. If so, why?

8. Have you encountered any challenges in leveraging snow fences?

   a. If so, have you had any success in overcoming such challenges that you can share?

9. What type of annual maintenance do you conduct on snow fences if there are any in your unit?

10. How does your agency train or pass on knowledge of snow fences to other employees?

Agreements are stored in file directory. But most information is shared with the Maintenance Supervisor.

Huron Area

8/15/24

From crash data, they see the major issues are tied to crops (e.g., which is growing that season, beans or corn).

All crash data is from police reports which is maybe not as good as it should be. Biggest issue is Hwy 28 mm 277-281, cut slopes on the side of the road are high and drifts in, there is not much they can do. Hwy 26 mm 278-271 (if this site is drifting bad, locals will call in), but this site it is very hit and miss, hard to predict if it is going to drift. The amount of snow and conditions they get, the snow gets locked down/fixed by freezing rain (see image below).

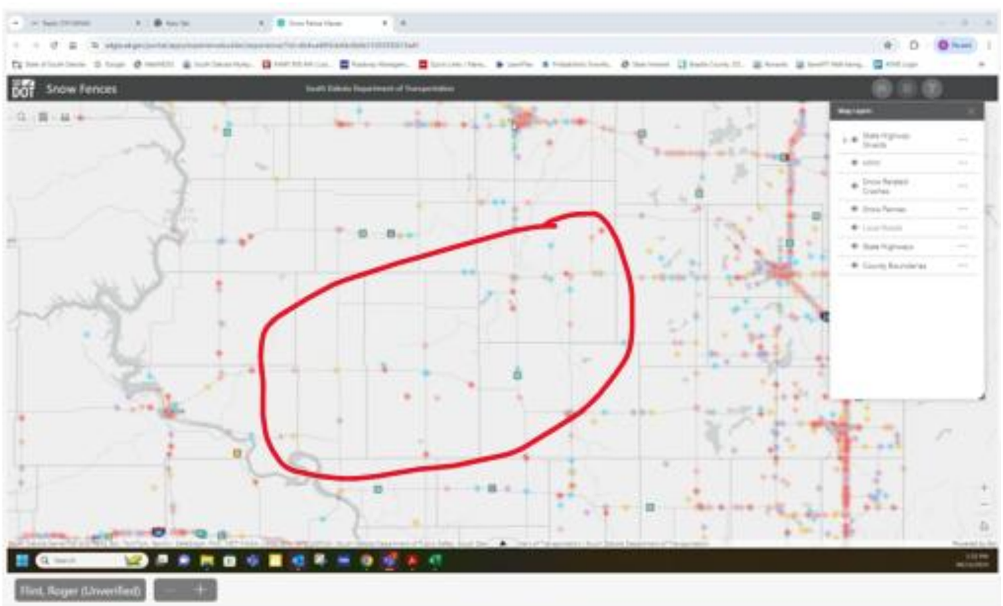


Figure 75: Area of concern in the Huron Maintenance Area for snow and freezing rain.

Two sites with the biggest issues in the image below are: 1) De Smet #2 Hwy 28 mm 319.4-319.9 biggest issue (Bryant Corner is the worst!), 2) Clark #3 Hwy 212 mm 352-352.3 road grading issue. Both sites need to be checked regularly. But really all the places listed are trouble spots.

Blowing Snow Areas (Unit 191)

	Hwy #	MRM	Recommended Solution (Include Side of Road)
Huron			
1	37	136-136.7	During beans nothing catch, then comes off of tree strips WS road
2	14	324-325	Ditch is higher than the road nothing to stop it by WEB water plant
3	14	326.1-333.4	RR tracks, then the HWY sits at a crooked angle and catches snow
4	14	358-362	when beans nothing to catch NS side of the road
5	37	115-1158	Ditch is higher when beens nothing to catch WS road
Clark			
1	212	349.8-350.5	Standing corn Northside of HWY living snow fence Aurthers Buildings
2	212	352.0-352.3	Standing corn Northside of HWY living snow fence West of GCI
3	212	352.0-352.3	Beans Northside field is higher than road. snow fence Deckers Hill
4	20	368.0-368.3	trees on both sides of road snow fence in field Wedge east of Bradley
5	28	285.99-285.99	
De Smet			
1	14	398.8-399.35	standing corn north side of HWY tank farm area
2	28	319.4-319.9	standing corn west side of HWY bryant corner hill
3	25	127-127.8	standing corn west side of HWY prairie retreat hill
4	14	390-390.9	standing corn north side of HWY gevo and up the hill
5	25	96.5-96.85	standing corn west side of HWY abortion sign area

Figure 76: A list of blowing snow problem areas for SDDOT Unit 191.

1. Does your region experience challenges related to blowing snow?

(see above)

   a. If yes, excluding interstates, please identify (by MRM if possible) where you experience blowing snow challenges.

2. Does your unit use wind forecasts to inform maintenance operations?

If the wind is going to blow hard enough to blow snow they won't salt. With light winds they will plow and then plan accordingly. If winds are 25 mph or more, blowing snow will not stick on the road and will then focus efforts on sheltered areas, etc.

It is not necessarily the wind direction that is the issue, it is more wind speed. Also road temperatures can warm up and blowing snow can stick. When winds are 30 mph they have visibility issues and drifting. Snow type is important too in terms of if it will blow/drift or not. It is a complicated issue.

   a. If so, how?

3. Has your region ever closed a roadway as a result of the impacts of blowing snow?

Can advise no travel, but don't close roads. Will list road as blocked, impassable on 511, find alternate route; likely due to traffic on road or visibility. Work with Emergency Manager.

They seemed unaware of the change in law to allow roads to be closed.

4. Where has your region observed above average snow removal costs from blowing snow?

Yes, they need to work extra hours for two sites (DeSmet #2 and Clark #3). The Hwy 28 section is really bad and costs them extra, but it's slated to be fixed. They have no way to track the extra costs right now, but did ask the state if they could create a snow drift cost tracking option.

5. Has your region experienced any pavement repair costs that are believed to be the product of blowing snow?

No.

6. Has your region considered implementing snow fences to address blowing snow problems?

Do not really have any snow fences. It depends on which crops are planted and landowners wanting to participate in leaving standing corn rows. Does not know the program very well.

Near Hwy 37, had beans that year (4.5 miles). Farmers did not want to participate because they had already put in fertilizer so did not want to disturb the soil. Did not allow windrowing (ridging). Hwy 45 south of Miller had farms that left standing corn on both sides of the road and caused snow to stay in place where they didn't want it due to a lack of wind. Caused more of a problem by leaving corn stands in the wrong place.

Have not really considered snow fences. Not familiar with what that process looks like. They are more reactive right now because next year corn will be planted. The roads with issues are long stretches, 0.5 miles. Feels like building snow fence this long would not be cost effective. Have had farmers not want the snow melt water on the field.

In one spot he tried to get a farmer to put bales in, did not work out due challenges getting landownership permission, and the cost of the bales was too much.

   a. If no, what are barriers to implementing them?

7. Do you have a preferred snow fence type?

Does not really have areas that are that bad to need a long fence. Not really interested. Use the loader mounted snow blowers and clean out the ditches for snow storage, can work for a day or two or up to a week, depends on the weather.

Does not know if they have looked at snow fencing. Has done some snow ridging, but it doesn't last long and leaves too much water in the fields.

   a. If so, why?

8. Have you encountered any challenges in leveraging snow fences?

Have not really tried. The only option he was aware of was the plastic snow fencing.

   a. If so, have you had any success in overcoming such challenges that you can share?

9. What type of annual maintenance do you conduct on snow fences if there are any in your unit?

NA

10. How does your agency train or pass on knowledge of snow fences to other employees?

Training fill out 320 form, ride-along program for 40 hours in the passenger seat to learn how to run routes, about problem area, etc.

There is some information in the maintenance manual but do not really use much.

Watertown Area

7/15/24

1. Does your region experience challenges related to blowing snow?
   Area unique due to a ridge of hills with constant blowing areas (90% of the time) along a 15 mile stretch. Pastureland that you cannot do any ridging, continuously blows. I-29 Grant and Roberts County 219-204 is the worst; Buffalo ridge angles from north of summit to Lake Batten, Minnesota. Have snow fence up by Geary at the Minnesota border (380-408 on Hwy 212, north winds), and near Toronto, Hwy 10 345-350 west of Waterton long hallow west. Hwy 20 to 15, others? They will print map and circle/identify blow snow locations on the map and rank by issue/importance. Will scan and provide to us.

   a. If yes, excluding interstates, please identify (by MRM if possible) where you experience blowing snow challenges.
2. Does your unit use wind forecasts to inform maintenance operations?
   a. If so, how? Yes, use wind forecasts, and this will really affect deicer applications. Deicers on the road can cause blowing snow to stick to the road and make it icy.
      Blowing snow issues start to occur at 14 mph out of the south-west, usually when they say 14 mph its actually 24 mph, so yeah 14 mph. They question what MDSS is reporting because it seems off by about 10 mph. They don't understand why because they have weather stations and cameras in the area. They have made them aware of the issue. Asked MDSS to fix issues with wind speed data, but also the NWS (National Weather Service) wind was off by 10 mph. The area where it is an issue is a pocket of the state. They have the data/weather sensors, but it seems it's not being used. They also noted that they would like for the MDSS routes to be shorter and to provide consistent recommendations (e.g., one road may have a recommended deicer treatment, but a road running parallel to it or that in proximity to it may have no treatment recommendation, why?

3. Has your region ever closed a roadway as a result of the impacts of blowing snow?
   Generally, do not close road but would due to poor visibility. Typically, only close the road if its going to plug/drift across. They have closed roads a couple of times in the last few years. Would shut a road down for a longer period of time due forecasts. Last year was the first time they would have been able to close a local road but did not need to, based on legislative action. Legislative change occurred due to issues from the severity of the previous winters storms.

4. Where has your region observed above average snow removal costs from blowing snow?
   Where blowing snow occurs they have to do a lot of maintenance/push back (areas mentioned above in Q1). At some sites they may have to go twice a week. Once the ditches are full they have issue with snow storage and drifting occurs.

5. Has your region experienced any pavement repair costs that are believed to be the product of blowing snow?
   Not so much pavement deterioration, just really the winter costs of removing the snow. Salt causes damage roads. Have both asphalt and concrete, interstate and a few state highways are concrete, but the remaining are asphalt (75% asphalt, 25% concrete on local highways (Hwys 12, 212, 14 have portions of concrete).

6. Has your region considered implementing snow fences to address blowing snow problems?
   Like Wyoming snow fence, want to try and think would be big enough. Have tried living snow fence. Very limited reaction from the farmers. Pastureland would be great for Wyoming fence. With corn rows they are usually planted the wrong direction to use for snow fencing, so doesn't seem to work in their area. The snow stored by the snow fences can cause wet spots in the farm field which is not good. Have tried many variation of snow fences, some parts of the state have had more luck than others. Cannot go out and ridge snow each year on the pastureland due to rocks, need annual permissions, etc.

   Snow capacity needed about 10+ft, so a Wyoming snow fence will work.

   If no, what are barriers to implementing them?

7. Do you have a preferred snow fence type? Wyoming, living snow fence will likely not work due poor soil and will likely not be wanted by farmers due to loss of pasture land. It is likely leaving crops is not feasible due to alternating corn/beans and farmers giving each other a hard time about not clearing their field, snow storage on field causing water issues, etc.
   a. If so, why?
8. Have you encountered any challenges in leveraging snow fences? Currently use and have had good luck with temporary snow fence with short runs of temporary fence (3-4 ft orange plastic or corn cribbing) and then use the collected snow to ridge. Temporary because it is farmland. Asked them to identify temporary location on the map.
   a. If so, have you had any success in overcoming such challenges that you can share?
9. What type of annual maintenance do you conduct on snow fences if there are any in your unit?
   Annually put and take down temporary snow fencing. Maintenance is that the temporary snow fences only last so many years, corn cribbing lasts longer (3+ years).

10. How does your agency train or pass on knowledge of snow fences to other employees?
    Have done online snow fence training (NDSU Effective Snow Fences - https://www.ndltap.org/resources/downloads/snow-fence-guide.mp4; NDSU Snow Fence Guide - https://onlinepubs.trb.org/onlinepubs/shrp/shrp-h-320.pdf). Training covers

everything from types of snow fences, now to use, etc.; have all taken this training. But really they know the trouble spots and direction they need put it in based on observations. At each shop everyone goes out and works on it, so the information gets passed down by doing the work.

Mitchell Area

8/26/24

1. Does your region experience challenges related to blowing snow?

We have issues on both interstate and local roads. The SDDOT Interstate project only identified a handful of sites, maybe only 10. They have some regions/section of interstate with issues that need to be addressed still.

Biggest blow snow issues in the state in their area. They will have close to 90 sites ID'd. Will send a list over.

   a. If yes, excluding interstates, please identify (by MRM if possible) where you experience blowing snow challenges.

2. Does your unit use wind forecasts to inform maintenance operations?

Oh yeah, if they see strong winds will not apply chemicals because it will cause more problems. Depends on the snow, if wet snow can go with higher wind speed; if a dry snow, then 10 mph.

Wind directions affect different areas differently. Have a lot of NW wind and plow to play the wind.

   a. If so, how?

3. Has your region ever closed a roadway as a result of the impacts of blowing snow?

Unless blocked, no. Need approval to close interstate. They now have authority to close state roads, but in the past would post roads closed as No Travel Advised (511 – blocked), not an enforced closure. Did that on Hwy 44 last winter once. Will likely see more of that. Have issues of folks using parallel state roads when the highways are closed.

4. Where has your region observed above average snow removal costs from blowing snow?

I'm sure once we have to take a blower out. A few years ago spent a lot of time on Hwy 34 blowing out the shoulders to create snow storage capacity.

Hwy 44 has 6 bridges, and the road can be good until you get to a bridge and then you'll see drifting on them. All of these sites (bridges) are high on his list for snow fence. Spend a lot of time and money to go out and have to hit those spots (e.g., they are running this route sometimes only to treat the bridges). Need to run a 50 miles route for the bridges. Otherwise, would not need to go out to these sites. Have tried some corn cribbing and they are talking about portable snow fence at these sites.

They have trouble convincing land owners to allow the DOT to work on their property. Leaving something permanent is a no-no here. Have left standing corn but it depends on the year. Have corn/bean farming cycle. Bean years have issues with drifting.

Portable snow fences feel like the only option really.

5. Has your region experienced any pavement repair costs that are believed to be the product of blowing snow?

No

6. Has your region considered implementing snow fences to address blowing snow problems?

Yes

   a. If no, what are barriers to implementing them?

7. Do you have a preferred snow fence type?

Perma rail? Cable style install, a permanent installation. Farmers don't want permanent.

Temporary – corn rows, corn cribbing, w-beam

Ideally would be living snow fence, but convincing landowners is tough. They work Excellent. Work for 20 years, then require some maintenance. Farmland is so valuable, can't pay them enough (worth $10-$35K an acre) but also some folks don't want it broken up and others don't want the hassle of working around them. The majority of farmers are local.

   a. If so, why?

8. Have you encountered any challenges in leveraging snow fences?

Yes, don't want on farmland. Temporary snow fence is likely the best option.

   a. If so, have you had any success in overcoming such challenges that you can share?

9. What type of annual maintenance do you conduct on snow fences if there are any in your unit?

Have corn cribbing, which requires a lot of maintenance to install in fall and take out as early in the spring. Farmers want it out quick and early in the spring, so its muddy.

Look to make more portable snow fence, like for cattle, set in field.

Last winter made a portable snow fence 3 rows high of w-beam guard rail that they had on hand. Rail is 25 ft in length, haul out and set in field. Avoid pounding posts with the w-beam. Feel it would be quicker and easier, and maybe get more farmers on board. They got this idea from Sioux Falls.

10. How does your agency train or pass on knowledge of snow fences to other employees?

Talk to landowner to get buy in, usually once one is in, more will come. Hand out the SDDOT flier. Struggle with how much to pay them, there is some structure. Struggle with payment when they put posts in field; if they are going to pay one, they should pay them all. Setting up agreements can take time, getting the W9 filled out correctly, etc. They don't do this a lot so maybe they need to be better about explaining what needs to be done. For the corn cribbing, it is all based on a handshake agreement, no formal contract or payment at this time.

Modification to the flier – does not really have portable snow fence options provided.

The local person needs to do the agreements. If it were someone regional, or from the Capital, the farmers would likely not consider it.

Yankton Area

7/17/24

1. Does your region experience challenges related to blowing snow?

A pdf with blowing/drifting snow hot spots was sent (see below), 10 year old document that is still relevant. Likely needs to be updated but is a good start. Will look at the document to see what sites are still the same.

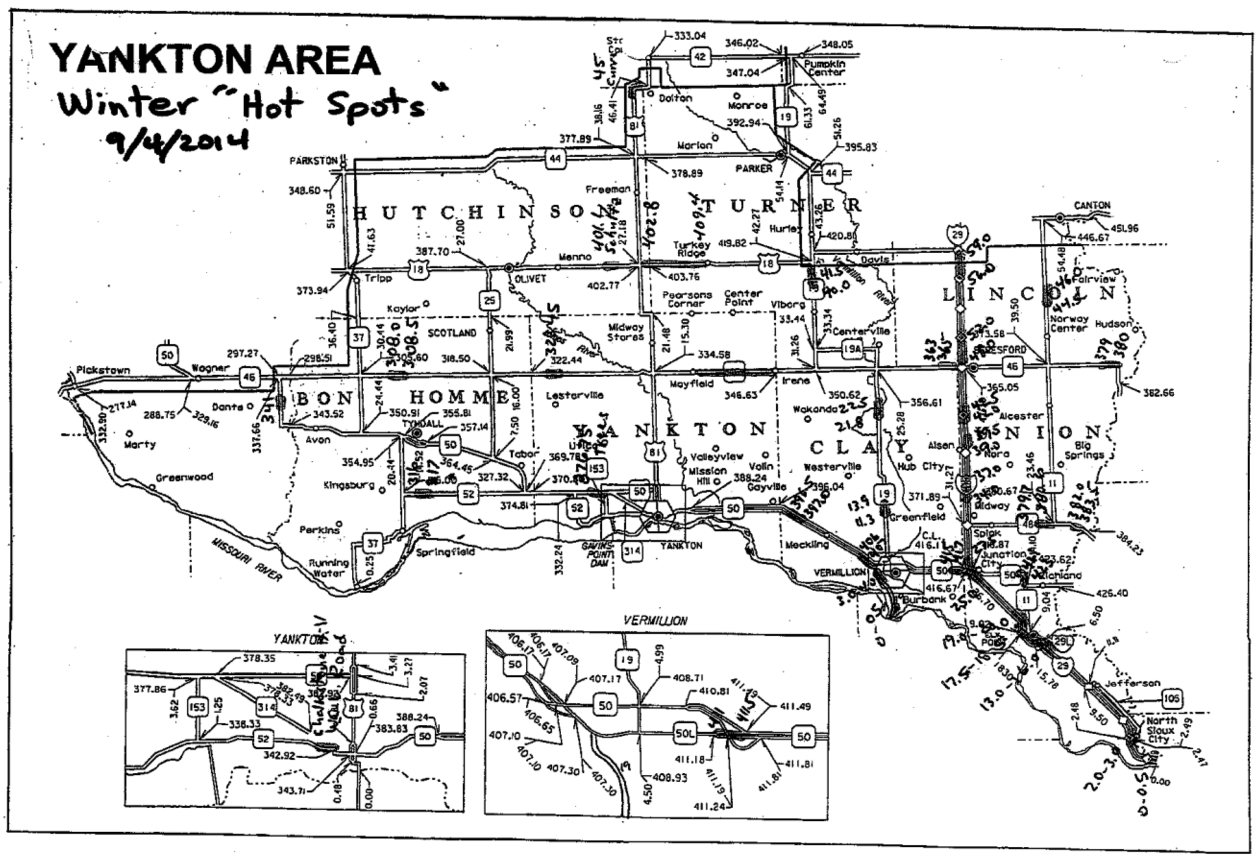


Figure 77: Winter "Hot Spots" in Yankton Area as noted in 2014.

At one site planted some willows on the west fence line and that really helped, on I-29 mm 42N to 45N, a 3 miles stretch. Planted 4 or 5 years ago, it took a while to establish, but now the willows are 4-5 ft tall and they really noticed a difference. They guys really like the willows, some have died off and they want to replant.

Do not have a lot of snow fences, have some living snow fences but they are old. In the past they have talked with farmers about putting hay bales by the road (I-29 but never did), but this last year no farmers were interested. Alternating crops, corn and bean, means that in a bean year don't have tall corn stalks to leave standing.

Hwy 11 mm 44.5-46, only about a half mile in there, farmer put hay bales that he lined up on this own but was not coordinate with the DOT. Worked well as a snow fence but not sure if done on purpose.

Hwy 50 (Taber to Tindle), N side the railroad parked some old crude oil cars rail cars, and they worked as snow fences. Hwy 50 (415-417 (note sure if these are road numbers or mm)) had corn stalks standing for about a half mile and really worked, only did one year and then the farmer did not want to do again. Corn stalks were located just west of the junction of Hwy 50 and Hwy 29 and went for the first 0.5 mile.

Compensation – would have to look it up. Pay for the bushels double estimate for the field and then could harvest still in the spring. Either double or triple what the corn is worth. They have heard of boy scouts going in the spring to pick the standing corn.

To contact farmers adjacent to the roads they just call them directly to set it up. But not with a lot of luck.

Have not done any temporary snow fencing but do use snow ridging. They talk to landowners to allow snow ridging on their land. Snow ridging is done: I-29 W toward Vermillion, Hwy 81 mm 45.

One living snow fence green on map provided by researchers, Hwy 50 east of Vermillion, paid to put in and contract with landowner that is paid annually. More living snow fences are shown on the map, but they are not paying on them, so they are unsure of the status. Maybe check in on these.

Asked to label map with top 10 sites.

   a. If yes, excluding interstates, please identify (by MRM if possible) where you experience blowing snow challenges.

2. Does your unit use wind forecasts to inform maintenance operations?

Wind plays into the equation, at times when wind is forecasted, they will not treat the roads because it will cause snow to stick. If it is going to be really windy they will just plow. Wind direction can really be important, but yes wind is always on their mind. No specific threshold for wind.

Northwest, west wind really gets them on N-S roads. Same for the whole area. If they get a southernly breeze, they are usually warmer so does not cause issues.

   a. If so, how?

3. Has your region ever closed a roadway as a result of the impacts of blowing snow?

The only road officially closed was I-29, but that was a long time ago. Can now officially close local and state roads. They have been lucky and did not have as bad of weather as other parts of the state. They are called the "banana belt."

4. Where has your region observed above average snow removal costs from blowing snow?

No, not really. Once in a while they will contract out a maintainer with a big wing to clean things up. Hired a local guy, he ran a few routes pushing back drifts. Paid him $160-$170 an hour, contract was $25,000 but did not use him for that amount. This was the big year, with 60+ inches of snow, so not typical. Do have their own road graders, blowers, etc. so have a lot of equipment.

Overall, do not get a big snow base on the ground, tend to be warmer than areas North, so that helps. Obviously, it depends on the winter. The 3.5 weeks of winter they did have this last year were the worst they have seen in a long time, but then the rest of winter was mild.

5. Has your region experienced any pavement repair costs that are believed to be the product of blowing snow?

No, more issues from the freeze-thaw cycles. Had to dig out a ditch a few years ago because it was draining on to private land but this did not affect the roadway.

6. Has your region considered implementing snow fences to address blowing snow problems?
    a. If no, what are barriers to implementing them?

Snow fence has been a hot topic for his 3 years in the position statewide, but have not received a lot of direction, and they are not sure if funds available. Need to factor in grain prices to get land from a farmer. Almost need to put the snow fences in the right-of-way for it to work. The eastern half of SD is all farm land that they don't want to give up. There has not been a big push to reach out more farmers. Land is currently selling for $15k-$20k an acre.

Mitchell Area have a lot of issues with blowing snow and have been better about reaching out the farmers more along the I-90.

7. Do you have a preferred snow fence type?
    a. If so, why?

A snow fence with no maintenance, like living snow fence, don't own/don't maintenance. If you build a wooden snow fence you have to maintain it. Don't want that. Living snow fence is their preference. Would rather chase snow drifts than maintain a wooden snow fence.

Willow or trees to create a shelter belt. It would depend on the location.

8. Have you encountered any challenges in leveraging snow fences?
    a. If so, have you had any success in overcoming such challenges that you can share?

No real challenges. Have not asked too many farmers over the years, only a handful. The amount of money they get is not worth the spring time effort. Had folks question why corn rows were left up.

9. What type of annual maintenance do you conduct on snow fences if there are any in your unit?

Right now, maintenance includes mowing around the willows, go out and replant some willows that died. This is the only spot they have to maintain. The conservation office planted the willow originally, but they will maintain them.

Other living snow fence sites are on private property. One specific living snow fence was put in before them (25 years old) and is ¼ to ½ mile long. The new property owner reached out, so they pay him to keep it. There is a wetland.

The interstate right of way is really wide, so planting at the fence line works. But for a narrow right of way, it won't work.

10. How does your agency train or pass on knowledge of snow fences to other employees?

Statewide conveying of information about snow fences, but knowledge of existing snow fences came from the Maintenance Managers. No formal snow fence training is provided, and they don't feel they need it. There is pamphlet the state made on snow fences for landowners.

How to communicate with landowners? The farmer was not paid until April so the farmer was not happy about that, but they do this to make sure they keep the corn rows there all winter. Be clear and up front about that. No formal training on communication.

Sioux Falls Area

7/16/24

1. Does your region experience challenges related to blowing snow?

    a. If yes, excluding interstates, please identify (by MRM if possible) where you experience blowing snow challenges.

Hwy 29 mm 114-120, quite a few areas through there that blow in, the snow gets deep there. Does a lot of snow ridging done in that area. Built some portable snow fence that was used there. Worked really well and hope to build more of those. Use old W beam guardrail, seemed to work and the guys were really impressed with what it did. On Hwy 29 working to get more portable snow fencing. Using a loader or skid steer to move the portable W beam snow fencing. Using 25 ft full stick W beams, learned how to build with spacing from roadway based on Wyoming work - W beam gaps and spacing. Very small snow year this last year but was very helpful. Last year was first year that they tried, made and used 100ft and it really helped. Will provide photos, cost about $60 for each panel, already paid for the W beam. And will send photos of snow ridging.

Talked to landowners about using standing row crops and hay bales for snow fencing but there was little to no interest from landowners. But they were very open to the portable snow fence option. Had one guy that put up hay bales, but his land was sold off so no longer an option at that site. On the secondary routes do a lot of snow ridging using a dozer to push back snow in that area.

Hwy 89, 19, 13 don't see as much snow.

Hwy 11 mm 91-102 (north from "Garretson" to Minnesota state line, open fields) get drifts 4-6 ft across the road, blocked or down to 1 lane due to drifting. Usually go in here and use the blower.

Hwy 38 mm 348.9-358 (Sioux Fall west to Humboldt) west bound side catches worst, get blocked or down to 1 lane. Ditches and hills are higher than the road. Snow fencing may not work here due to hillsides

Hwy 115 from 273rd street to 271st street, issues in the south bound lanes from wind.

Hwy 11 in the city of Brandon, from Aspen St. to Madison St. (272 to 273?), get a big berm on the east side of the road, gets plugged all the way across.

Hwy 18 is under total reconstruction, going from a 2 lane and 4 lane raised concrete with median. There are criteria in the new road design for blowing snow to prevent building back slopes that are too steep to help, but there are not specific design elements to manage blowing/drifting snow. Hwy 18 is flat but with a lot of the trees being on private land that cannot be removed. The raised center media could affect snow storage. Working to keep the ditches as wide as possible for snow storage. It's so flat in Lincoln county. Project likely not done till 2026. Note this location as WATCH, potential future snow fence need.

Same issue on Hwy 42 east, with a total reconstruction in the next few years, similar to Hwy 18. A lot of clearing will occur. With the center median they will likely have snow issues. Not sure what future issues will be. Likely not done until 2028. Note this location as WATCH, potential future snow fence need.

2. Does your unit use wind forecasts to inform maintenance operations?

    a. If so, how?

Yes, use wind forecast in terms of how and what they will treat. At colder temps will not treat, and instead will allow snow to blow over and then just plow. In some cases, will put deicer on the shoulder to trap the blowing snow. Use pre-wet salt on the shoulder in this instance. Only use salt brine with beet heat in Sioux Falls.

Watch wind data and forecasts but it depends on the type of snow and if sun if present. For example, a light (low water content) snow on a cold day, with wind as little as 10 mph can cause problems. But if it is sunny, then snow may stick. Wind, temps, sun, are all used to make the decision, a more dynamic process than simply when wind is greater than 15 mph need to watch for blowing snow.

3. Has your region ever closed a roadway as a result of the impacts of blowing snow?

Two years ago had to close I-90 due to visibility issues with a big storm. Could not even see the road. On Hwy 29 north had issues but fought through it. Change in legislation to close local roads did not really affect them, due to small winter snow this last year. The biggest issues seen in some areas are folks leaving I-90 and heading to local roads because they are open, which helped prompt changing policy to close local/state roads.

Extended plow hours from Sioux Falls to Brooking, and a nighttime loop I-90, I-29, I-229. 4 am to 8pm for normal crew, then night crew on the interstate till midnight, then the loop from midnight till 4am.

4. Where has your region observed above average snow removal costs from blowing snow?

Yes, higher costs can happen in bigger years. 2 years ago, hired private contracts with blades with wings to help move the snow at a cost of $50,000 to run across all routes in one district, took 2 weeks to clear. This snow event, came and the snow stayed, was unrelenting, storage capacity was maxed out

5. Has your region experienced any pavement repair costs that are believed to be the product of blowing snow?

No, not directly from the blowing snow. See some guard rail hits, etc., have a guard rail repair contract. Use mostly cable guard rail. Have had flooding issues from the melting snow, has caused issues with ditches and slopes, but not the road or road base.

6. Has your region considered implementing snow fences to address blowing snow problems?

    a. If no, what are barriers to implementing them?

Would like to try snow fencing on Hwy 29 mm 115-120 area, like fast growing willows along the fence line. The snow drifts get deep there. Likely sufficient natural water to support this.

At another site had some type of brush, close growing trees, but too close to interstate and they created bigger drifting issues so removed last year. Have not seen if this will help.

Had some living snow fence contracts with landowners, right by Hartford along I-90; but none along local routes or state highways.

7. Do you have a preferred snow fence type?

    a. If so, why?

Have a narrow right of way so this is an issue. It is likely the landowner will not do a living snow fence, in part because the DOT cannot pay at a competitive price. The best option is the temporary/ portable snow fence and snow ridging. Landowners are not interested in permanent structures.

Crops along roads – corn, beans

One farmer left standing rows for one year and said it wasn't worth it, even with getting paid market price + $3. Cannot get folks interested. How they plant, corn rows going in the wrong direction. Farmers did not want to go back in and deal with it in spring before they plant. Not worth the effort.

8. Have you encountered any challenges in leveraging snow fences?

    a. If so, have you had any success in overcoming such challenges that you can share?

Put up some temporary orange snow fence in the past, three straps fences, regional engineer has been open to them trying things as long as the land owner is open to it. Have not come across a lot of options. W beam snow fences seem like the best option right now.

Because of the landowners they need to use temporary snow fencing that is cost effective – orange plastic snow fence, W beam snow fence.

9. What type of annual maintenance do you conduct on snow fences if there are any in your unit?

With the temporary W beam, last year was the first year so no maintenance was required. For living snow fence, maintenance will include removal if a plant dies. With the orange snow fence, they will leave posts in place sometimes but then see mowing issues. Orange snow fence last max 3 years and needs replacement.

10. How does your agency train or pass on knowledge of snow fences to other employees?

Have a high turnover rate, different person on a route every 2 years. Use word of mouth to ID trouble areas, but the new guys figure it out after the first few storms. Have had a few staff attend classes on snow fences. Do not have a formal map with snow fence area, drifting snow areas. They figure it out as they drive.

Did feel like the snow fence training was helpful with design and installation of the temporary snow fencing.

Appendix C: Blowing Snow Problem Areas

Each SDDOT maintenance area was asked to rank its identified blowing snow problem areas in order of priority. Table 32 – Table 43 provide details of these problem areas, organized by maintenance area.

Aberdeen Area

Table 32: All blowing snow problem areas identified by the Aberdeen Maintenance Area.

Name	Hwy	Maintenance Area	Length (Miles)	Begin MRM	End MRM	Area Priority
Hwy 20, MRM 318.22-318.56	Hwy 20	Aberdeen Area	0.33	318.22	318.56	1
Hwy 12 W, MRM 363.69-364.31	Hwy 12	Aberdeen Area	0.55	363.69	364.31	2
Hwy 12 W, MRM 364.51-364.76	Hwy 12	Aberdeen Area	0.26	364.51	364.76	3
Hwy 12 W, MRM 364.96-365.19	Hwy 12	Aberdeen Area	0.23	364.96	365.19	4
Hwy 12 W, MRM 365.59-366.01	Hwy 12	Aberdeen Area	0.42	365.59	366.01	5
Hwy 12 W, MRM 363-363.06	Hwy 12	Aberdeen Area	0.06	363	363.06	6
Hwy 12 W, MRM 361.66-362.76	Hwy 12	Aberdeen Area	1.10	361.66	362.76	7
Hwy 12 W, MRM 360.62-361.26	Hwy 12	Aberdeen Area	0.64	360.62	361.26	8
Hwy 12 W, MRM 360.1-360.16	Hwy 12	Aberdeen Area	0.06	360.1	360.16	9
Hwy 12 W, MRM 359.04-359.55	Hwy 12	Aberdeen Area	0.50	359.04	359.55	10
Hwy 20, MRM 318.75-319.08	Hwy 20	Aberdeen Area	0.32	318.75	319.08	11
Hwy 20, MRM 321.13-321.58	Hwy 20	Aberdeen Area	0.45	321.13	321.58	12
Hwy 20, MRM 311.67-312.36	Hwy 20	Aberdeen Area	0.68	311.67	312.36	13
Hwy 10, MRM 243.72-243.79	Hwy 10	Aberdeen Area	0.08	243.72	243.79	14
Hwy 10, MRM 244.21-244.27	Hwy 10	Aberdeen Area	0.07	244.21	244.27	15
Hwy 10, MRM 245.28-245.35	Hwy 10	Aberdeen Area	0.07	245.28	245.35	16
Hwy 10, MRM 245.62-245.65	Hwy 10	Aberdeen Area	0.02	245.62	245.65	17
Hwy 10, MRM 246.64-246.69	Hwy 10	Aberdeen Area	0.05	246.64	246.69	18
Hwy 10, MRM 246.82-246.84	Hwy 10	Aberdeen Area	0.02	246.82	246.84	19
Hwy 10, MRM 237.64-237.74	Hwy 10	Aberdeen Area	0.10	237.64	237.74	20
Hwy 10, MRM 237.78-237.83	Hwy 10	Aberdeen Area	0.05	237.78	237.83	21
Hwy 10, MRM 237.91-238.06	Hwy 10	Aberdeen Area	0.16	237.91	238.06	22
Hwy 10, MRM 238.21-238.46	Hwy 10	Aberdeen Area	0.25	238.21	238.46	23
Hwy 10, MRM 238.67-238-74	Hwy 10	Aberdeen Area	0.07	238.67	238.74	24
Hwy 10, MRM 238.9-238.95	Hwy 10	Aberdeen Area	0.05	238.9	238.95	25
Hwy 10, MRM 239.47-239.6	Hwy 10	Aberdeen Area	0.13	239.47	239.6	26
Hwy 10, MRM 239.79-239.9	Hwy 10	Aberdeen Area	0.11	239.79	239.9	27
Hwy 10, MRM 240.38-240.42	Hwy 10	Aberdeen Area	0.04	240.38	240.42	28
Hwy 10, MRM 241.02-241.05	Hwy 10	Aberdeen Area	0.03	241.02	241.05	29
Hwy 10, MRM 248.81-248.91	Hwy 10	Aberdeen Area	0.10	248.81	248.91	30
Hwy 10, MRM 249.21-249.23	Hwy 10	Aberdeen Area	0.02	249.21	249.23	31
Hwy 10, MRM 249.98-250.05	Hwy 10	Aberdeen Area	0.08	249.98	250.05	32
Hwy 10, MRM 250.11-250.17	Hwy 10	Aberdeen Area	0.06	250.11	250.17	33
Hwy 10, MRM 251.04-251.13	Hwy 10	Aberdeen Area	0.08	251.04	251.13	34
Hwy 10, MRM 251.39-251.52	Hwy 10	Aberdeen Area	0.13	251.39	251.52	35
Hwy 10, MRM 251.61-251.71	Hwy 10	Aberdeen Area	0.09	251.61	251.71	36
Hwy 10, MRM 252.66-252.62	Hwy 10	Aberdeen Area	0.06	252.56	252.62	37
Hwy 10, MRM 252.71-252.75	Hwy 10	Aberdeen Area	0.05	252.71	252.75	38

Name	Hwy	Maintenance Area	Length (Miles)	Begin MRM	End MRM	Area Priority
Hwy 10, MRM 255.19-255.37	Hwy 10	Aberdeen Area	0.18	255.19	255.37	39
Hwy 10, MRM 255.8-255.82	Hwy 10	Aberdeen Area	0.03	255.8	255.82	40
Hwy 10, MRM 255.84-255.88	Hwy 10	Aberdeen Area	0.04	255.84	255.88	41
Hwy 10, MRM 255.96-256.02	Hwy 10	Aberdeen Area	0.03	255.96	256.02	42
Hwy 10, MRM 256.17-256.2	Hwy 10	Aberdeen Area	0.04	256.17	256.2	43
Hwy 10, MRM 256.44-256.57	Hwy 10	Aberdeen Area	0.13	256.44	256.57	44
Hwy 10, MRM 257.28-257.33	Hwy 10	Aberdeen Area	0.05	257.28	257.33	45
Hwy 10, MRM 257.41-257.43	Hwy 10	Aberdeen Area	0.02	257.41	257.43	46
Hwy 10, MRM 257.47-257.66	Hwy 10	Aberdeen Area	0.19	257.47	257.66	47
Hwy 10, MRM 257.77-257.84	Hwy 10	Aberdeen Area	0.07	257.77	257.84	48
Hwy 12 W, MRM 346.17-346.18	Hwy 12	Aberdeen Area	0.03	346.17	346.18	49
Hwy 12 W, MRM 348.89-348.98	Hwy 12	Aberdeen Area	0.10	348.89	348.98	50
Hwy 12, MRM 349.24-349.38	Hwy 12	Aberdeen Area	0.14	349.24	349.38	51
Hwy 12, MRM 352.55-352.6	Hwy 12	Aberdeen Area	0.05	352.55	352.6	52
Hwy 12, MRM 352.77-352.81	Hwy 12	Aberdeen Area	0.04	352.77	352.81	53

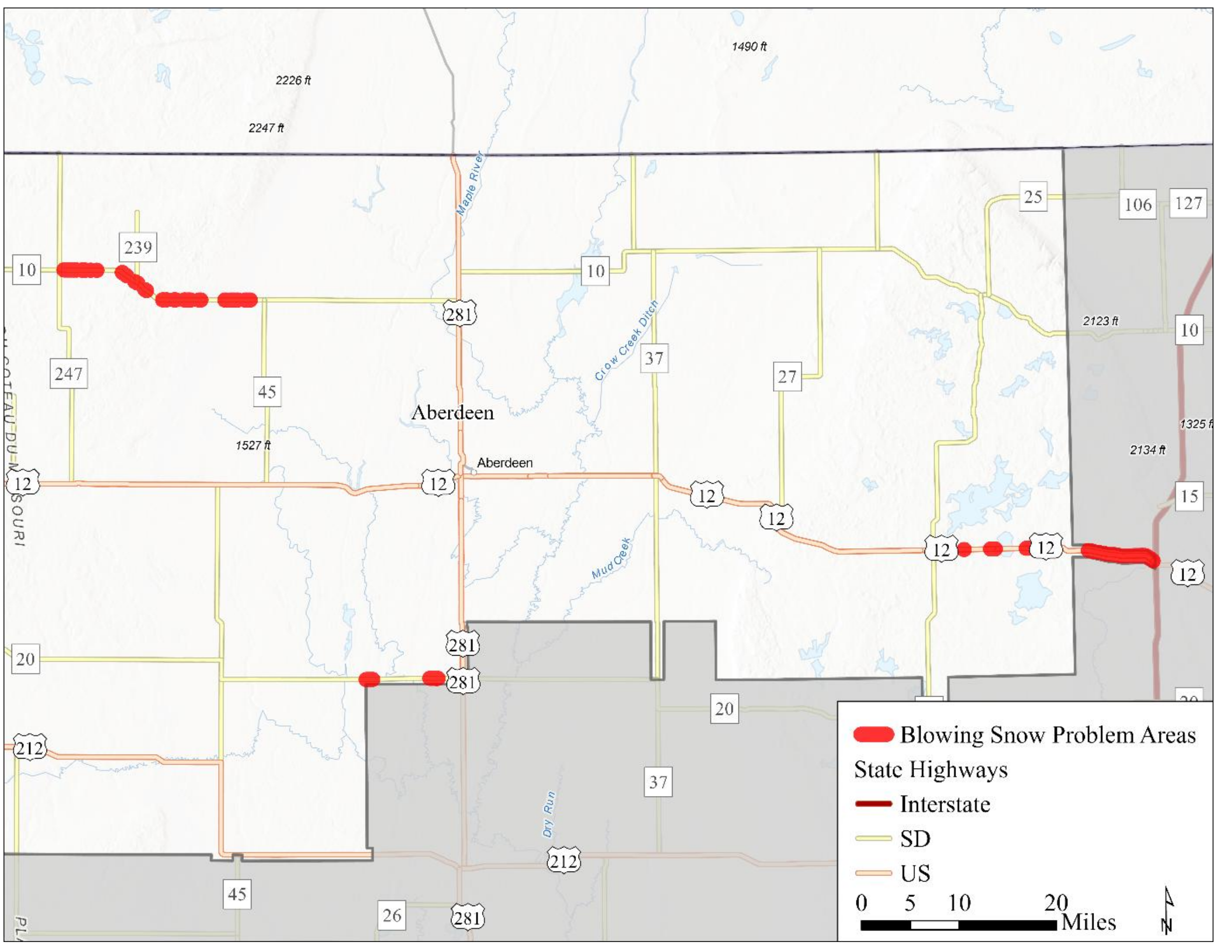


Figure 78: Map of the Aberdeen blowing snow problem areas mapped as red dots.

Belle Fourche Area

Table 33: All blowing snow problem areas identified by the Belle Fourche Maintenance Area.

Name	Hwy	Maintenance Area	Length (Miles)	Begin MRM	End MRM	Area Priority
Hwy 73, MRM 196	Hwy 73	Belle Fourche Area	0.09	195.95	196.05	1
Hwy 34, MRM 23-25	Hwy 34	Belle Fourche Area	1.99	23	25	2
Hwy 20, MRM 2-3	Hwy 20	Belle Fourche Area	0.95	2	3	3

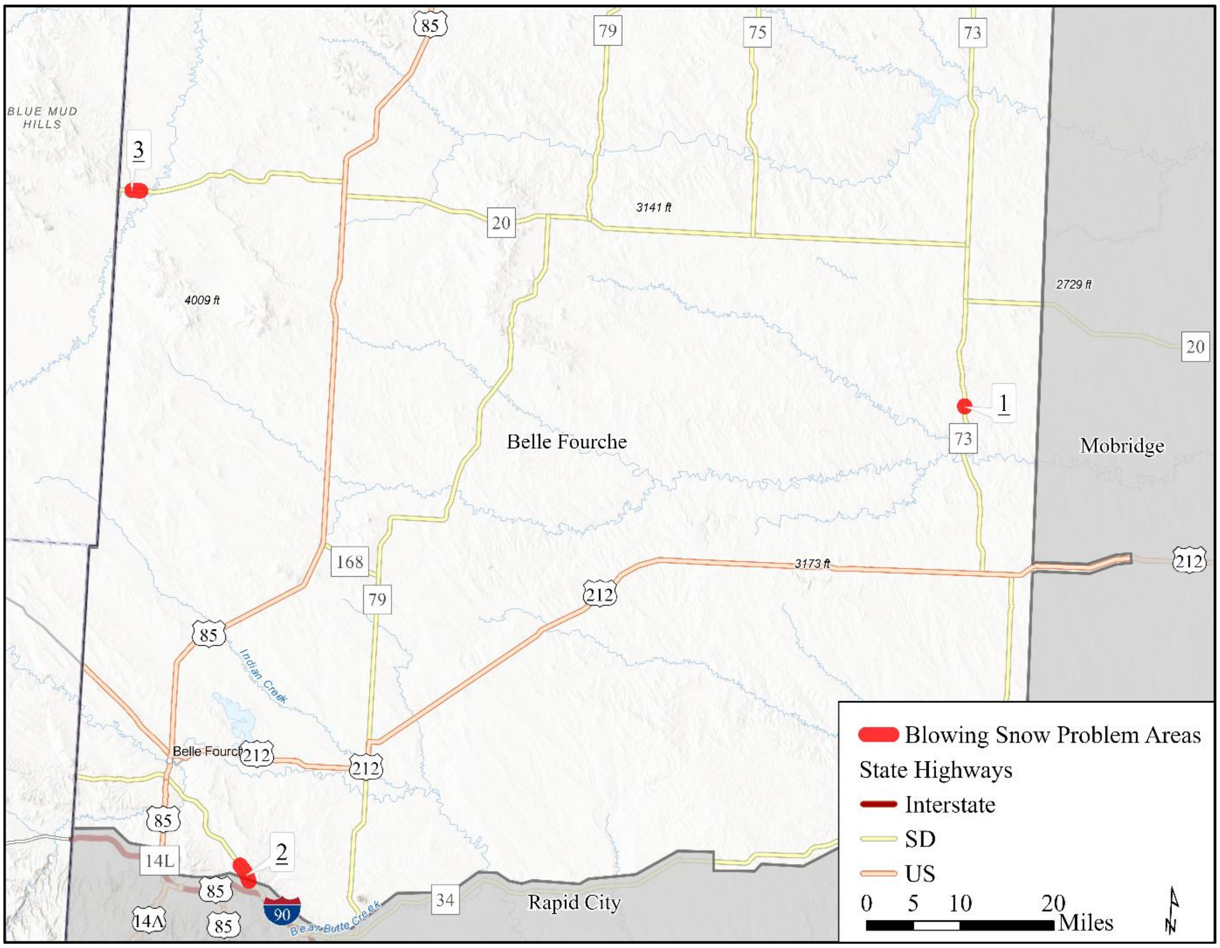


Figure 79: Map of the Belle Fourche blowing snow problem areas mapped as red dots.

Custer Area

Table 34: All blowing snow problem areas identified by the Custer Maintenance Area.

Name	Hwy	Maintenance Area	Length (Miles)	Begin MRM	End MRM	Area Priority
Hwy 16, MRM 30-32	Hwy 16	Custer Area	2.00	30	32	1
Hwy 18, MRM 22-25	Hwy 18	Custer Area	3.00	22	25	2
Hwy 18, MRM 48-62.27	Hwy 18	Custer Area	14.25	42	62.27	3
Hwy 18, MRM 103.53-121	Hwy 18	Custer Area	17.46	103.53	121	4
Hwy 18, MRM 88.03-103.53	Hwy 18	Custer Area	15.47	88.03	103.53	5
Hwy 18, MRM 62.27-88.03	Hwy 18	Custer Area	25.76	62.27	88.03	6
Hwy 16, MRM 19	Hwy 16	Custer Area	0.09	18.95	19.05	7
Hwy 385 SB, MRM 0-13	Hwy 385 SB	Custer Area	13.02	0	13	8
Hwy 385 NB, MRM 0-13	Hwy 385 NB	Custer Area	13.02	0	13	9
Hwy 16, MRM 4	Hwy 16	Custer Area	0.10	3.95	4.05	10
Hwy 385, MRM 55.3	Hwy 385	Custer Area	0.10	55.25	55.35	11
Hwy 385, 64.5	Hwy 385	Custer Area	0.11	64.45	64.55	12
Hwy 40, MRM 50-67	Hwy 40	Custer Area	17.09	50	67	13
Hwy 40, MRM 47-47.8	Hwy 40	Custer Area	0.86	47	47.8	14

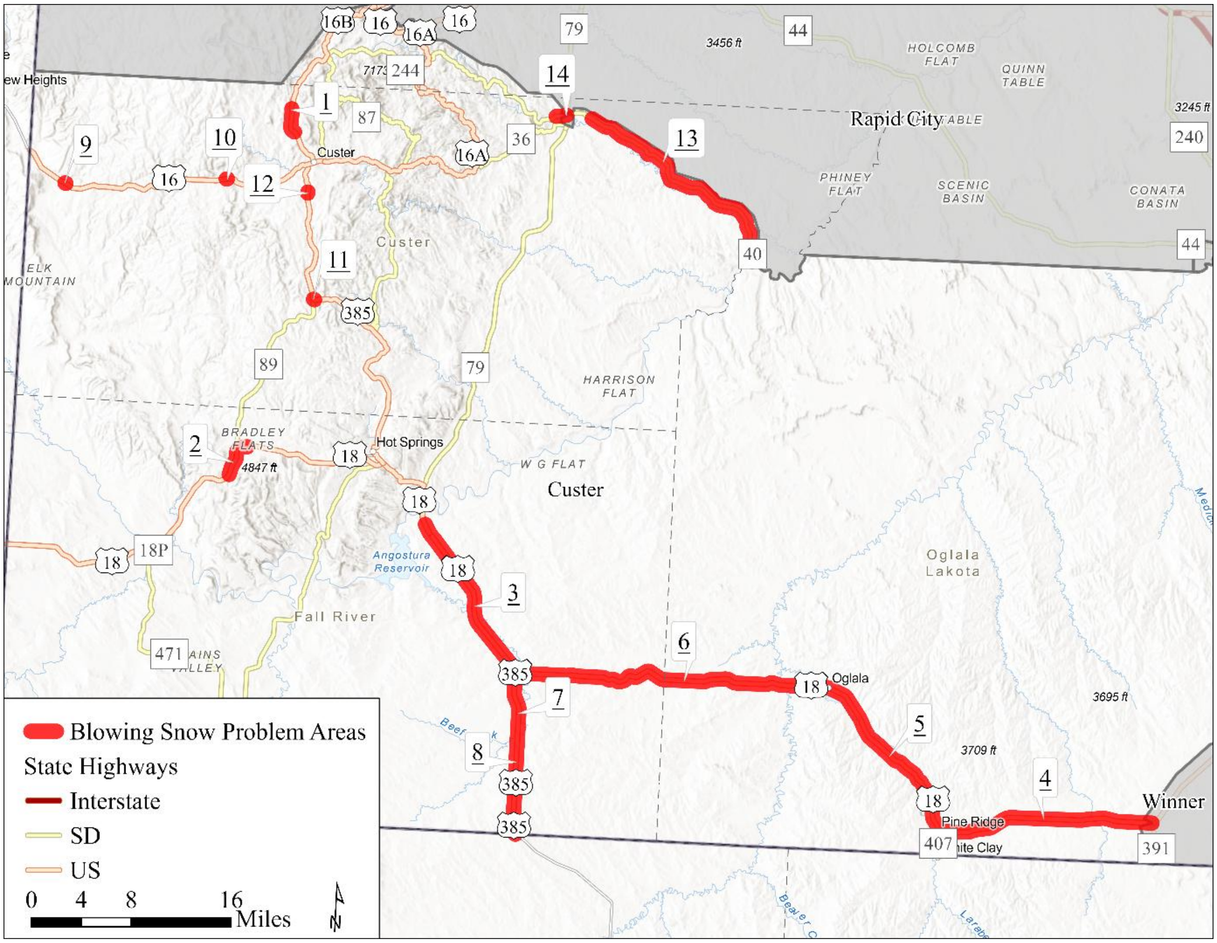


Figure 80: Map of the Custer blowing snow problem areas mapped as red dots.

Huron Area

Table 35: All blowing snow problem areas identified by the Huron Maintenance Area.

Name	Hwy	Maintenance Area	Length (Miles)	Begin MRM	End MRM	Area Priority
Hwy 28, MRM 319.4-319.9	Hwy 28	Huron Area	0.48	319.4	319.9	1
Hwy 25, MRM 127-127.8	Hwy 25	Huron Area	0.80	127	127.8	2
Hwy 212, MRM 349.8-350.5	Hwy 212	Huron Area	0.71	349.8	350.5	3
Hwy 212, MRM 352-352.3	Hwy 212	Huron Area	0.30	352	352.3	4
Hwy 37, MRM 136-136.7	Hwy 37	Huron Area	0.70	136	136.7	5
Hwy 14, MRM 324-325	Hwy 14	Huron Area	0.99	324	325	6
Hwy 14, MRM 326.10-333.4	Hwy 14	Huron Area	6.75	326.1	333.4	7
Hwy 14, MRM 398.8-399.35	Hwy 14	Huron Area	0.55	398.8	399.35	8
Hwy 20, MRM 368-368.3	Hwy 20	Huron Area	0.31	368	368.3	9
Hwy 14, MRM 358-362	Hwy 14	Huron Area	4.00	358	362	10
Hwy 14, MRM 390-390.9	Hwy 14	Huron Area	0.90	390	390.9	11
Hwy 37 S, MRM 115-115.8	Hwy 37 S	Huron Area	0.82	115	115.8	12
Hwy 25, MRM 96.5-96.85	Hwy 25	Huron Area	0.34	96.5	96.85	13
Hwy 26, MRM 271-278	Hwy 26	Huron Area	7.01	271	278	14
Hwy 28, MRM 277-281	Hwy 28	Huron Area	3.98	277	281	15
Hwy 28, MRM 285.99	Hwy 28	Huron Area	1.01	285.49	286.49	16

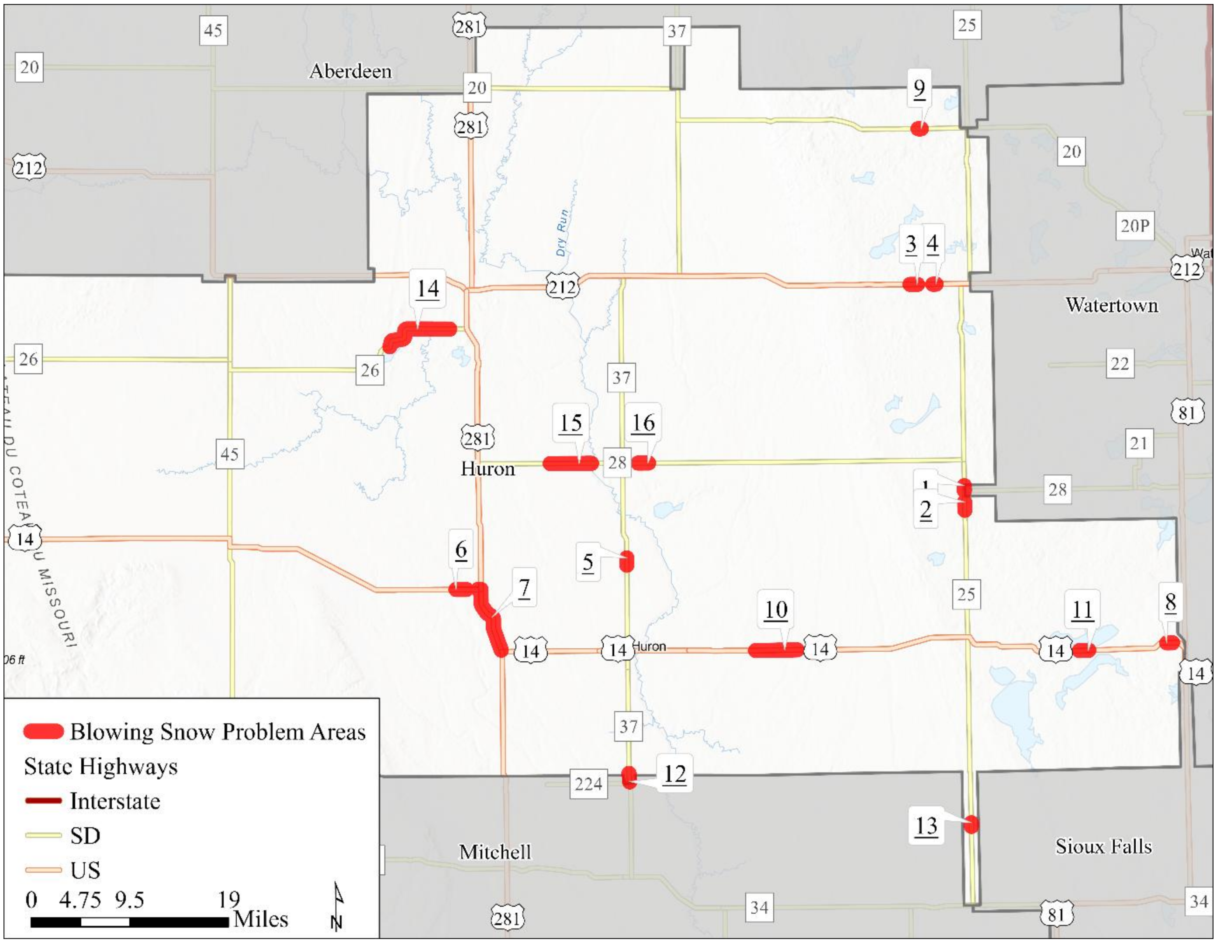


Figure 81: Map of the Huron blowing snow problem areas mapped as red dots.

Mitchell Area

Table 36: All blowing snow problem areas identified by the Mitchell Maintenance Area.

Name	Hwy	Maintenance Area	Length (Miles)	Begin MRM	End MRM	Area Priority
Hwy 44, MRM 334.1 Hoffman Bridge	Hwy 44	Mitchell Area	0.10	334.05	334.15	1
Hwy 44, MRM 343.24 County Line Bridge	Hwy 44	Mitchell Area	0.09	343.19	343.29	2
Hwy 44, MRM 344.43 Pekas Bridge	Hwy 44	Mitchell Area	0.11	344.38	344.48	3
Hwy 44, MRM 347.42 No Name Bridge	Hwy 44	Mitchell Area	0.10	347.37	347.47	4
Hwy 44, MRM 348.24 Wolf Bridge	Hwy 44	Mitchell Area	0.09	348.19	348.29	5
Hwy 38, MRM 347.3 Hill W of Humboldt	Hwy 38	Mitchell Area	0.10	347.25	347.35	6
Hwy 38, MRM 347.8 Hill W of Humboldt	Hwy 38	Mitchell Area	0.10	347.75	347.85	7
Hwy 81, MRM 58.1 Willbur Ellis	Hwy 81	Mitchell Area	0.10	58.05	58.15	8
Hwy 42, MRM 334.6 First Bridge	Hwy 42	Mitchell Area	0.10	334.55	334.65	9
Hwy 42, MRM 338.6 Shelter Belt	Hwy 42	Mitchell Area	0.10	338.55	338.65	10
Hwy 42, MRM 340.9 Hill by Schmidt Motors	Hwy 42	Mitchell Area	0.10	340.85	340.95	11
Hwy 42, MRM 324.88 Wolf Creek Bridge	Hwy 42	Mitchell Area	0.11	324.83	324.93	12
Hwy 34, MRM 301.6-302.7	Hwy 34	Mitchell Area	1.09	301.6	302.7	13
Hwy 34, MRM 307.6-308.6	Hwy 34	Mitchell Area	0.99	307.6	308.6	14
Hwy 34, MRM 363.7-365	Hwy 34	Mitchell Area	1.30	363.7	365	15
Hwy 34, MRM 280.2-280.9	Hwy 34	Mitchell Area	0.69	280.2	280.9	16
Hwy 34, MRM 314.1-314.6	Hwy 34	Mitchell Area	0.50	314.1	314.6	17
Hwy 44, MRM 274.48 44-47 Junction	Hwy 44	Mitchell Area	0.11	274.43	274.53	18
Hwy 46, MRM 286.41-286.51 Jct 46-50	Hwy 46	Mitchell Area	0.10	286.41	286.51	19
Hwy 50, MRM 310.1-310.32 Housing Rd	Hwy 50	Mitchell Area	0.21	310.1	310.32	20
Hwy 42, MRM 331.6	Hwy 42	Mitchell Area	0.10	331.55	331.65	21
Hwy 42, MRM 332.1	Hwy 42	Mitchell Area	0.10	332.05	332.15	22
Hwy 50, MRM 308.32-309.32 River Ranch Rd	Hwy 50	Mitchell Area	1.00	308.32	309.32	23
Hwy 50, MRM 299.68-300.26 Dave Scott Field	Hwy 50	Mitchell Area	0.54	299.68	300.26	24
Hwy 18, MRM 346.9-348.32	Hwy 18	Mitchell Area	1.42	346.9	348.32	25
Hwy 18, MRM 344.14-344.29	Hwy 18	Mitchell Area	0.15	344.14	344.29	26
Hwy 50, MRM 324.82-325.82	Hwy 50	Mitchell Area	0.99	324.82	325.82	27
Hwy 42, MRM 306.5 Lingeman Shelter Belt S	Hwy 42	Mitchell Area	0.11	306.45	306.55	28
Hwy 42, MRM 321.8 Whelldryer Shelter Belt South	Hwy 42	Mitchell Area	0.11	321.75	321.85	29
Hwy 38, MRM 309.2 Shelterbelt on S Side	Hwy 38	Mitchell Area	0.09	309.15	309.25	30
Hwy 34 W, MRM 333.5-334	Hwy 34 W	Mitchell Area	0.50	333.5	334	31
Hwy 34 E, MRM 333.5-334	Hwy 34 E	Mitchell Area	0.50	333.5	334	32

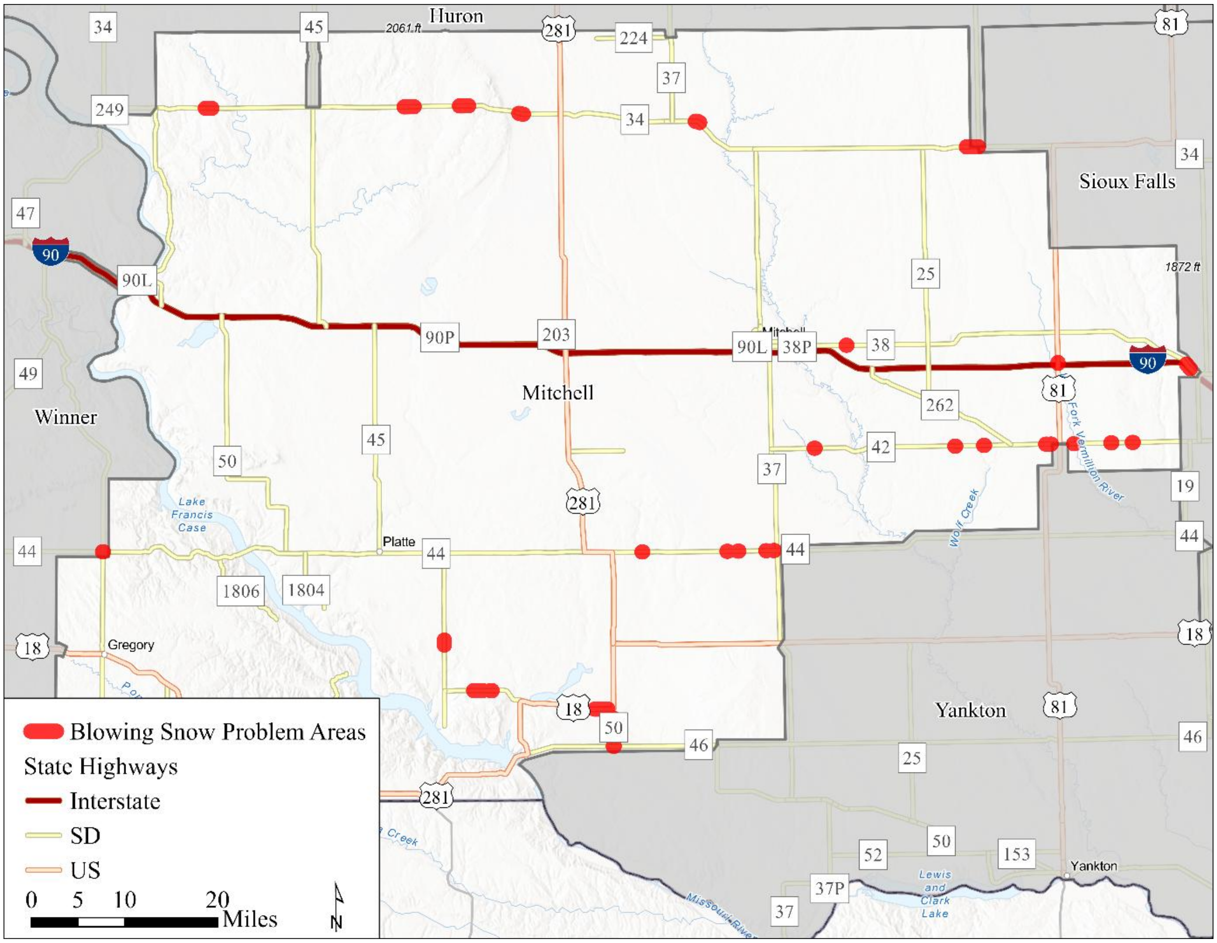


Figure 82: Map of the Mitchell blowing snow problem areas mapped as red dots.

Mobridge Area

Table 37: All blowing snow problem areas identified by the Mobridge Maintenance Area.

Name	Hwy	Maintenance Area	Length (Miles)	Begin MRM	End MRM	Area Priority
Hwy 12 Near MRM 141	Hwy 12	Mobridge Area	0.15	141.01	141.16	1
Hwy 212 Near MRM 193	Hwy 212	Mobridge Area	1.55	193.2	194.42	2
Hwy 12 Near MRM 139	Hwy 12	Mobridge Area	0.21	139.44	139.61	3
Hwy 65 Near MRM 206	Hwy 65	Mobridge Area	0.15	206.11	206.36	4
Hwy 1804 Near MRM 367	Hwy 1804	Mobridge Area	0.14	367.3	367.44	5
Hwy 1804 Near MRM 372	Hwy 1804	Mobridge Area	0.28	372.77	373.05	6

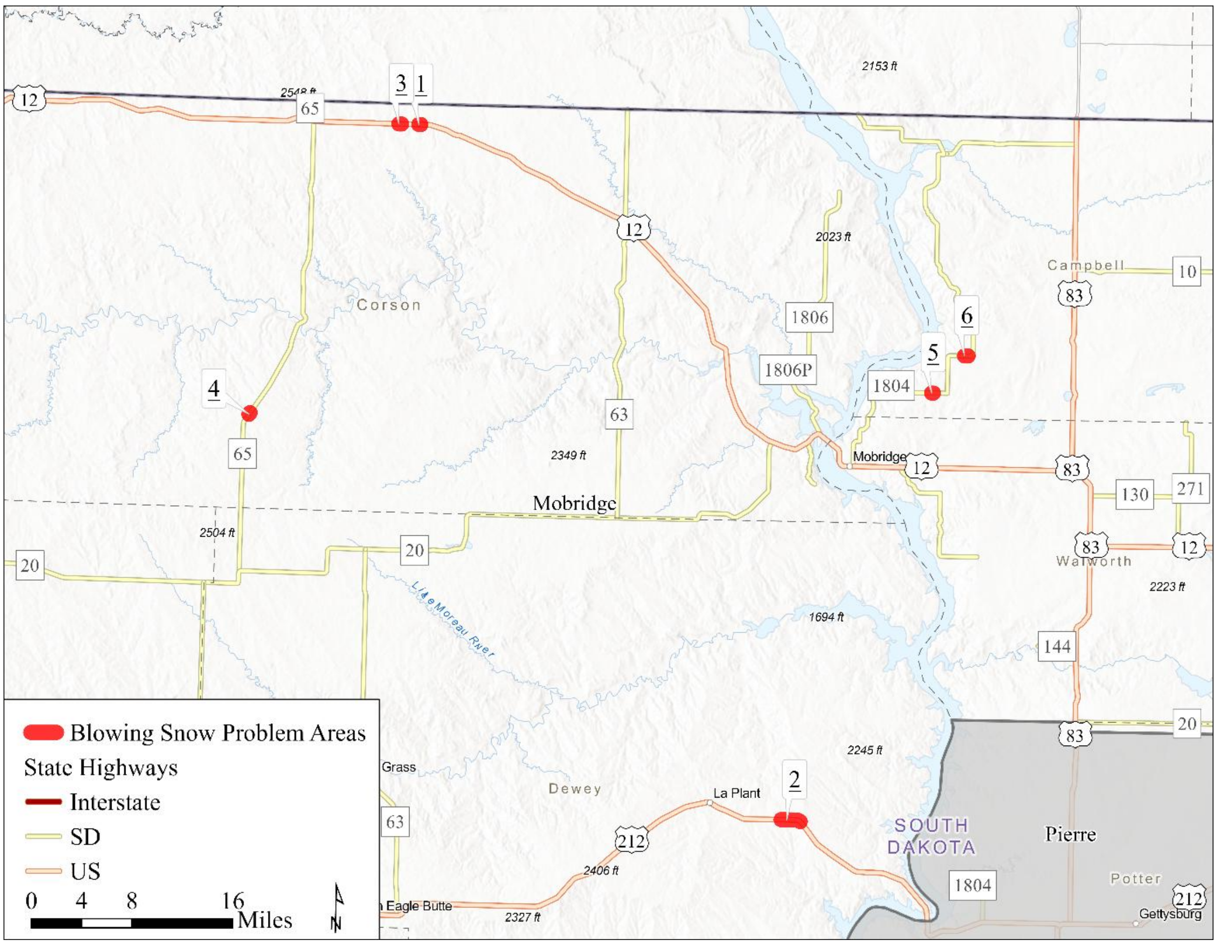


Figure 83: Map of the Mobridge blowing snow problem areas mapped as red dots.

Pierre Area

Table 38: All blowing snow problem areas identified by the Pierre Maintenance Area.

Name	Hwy	Maintenance Area	Length (Miles)	Begin MRM	End MRM	Area Priority
Hwy 14, MRM 207.7-215.3	Hwy 14	Pierre Area	7.63	207.7	215.3	1
Hwy 1806, MRM 138.46-139.5	Hwy 1806	Pierre Area	0.42	138.46	139.5	2
Hwy 1806, MRM 150.8-151.2	Hwy 1806	Pierre Area	0.41	150.8	151.2	3
Hwy 34, MRM 151-153	Hwy 34	Pierre Area	2.00	151	153	4
Hwy 212, MRM 227-229	Hwy 212	Pierre Area	2.00	227	229	5
Hwy 63, MRM 121.5-122.5	Hwy 63	Pierre Area	1.00	121.5	122.5	6
Hwy 212, MRM 220-224	Hwy 212	Pierre Area	3.99	220	224	7
Hwy 34, MRM 134-135	Hwy 34	Pierre Area	0.96	134	135	8
Hwy 14 Near Junction of 14 and 83	Hwy 14	Pierre Area	1.00	246	247	9
Hwy 14, Near Blunt Cemetery	Hwy 14	Pierre Area	1.04	248.5	249.5	10
Hwy 83S, MRM 103-105	Hwy 83 S	Pierre Area	2.01	103	105	11
Hwy 83N, MRM 103-105	Hwy 83 N	Pierre Area	2.00	103	105	12
Hwy 14, MRM 129.3-130.5	Hwy 14	Pierre Area	1.22	129.3	130.5	13

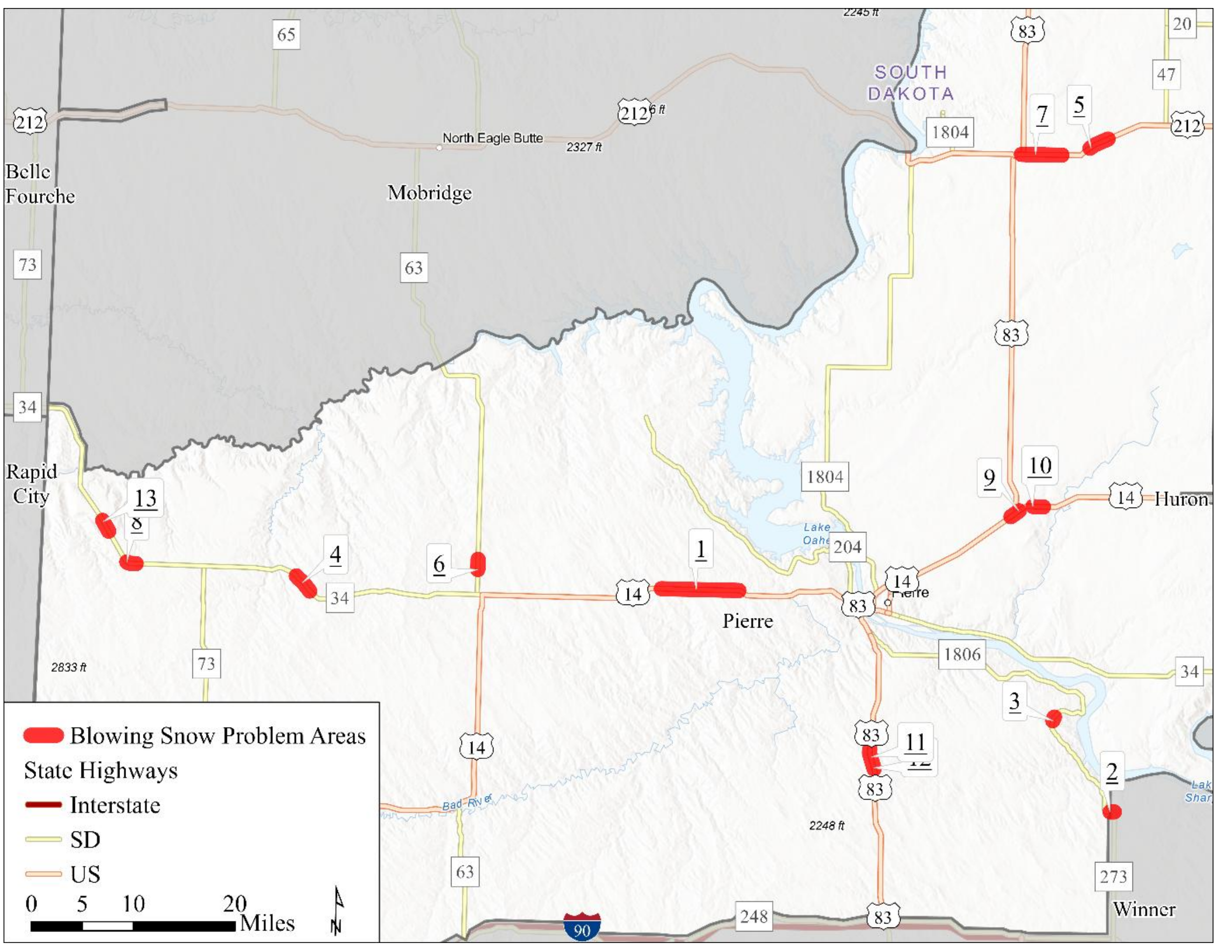


Figure 84: Map of the Pierre blowing snow problem areas mapped as red dots.

Rapid City Area

Table 39: All blowing snow problem areas identified by the Rapid City Maintenance Area.

Name	Hwy	Maintenance Area	Length (Miles)	Begin MRM	End MRM	Area Priority
Hwy 42, MRM 48	Hwy 34	Rapid City Area	0.10	47.95	48.05	1
Hwy 385, MRM 108	Hwy 385	Rapid City Area	0.10	107.95	108.05	2
Hwy 385, MRM 116	Hwy 385	Rapid City Area	0.10	115.95	116.05	3
Hwy 44E, MRM 85-88	Hwy 44 E	Rapid City Area	3.01	85	88	4
Hwy 85, MRM 32-35	Hwy 85	Rapid City Area	2.98	32	35	5
Hwy 473, Lead to Ski Lodge	Hwy 473	Rapid City Area	3.19	91	94.16	6
Hwy 14, MRM 113-115	Hwy 14	Rapid City Area	1.91	113	115	7
Hwy 14, MRM 121 Near Big Foot Road	Hwy 14	Rapid City Area	1.00	120.5	121.5	8
Hwy 79, MRM 69 Near Spring Creek	Hwy 79	Rapid City Area	0.10	68.95	69.05	9
Hwy 16E, MRM 56-57	Hwy 16 E	Rapid City Area	0.99	56	57	10
Hwy 16W, MRM 56-57	Hwy 16 W	Rapid City Area	0.99	56	57	11
Hwy 14A, MRM 46-48	Hwy 14A	Rapid City Area	2.00	46	48	12
Hwy 16B EB, MRM 65	Hwy 16B EB	Rapid City Area	0.10	64.95	65.05	13
Hwy 16B WB, MRM 65	Hwy 16B WB	Rapid City Area	0.10	64.95	65.05	14
Hwy 16B EB, MRM 67-69	Hwy 16B EB	Rapid City Area	1.99	67	69	15
Hwy 16B WB, MRM 67-69	Hwy 16B WB	Rapid City Area	2.00	67	69	16
Hwy 16B EB, MRM 72	Hwy 16B EB	Rapid City Area	0.10	71.95	72.05	17
Hwy 16B WB, MRM 72	Hwy 16B WB	Rapid City Area	0.10	71.95	72.05	18

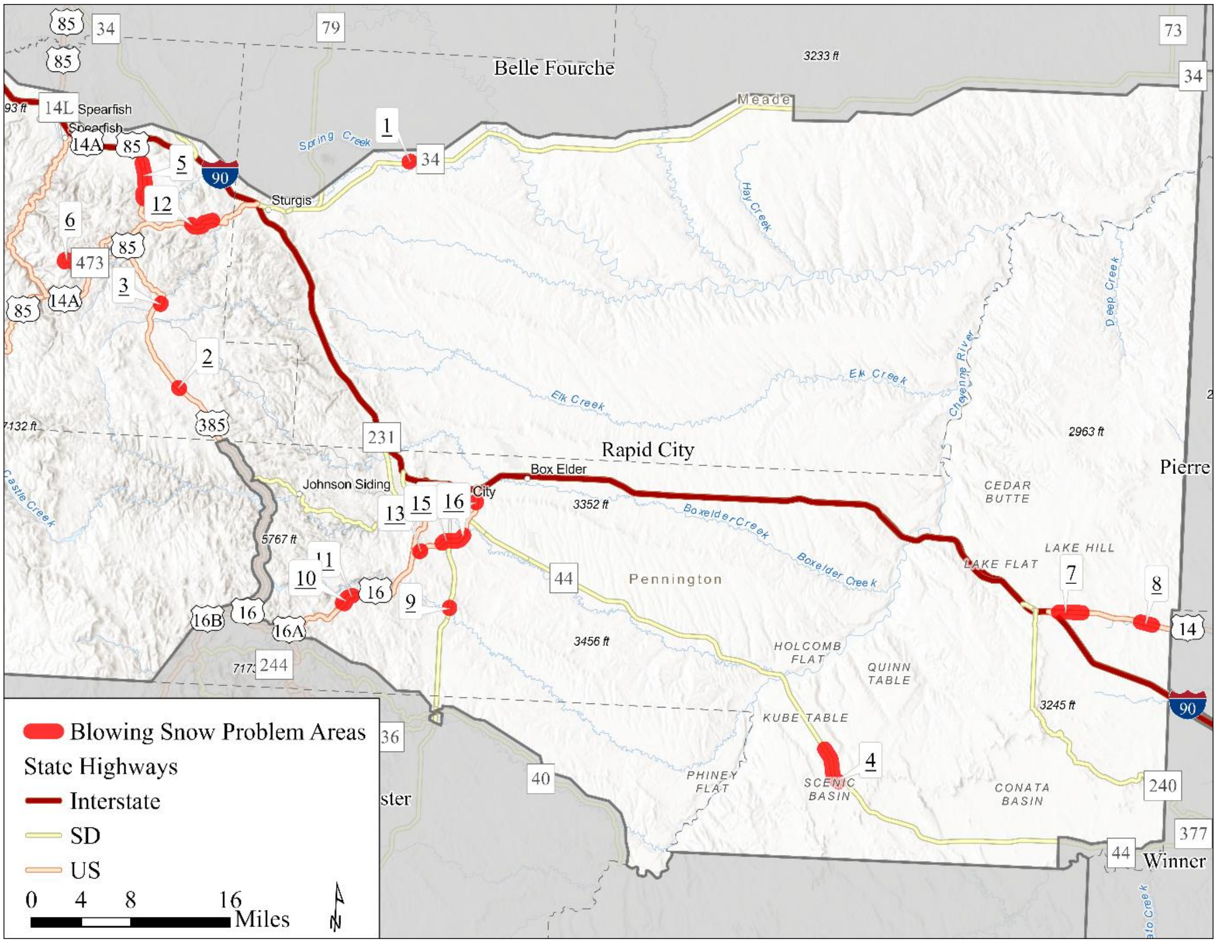


Figure 85: Map of the Rapid City blowing snow problem areas mapped as red dots.

Sioux Falls Area

Table 40: All blowing snow problem areas identified by the Sioux Falls Maintenance Area.

Name	Hwy	Maintenance Area	Length (Miles)	Begin MRM	End MRM	Area Priority
Hwy 11 Garretson to MN	Hwy 11	Sioux Falls Area	10.65	92	102.55	1
Hwy 115 Harrisburg	Hwy 115	Sioux Falls Area	2.00	76.33	78.34	2
Hwy 38 Sioux Falls to Humboldt	Hwy 38	Sioux Falls Area	8.94	349	358	3
Hwy 18 E of I-29	Hwy 18	Sioux Falls Area	13.69	438.26	451.88	4
Hwy 11 S of Brandon	Hwy 11	Sioux Falls Area	2.32	77.18	79.5	5
Hwy 42 E of Sioux Falls	Hwy 42	Sioux Falls Area	5.11	373.04	378.17	6

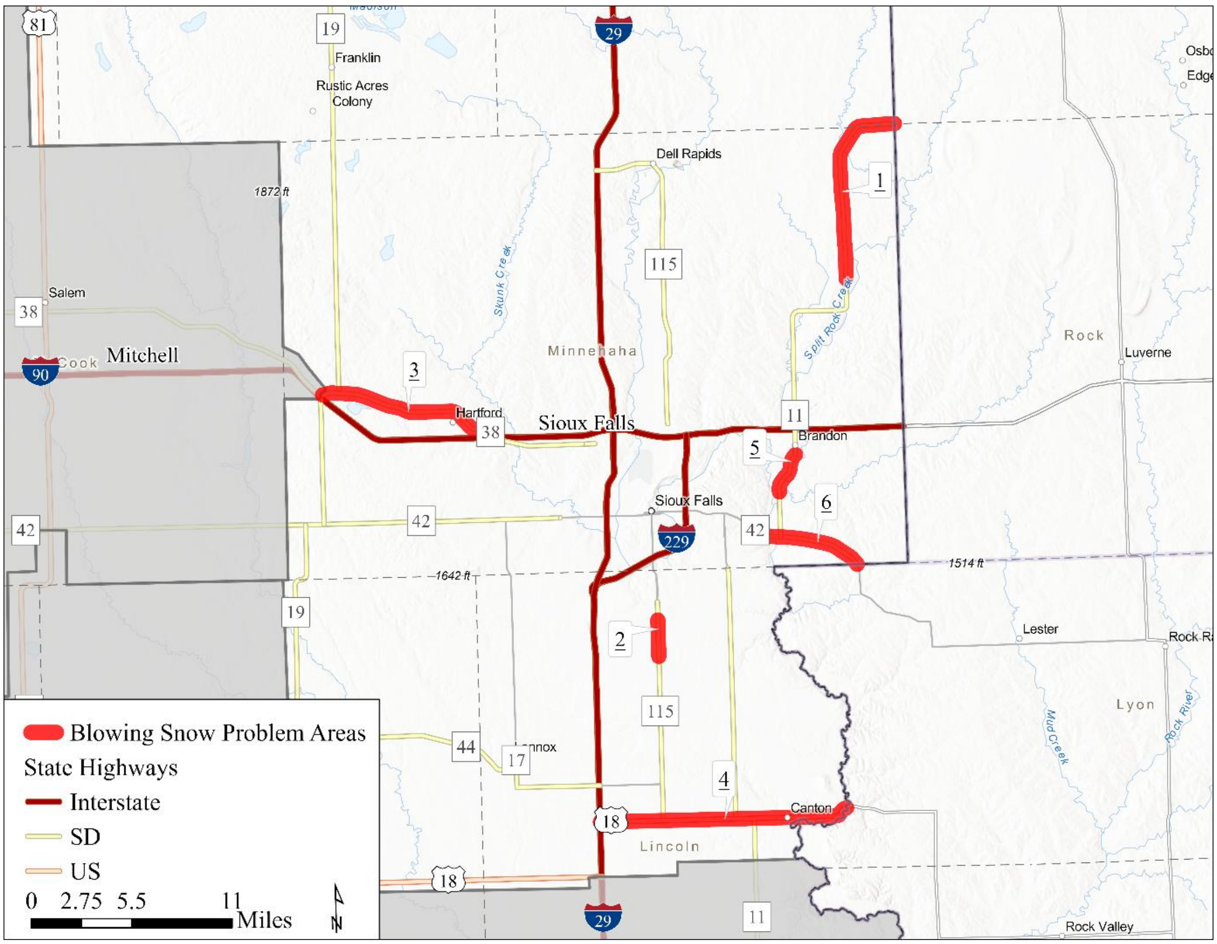


Figure 86: Map of the Sioux Falls blowing snow problem areas mapped as red dots.

Watertown Area

Table 41: All blowing snow problem areas identified by the Watertown Maintenance Area.

Name	Hwy	Maintenance Area	Length (Miles)	Begin MRM	End MRM	Area Priority
Hwy 10 Near Long Hollow	Hwy 10	Watertown Area	9.92	345	355	1
Hwy 12 Near Marvin	Hwy 12	Watertown Area	7.64	366.37	374	2
Hwy 22 E of Clear Lake	Hwy 22	Watertown Area	5.49	372	377.59	3
Hwy 28 Near Toronto	Hwy 28	Watertown Area	8.03	367	375	4
Hwy 20 Near South Shore Stockholm	Hwy 20	Watertown Area	18.55	416.45	435	5
Hwy 212 E of Hwy 15	Hwy 212	Watertown Area	5.01	403	408	6
Hwy 212 Near Goodwin	Hwy 212	Watertown Area	7.73	389	397	7
Hwy 22 W of Clear Lake	Hwy 22	Watertown Area	5.06	364	369	8

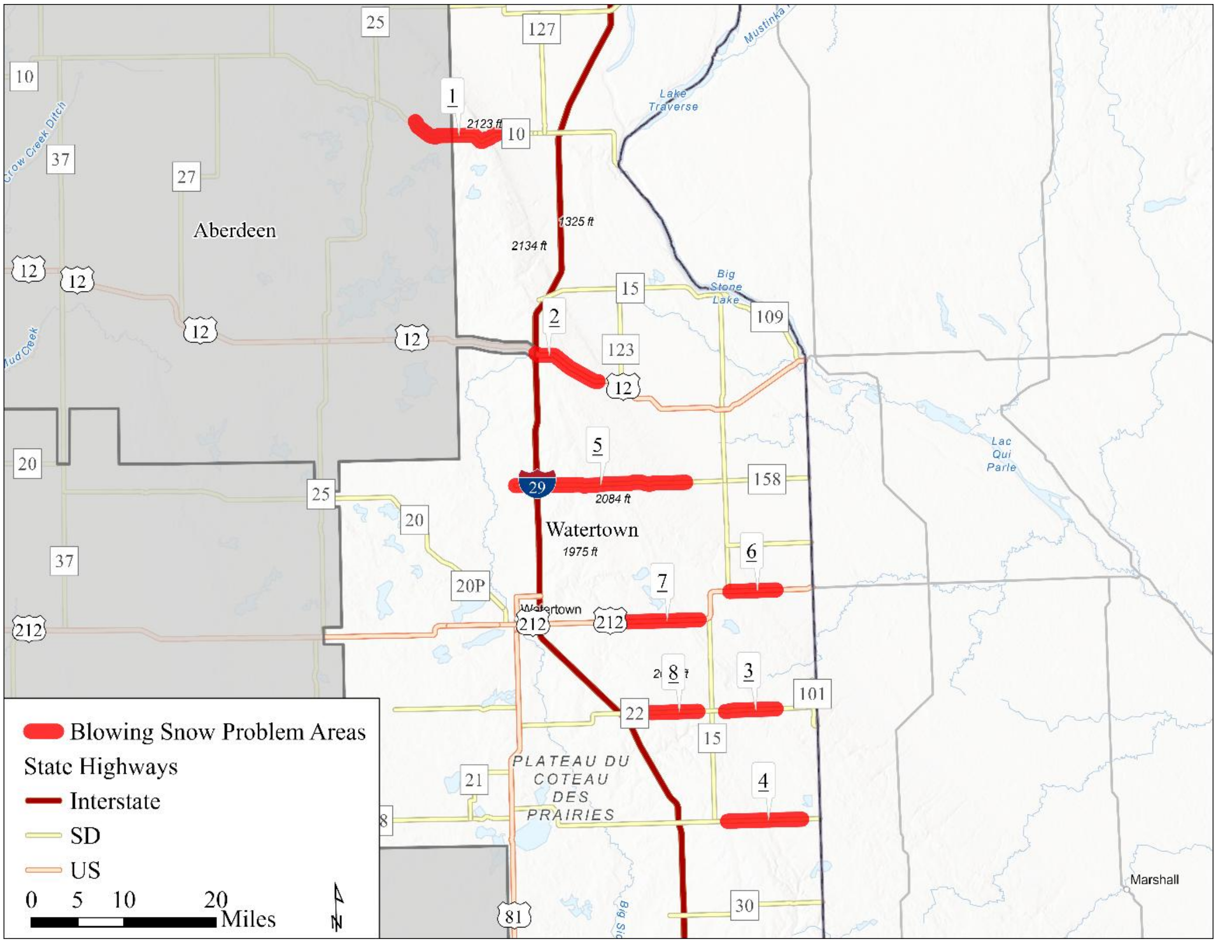


Figure 87: Map of the Watertown blowing snow problem areas mapped as red dots.

Winner Area

Table 42: All blowing snow problem areas identified by the Winner Maintenance Area.

Name	Hwy	Maintenance Area	Length (Miles)	Begin MRM	End MRM	Area Priority
Hwy 248	Hwy 248	Winner Area	12.98	208	221	1
Hwy 273	Hwy 273	Winner Area	12.01	62	74	2

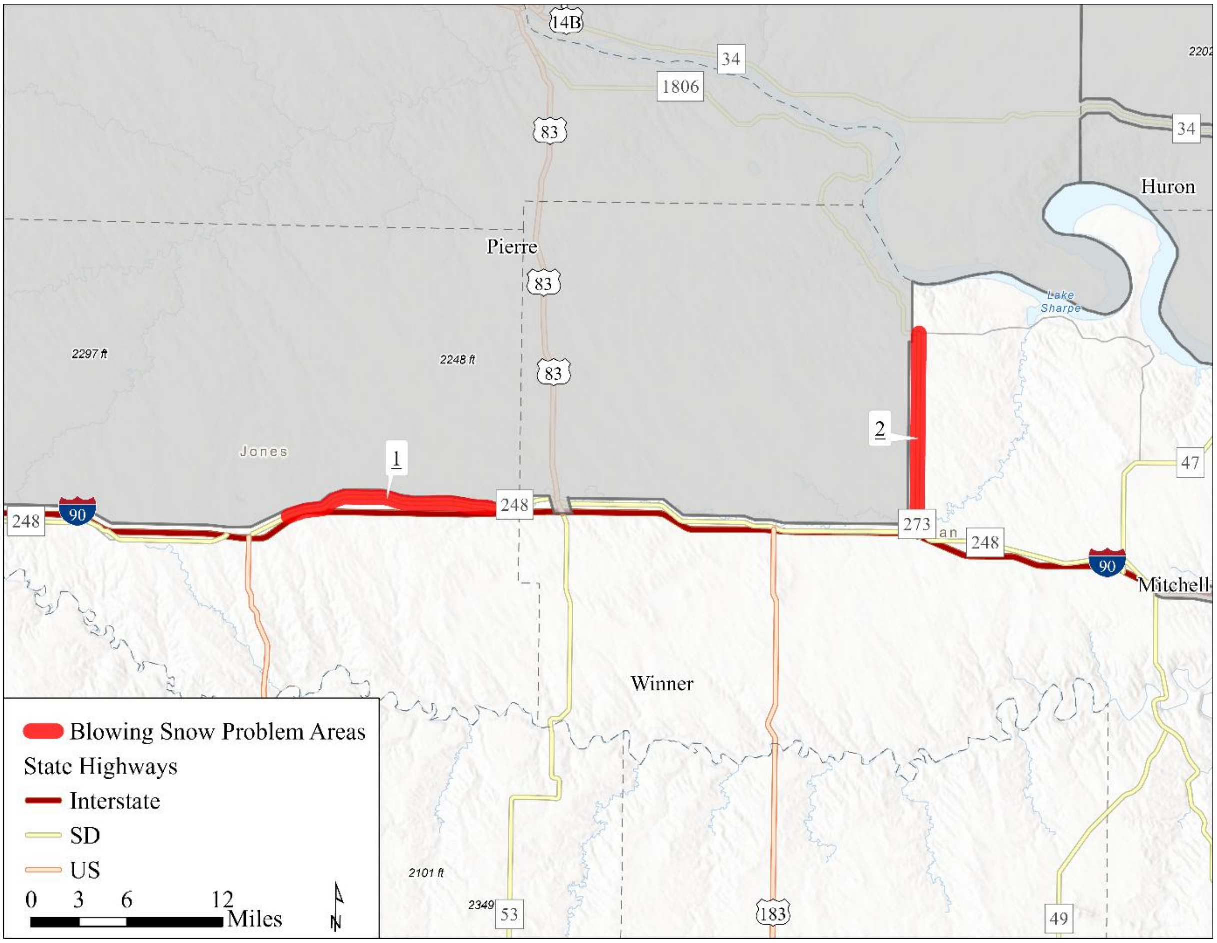


Figure 88: Map of the Winner blowing snow problem areas mapped as red dots.

Yankton Area

Table 43: All blowing snow problem areas identified by the Yankton Maintenance Area.

Name	Hwy	Maintenance Area	Length (Miles)	Begin MRM	End MRM	Area Priority
Hwy 81, on Curve	Hwy 81	Yankton Area	2.01	44	46	1
Hwy 50W, MRM 415-417	Hwy 50 W	Yankton Area	2.06	415	417	2
Hwy 18, MRM 380-384	Hwy 18	Yankton Area	4.02	380	384	3
Hwy 50, MRM 407-408	Hwy 50	Yankton Area	0.95	407	408	4
Hwy 44, MRM 387-388	Hwy 44	Yankton Area	1.00	387	388	5
Hwy 11 SB, MRM 46-44.5	Hwy 11	Yankton Area	1.52	44.5	46	6
Hwy 37, MRM 40-42	Hwy 37	Yankton Area	2.01	40	42	7
Hwy 50W, MRM 396.5-397	Hwy 50 W	Yankton Area	0.40	396	396.5	8
Hwy 44, MRM 349-353	Hwy 44	Yankton Area	4.00	349	353	9
Hwy 52, MRM 316-317	Hwy 52	Yankton Area	0.99	316	317	10

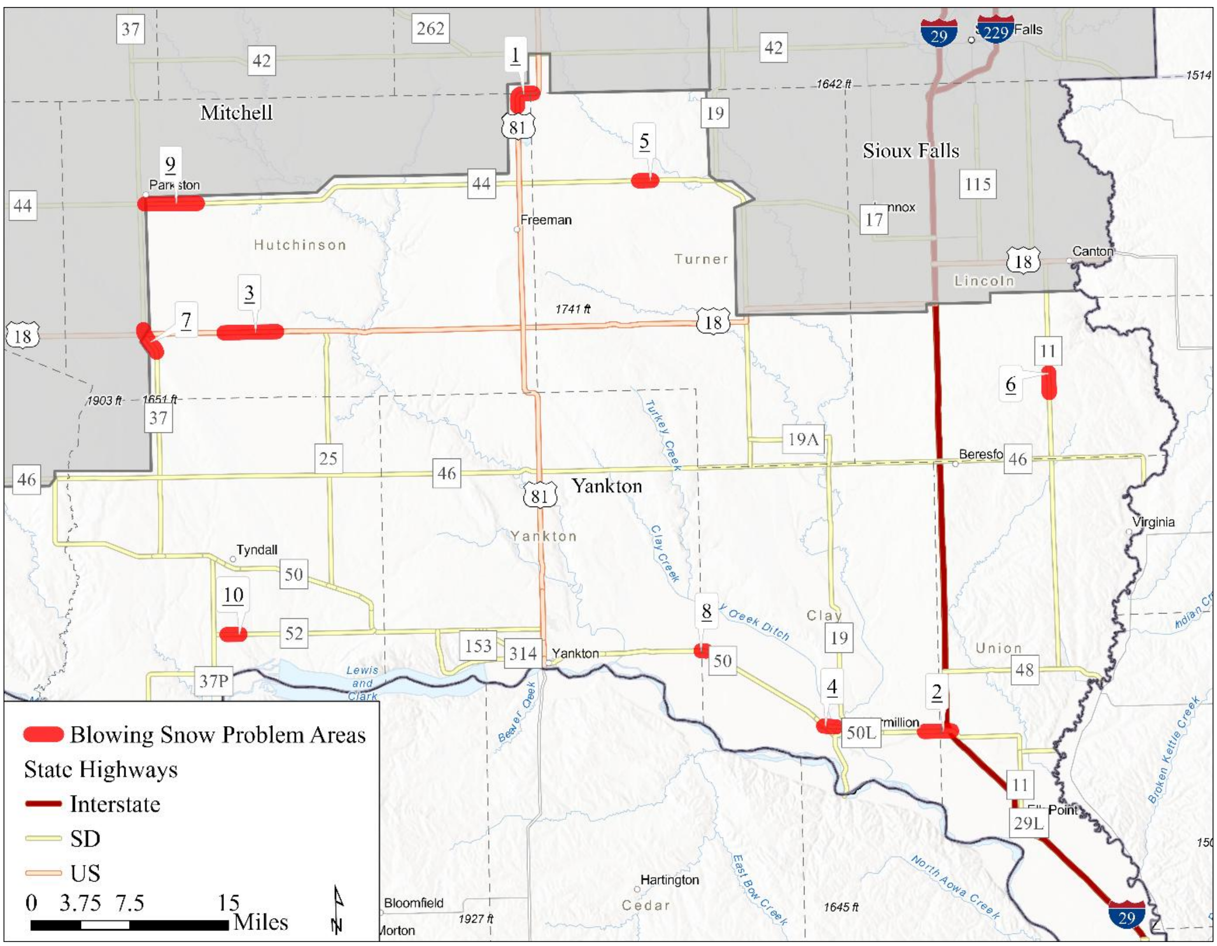


Figure 89: Map of the Yankton blowing snow problem areas mapped as red dots.

Appendix D: RWIS Blowing Snow Wind Speed Analysis

As explained in section 4.6.1.6 Prevailing Wind Direction, the RWIS data is recorded in 5-minute intervals; therefore, this analysis assumes that each data element accounts for the full 5 minutes. This analysis was completed for RWIS stations located within 250 feet, 1 mile, and 5 miles of blowing snow problem areas for the two most recent winter seasons (2022-2023 and 2023-2024) as shown in Figure 90, Figure 91, Figure 92, and Figure 93.

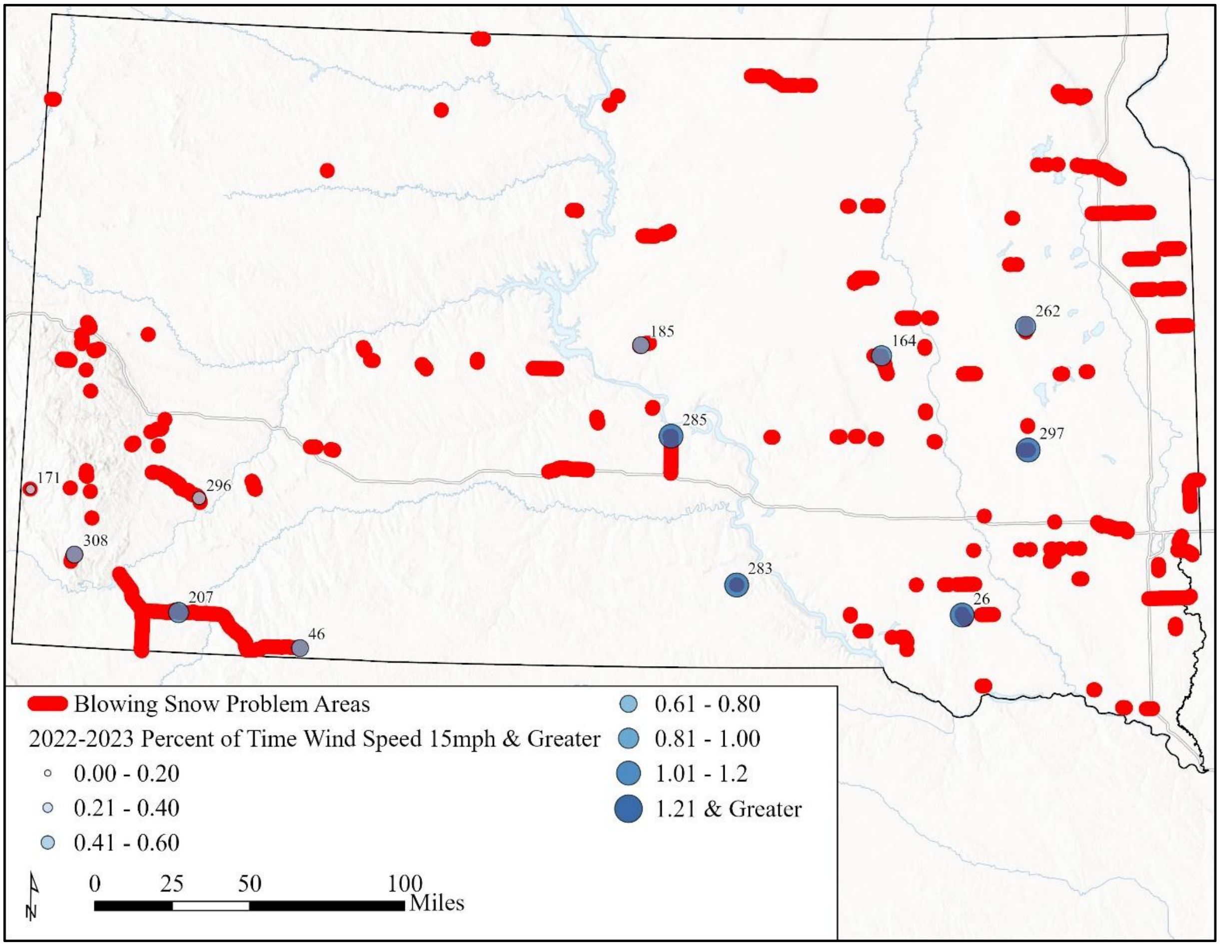


Figure 90: Winter Season 2022-2023, RWIS sites within 250 feet of a blowing snow problem area.

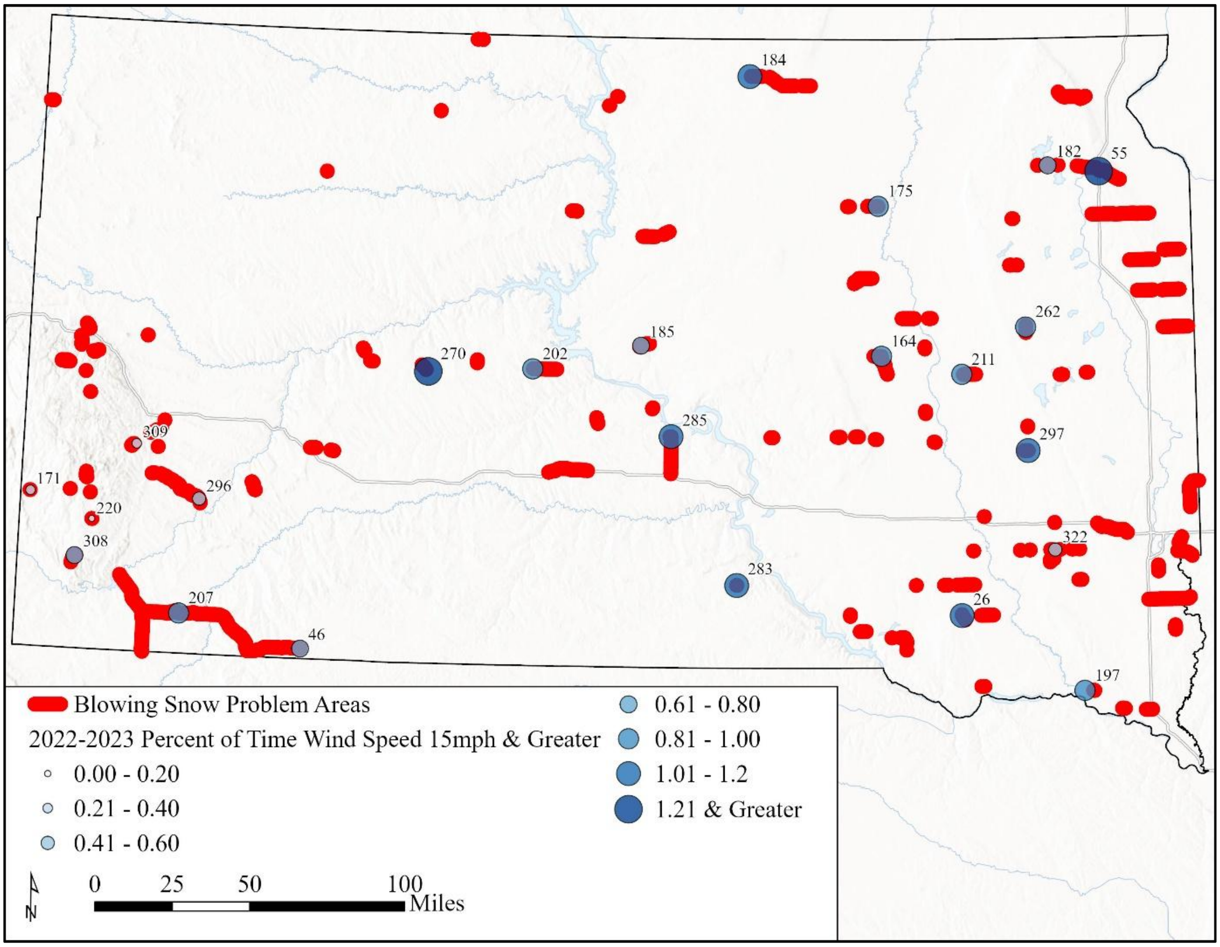


Figure 91: Winter Season 2022-2023, RWIS sites within 1 mile of a blowing snow problem area.

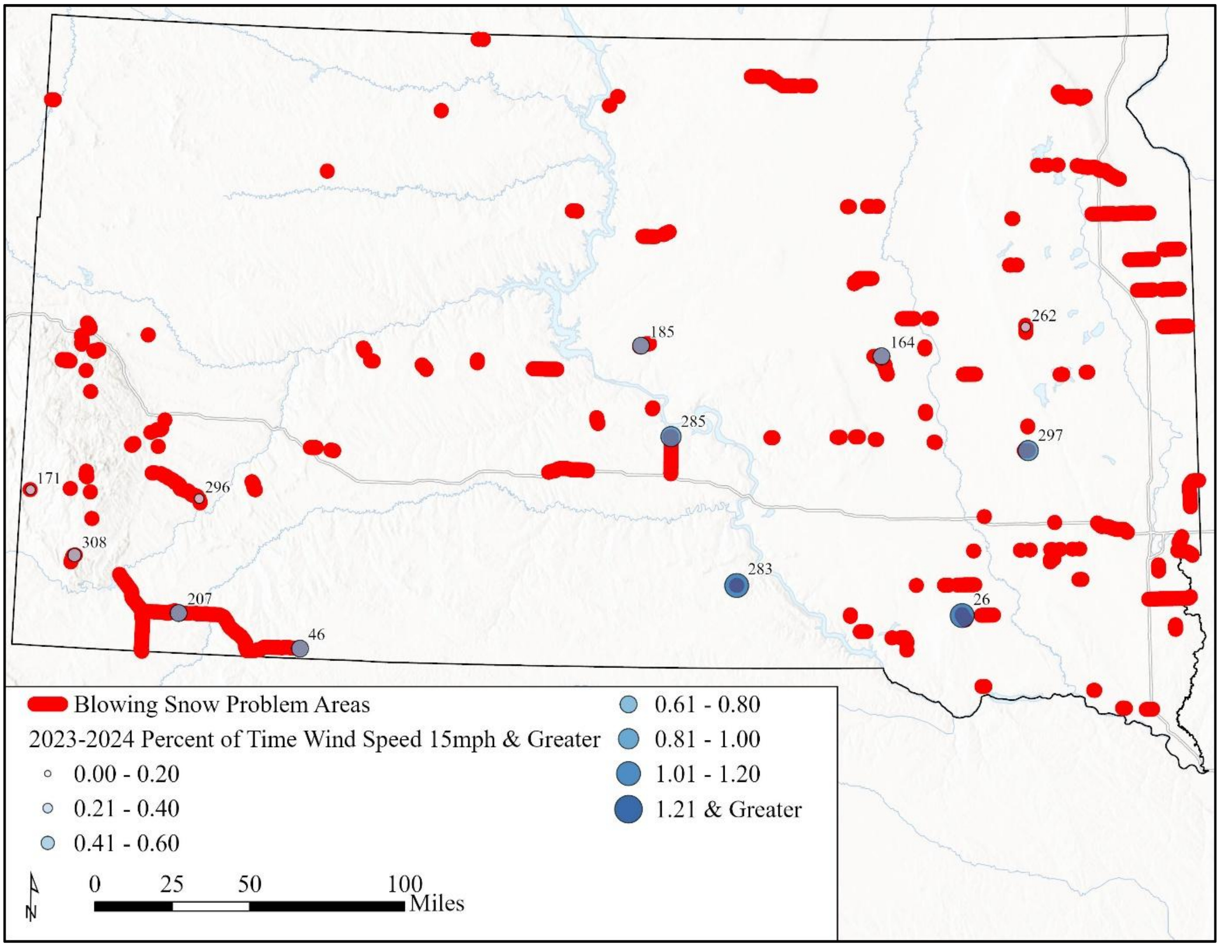


Figure 92: Winter Season 2023-2024, RWIS sites within 250 feet of a blowing snow problem area.

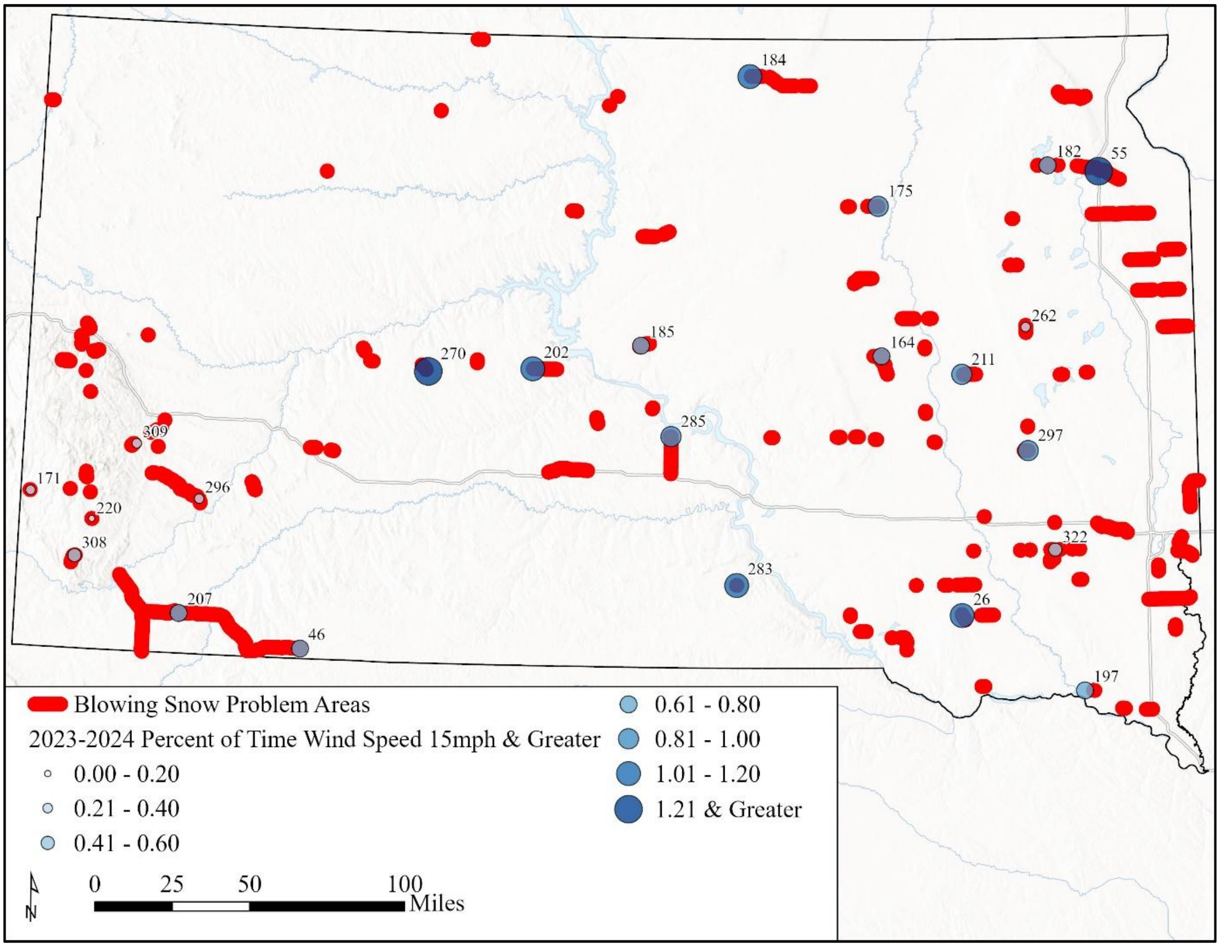


Figure 93: Winter Season 2023-2024, RWIS sites within 1 Mile of a blowing snow problem area.

Appendix E: Additional Variables Considered

The following additional variables, described hereafter, were considered as a part of the prioritization methodology but were ultimately not utilized due to a lack of access to data.

- Winter Severity
- Carbon Sequestration and Emissions
- Soils
- Geology
- Right-of-way
- Terrain
- Context Sensitivity
- Wildlife Migration
- Existing Snow Fences
- Additional Crash Analysis.

These additional variables could be utilized to further refine the top 100 rural blowing snow locations in future analyses.

Winter severity: SDDOT's maintenance decision support system (MDSS) provides a winter severity index at the statewide and maintenance region level. Ultimately, this data was not used because the research team could not determine how this data related to blowing snow conditions. SDDOT is encouraged to work with the MDSS provider to better ascertain this relationship and determine a method to incorporate this variable into this methodology.

Carbon sequestration and emissions: If SDDOT is interested, future work could define emissions (a cost or negative impact) associated with each piece of equipment used to treat a blowing snow problem area and carbon sequestration (benefit) associated with each blowing snow treatment strategy. These variables could then be included in this methodology.

Soils: Soils data could be obtained through the USDA National Resource Conservation Service Soil Surveys which provides soil characteristics at the county level. Soils data can be used to inform the viability of a living snow fence, as well as how well anchors for a structural snow fence may perform. Because this data is available at the county level, site-specific locations should be investigated on a case-by-case basis. It is anticipated that this data source would be pursued at the project-level analysis and consequently is outside the scope of this effort.

Geology: SDDOT provided South Dakota geology data, which describes the distribution of geologic features across the state. Geologic data may be helpful in determining the type of snow fence for each site. This data should be assessed on a case-by-case basis. It is anticipated that this data source would be pursued at the project-level analysis, thus consequently, it is outside the scope of this effort.

Right-of-way: Information on available right-of-way can be used when determining the most appropriate blowing snow mitigation strategy for an individual rural blowing snow location and the appropriate place to site the chosen strategy (snow fence, grading, etc.). It is anticipated that this data source would be pursued at the project-level analysis, thus consequently it is outside the scope of this effort.

Terrain: Terrain, or ground surface features, are specific to each site and may be the cause or contributor of blowing snow issues on roadways. For each blowing snow location identified, the surrounding terrain should be assessed to determine if terrain is the cause or a contributing factor. This should be assessed on a case-by-case basis. Site specific terrain mapping could be used by SDDOT once blowing snow problem locations are identified and selected for treatment. This will aid in the determination of the blowing snow treatment strategy.

Context sensitivity: To prioritize blowing snow locations, consider land ownership, land use plans, future building, roadway expansion plans, and potential growth centers.

- **Land ownership**: Determine if the land use adjacent to the roadway lends itself to snow fence placement or other options (grading), whether that be on and off years of standing corn rows left in place, use of temporary snow fences that are installed in the fall and removed in the spring, structural snow fence installations (Wyoming snow fences), or LSFs.
- **Land use planning**: Where blowing snow is a known problem, communities and roadways may be planned for expansion. If development is planned to occur, SDDOT could coordinate with the project to address blowing snow issues. SDDOT can consider future land use once blowing snow problem locations are identified.

Wildlife migration: SDDOT provided wildlife-vehicle collision (WVC) reported crashes, carcass data, and GPS collar locations for four wildlife species (e.g., white-tailed deer, mule deer, elk, and pronghorn). Site-specific analysis is recommended once grading or snow fence locations have been identified. Future work could analyze how WVC, carcass and reported crashes are represented in both data sources (including if there is underreporting), hot spot analysis could be conducted to determine if WVC rates are positively or negatively influenced by snow fences (including differences with different types of snow fences), and GPS tracking data could be used to analyze wildlife avoidance or acceptance of snow fences.

Existing snow fences: SDDOT has provided a GIS file of existing snow fence locations with information on the type of snow fence. This information can be used to determine the level of experience a maintenance area has with installation and maintenance of snow fences, provide insights on snow fence types that work in the area, and working with landowners. Additionally, SDDOT may consider if identified blowing snow locations are adjacent to existing snow fence locations, expansion of an existing treatment may be needed to address the issue.

Additional crash analysis: The analysis of crashes and slide-in data are centered on the blowing snow problem locations identified by SDDOT maintenance areas. A high-level review of the crash and slide-in data suggests that crash and slide-in clusters exist outside of these prioritized locations (see Figure 37 which is focused on blowing snow crashes). These additional locations could be where solutions (grading, snow fences) are already programmed in by projects. The locations could also be undetected by SDDOT maintenance areas (an analysis could identify why), or they may reflect lower priorities for SDDOT maintenance areas. A future research effort could review crash and slide-in clusters. As treatments are applied to address blowing snow problem areas, the data of installation could be recorded and future research project could be developed to analyze the impact of treatments on crash and incident occurrence.

Appendix F: Informational Pamphlets

The following are brochures and pamphlets developed by state, local and conservation agencies to provide information on blowing snow mitigation strategies to the public.

- The Living Snow Fence Program in South Dakota (Dept. of Agriculture and Natural Resources)
- Blowing Snow Control / Standing Corn Rows (Minnesota DOT)
- McHenry County Living Snow Fence Program (McHenry County, Iowa)
- Living Snow Fence (US Forest Service)
- Iowa's Cooperative snow Fence Program (Iowa DOT)
- Wisconsin's Standing Corn Row Snow Fence Program (Wisconsin DOT)

The Living Snow Fence Program in South Dakota (Dept. of Agriculture and Natural Resources)

History

As long ago as 1939, living snow fences were being planted along highways in our neighboring state of Minnesota. The original intent was to compare plant materials with slatted snow fences as a means of keeping highways free of snow. A July 1957 report had Minnesota saving $539.00 per mile annually where tree plantings replaced wooden snow fences. The Minnesota state engineer of roadside development said, "The living pine snow fencing has several attributes besides its efficiency in keeping snow off the highway and in highway beauty. The tree fencing is permanently eliminating the fall and spring handling required for the usual slat fences that cost the highway department $323,658 annually."

The average cost-benefit ratio of implementing a living snow fence practice is 17:1, a $17 return for every program dollar spent.

From 1985 to 1999, 65 living snow fences were established in 24 South Dakota counties covering a total of 180 acres, and protecting approximately 72,000 feet (about 13.5 miles) of highway from drifting snow.

In 1999, new Federal Transportation Enhancement Program guidelines made it possible to expand that program to include cost-share for local transportation routes. In cooperative effort between the Departments of Transportation and Agriculture a program is now available to help local route living snow fence needs.

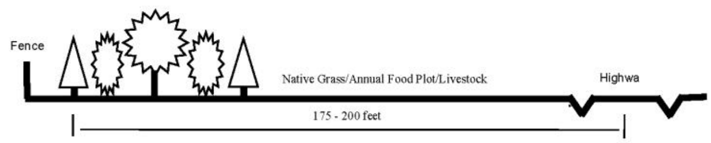
Since 1999, 122 new living snow fences were established covering 378 acres, and protecting approximately 192,170 feet (about 36.5 miles) of South Dakota roads.

What Are Living Snow Fences?

Living snow fences are tree and shrub windbreaks strategically planted in critical locations to prevent road closure caused by drifting snow. Windbreaks have been proven effective in protecting farmsteads and livestock from harsh winter winds and blowing snow. A properly designed living snow fence will cause snow to accumulate within and adjacent to the snow fence and not on the road. There are several advantages to using living plants instead of traditional slatted snow fences:

1. Improved snow control due to greater snow storage capacity.
2. Longer life span than slatted snow fences.
3. Can be designed to provide winter livestock protection.
4. Provide and enhance wildlife habitat.
5. Aid in soil erosion control.
6. Sequester carbon to reduce atmospheric carbon dioxide.
7. More aesthetically pleasing than slatted snow fence.
8. Relatively maintenance free once established.
9. Approximately ten times cheaper to install and maintain than slatted snow fence, based on cost comparisons over the expected life of a living snow fence.
10. Reduced snow removal costs.

Living snow fences have a few disadvantages: they require more space than slatted fences and they can take three to five years after planting to be effective. Living snow fences must be protected from livestock.



Design and Location

To be effective, a living snow fence must be properly designed and located with respect to the highway in need of protection. A living snow fence that is placed wrong may not do an adequate job of protecting the road and may even cause snow to accumulate on the road. The windward row should be located no closer than 175 feet from the centerline of the road. This will allow adequate room for snow storage during severe blizzards. The planting needs to be extended 100 feet beyond the area protected to prevent snow from sweeping around the ends of the planting. At least two rows of conifers (junipers) and a shrub row are needed to provide a dense and effective barrier. One of South Dakota's most effective living snow fences, located along I-90 just east of Rapid City is composed of five rows: Rocky Mt. Juniper, Russian-olive, Green Ash, Russian-olive and Rocky Mt. Juniper. It is doing a remarkable job of controlling snow.

Figure 94: South Dakota's "What are Living Snow Fences?" pamphlet.

BLOWING SNOW CONTROL/ STANDING CORN ROWS

Farmer and landowner information

MnDOT's minimum payment is $1,000 per acre. Actual compensation rates vary depending on the severity of MnDOT's operational costs beyond routine snow plowing and salt applications.

What is a STANDING CORN ROW?

During fall harvest farmers and landowners can leave a few rows of corn, or hay bales, along the roadside to use as temporary fencing to control blowing snow. These standing corn rows trap snow as it blows across fields, piling it up before it reaches a road, waterway, farmstead or community.

MnDOT pays farmers annually for standing corn rows to serve as snow fences adjacent to sections of highways that have a history of blowing and drifting snow. Corn needs to be planted parallel to the road to serve as a fence. A typical standing corn row snow fence is one-quarter-mile long and 33 feet wide covering an average of 1 acre. The fence is set back 120 to 240 feet from theshoulder of the road to provide adequate space to store the snow.

For standing corn rows, or stacked bales, MnDOT enters into a short-term (one winter season) agreement with you, with payment made to you at the end of winter. Corn can be hand-picked, since MnDOT is paying for the corn stalks needed to catch the blowing snow. If a participating farmer chooses to harvest the corn in the spring they are allowed to keep the corn to use as they choose.

Help us keep blowing snow off your roads

Farmers' civic responsibility and leadership help keep winter roads open across Minnesota by leaving standing corn rows, hay bales or silage bags to protect selected state highways throughout the winter with our living snow fence program.

"**The Living Snow Fence program** is a great way for us to give back to our community and be an advocate for **safer driving conditions** in the winter," said Louise Kiecker, a farmer in Fairfax, Minn. "Our family and friends travel that road daily and they know that this stretch of the highway will be clear. I really see our participation in the program as a **public service**."

DEPARTMENT OF TRANSPORTATION

Figure 95: MnDOT's Blowing Snow Control/Standing Corn Rows pamphlet.

How do I enroll in MnDOT's living snow fence program?

1. Talk to your local MnDOT district snow fence coordinator (***www.mndot.gov/environment/livingsnowfence/contacts.html***). Your local coordinator will be able to verify that there is a blowing snow control program along the section of highway adjacent to the section of your property you would like to enroll in the program.

2. If your site is eligible and you want to enroll in the program, you will need to become a state vendor.

3. To get paid by MnDOT for a snow fence on your location, complete the online state vendor registration form. You can even sign-up for direct deposit through this system.

You can find this form online at: ***https://supplier.systems.state.mn.us/psc/fmssupap/SUPPLIER/ERP/c/NUI_FRAMEWORK.PT_LANDINGPAGE.GBL?&***

4. Payment is made in April after the winter season of blowing snow control protection.

5. Each year you will receive a 1099 tax form which reports the amount received from MnDOT during the previous year.

For more information contact:

Dan Gullickson
Blowing Snow Control Shared Service Supervisor
daniel.gullickson@state.mn.us
651-366-3610

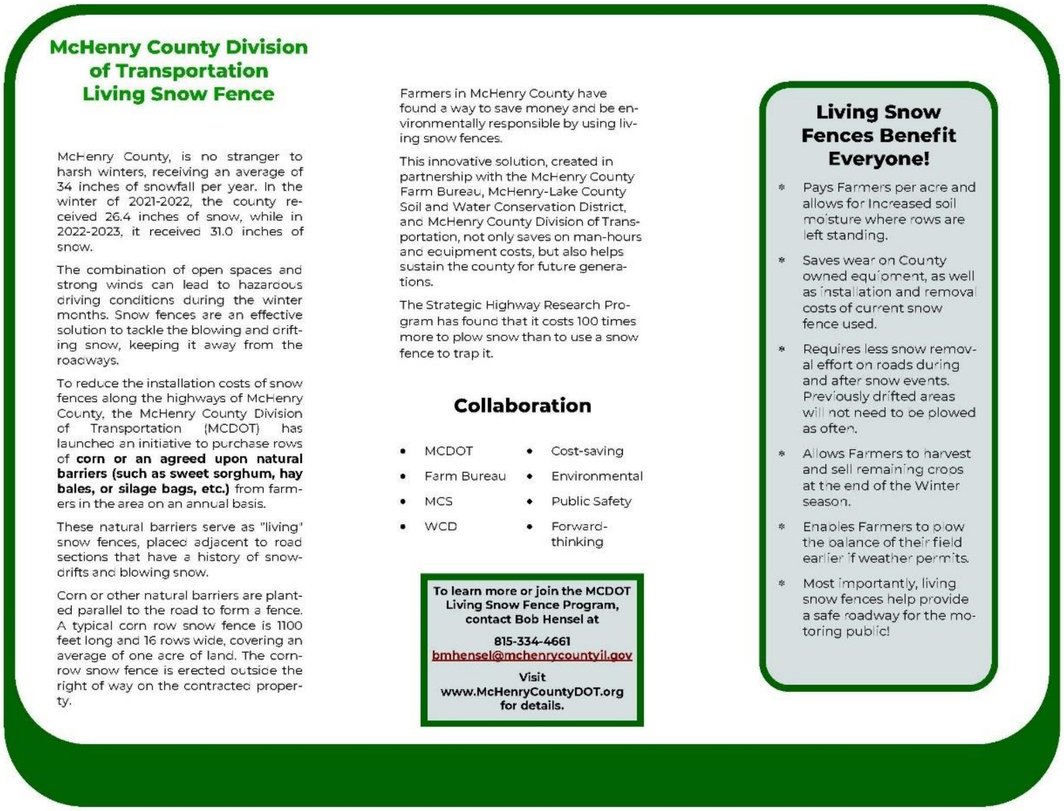
For more information regarding this program please visit:
www.mndot.gov/environment/livingsnowfence/

Local contact:

www.mndot.gov

Figure 96: MnDOT's "How do I enroll in MnDOT's living snow fence program?" information page.

Figure 97: McHenry County Living Snow Fence Program, page 1 (McHenry County, Iowa).



McHenry County Division of Transportation Living Snow Fence

McHenry County, is no stranger to harsh winters, receiving an average of 34 inches of snowfall per year. In the winter of 2021-2022, the county received 26.4 inches of snow, while in 2022-2023, it received 31.0 inches of snow.

The combination of open spaces and strong winds can lead to hazardous driving conditions during the winter months. Snow fences are an effective solution to tackle the blowing and drifting snow, keeping it away from the roadways.

To reduce the installation costs of snow fences along the highways of McHenry County, the McHenry County Division of Transportation (MCDOT) has launched an initiative to purchase rows of **corn or an agreed upon natural barriers (such as sweet sorghum, hay bales, or silage bags, etc.)** from farmers in the area on an annual basis.

These natural barriers serve as "living" snow fences, placed adjacent to road sections that have a history of snowdrifts and blowing snow.

Corn or other natural barriers are planted parallel to the road to form a fence. A typical corn row snow fence is 1100 feet long and 16 rows wide, covering an average of one acre of land. The corn-row snow fence is erected outside the right of way on the contracted property.

Farmers in McHenry County have found a way to save money and be environmentally responsible by using living snow fences.

This innovative solution, created in partnership with the McHenry County Farm Bureau, McHenry-Lake County Soil and Water Conservation District, and McHenry County Division of Transportation, not only saves on man-hours and equipment costs, but also helps sustain the county for future generations.

The Strategic Highway Research Program has found that it costs 100 times more to plow snow than to use a snow fence to trap it.

Collaboration

- MCDOT
- Farm Bureau
- MCS
- WCD
- Cost-saving
- Environmental
- Public Safety
- Forward-thinking

To learn more or join the MCDOT Living Snow Fence Program, contact Bob Hensel at

815-334-4661

bmhensel@mchenrycountyil.gov

Visit www.McHenryCountyDOT.org for details.

Living Snow Fences Benefit Everyone!

- Pays Farmers per acre and allows for increased soil moisture where rows are left standing.
- Saves wear on County owned equipment, as well as installation and removal costs of current snow fence used.
- Requires less snow removal effort on roads during and after snow events. Previously drifted areas will not need to be plowed as often.
- Allows Farmers to harvest and sell remaining crops at the end of the Winter season.
- Enables Farmers to plow the balance of their field earlier if weather permits.
- Most importantly, living snow fences help provide a safe roadway for the motoring public!

Figure 98: McHenry County Living Snow Fence Program, page 2 (McHenry County, Iowa).

CRP Conservation Reserve Program

It Pays

Clean Water
Reduced Erosion
Wildlife Habitat

Photo courtesy of Iowa DOT

Participating Organizations
USDA – Farm Service Agency
http://www.fsa.usda.gov/ia/
USDA – Natural Resources Conservation Service http://www.ia.nrcs.usda.gov/
Iowa Department of Natural Resources
www.iowadnr.com
Iowa Department of Transportation
www.dot.state.ia.us
Pheasants Forever
www.iowapheasantsforever.org

The Iowa DNR recommends trees, shrubs and prairie seed grown in Iowa, because these plants are suitable for Iowa's growing conditions. Plant materials can be purchased at local nurseries and seed dealers. Quality, affordable bare-root nursery stock is also available from the DNR State Forest Nursery. Call 800-865-2477 or check the DNR forestry Web site at www.iowatreeplanting.com.

USDA
Farm Service Agency
State Farm Service Agency
10500 Buena Vista Court
Des Moines, IA 50322

Living Snow Fence

CRP Continuous Sign-up

- **New** - Snow Catch Areas Eligible
- Save Money and Time
- Be Safe
- Attract Wildlife

Continuous Sign-up

Living Snow Fence

NEW Snow Catch Areas Eligible
For the first time, snow catch areas downwind of a living snow fence will be eligible for continuous CRP. These areas must be seeded to native grass species and can provide an added bonus for landowners interested in providing wildlife habitat, while reducing snow removal costs. Generally, these catch areas range from 75 to 100 feet wide or more depending on the design specifications.

Just as private landowners can save time and effort on snow removal with a properly placed living snow fence, the Iowa Department of Transportation can benefit when living snow fences are established on selected sections of state-maintained highways. Landowners along those sections have probably already had temporary snow fences placed in their crop fields.

Sign up at your county USDA-Farm Service Agency at any time. The USDA Natural Resource Conservation Service (NRCS) provides technical help on designing your snow fence and choosing plant materials. Contact a Department of Natural Resources (DNR) state forester for information about selecting trees and shrubs that will be hardy and adaptable for your soils and site conditions. Contact a DNR wildlife biologist for more information about native grass and flower species suitable for your site.

For more information
Contact your local USDA Farm Service Agency or check the FSA Web site at http://www.fsa.usda.gov/ia/.

Conservation Reserve Program

Design Example

Prevailing wind from west
Shrub Row 2
Conifer Row 1
Native Grasses
Snow Storage Area
Fence Line
Right-of-way
15' 25' 75' - 100' 50'

Actual site conditions will determine final design of living snow fence

Purpose

- Protect against prevailing winds to manage snow and decrease snow removal costs
- Enhance public safety
- Establish wildlife habitat
- Control erosion

Payments
Cost-share
50 percent cost-share, with a 40 percent practice incentive payment for establishment costs
Rental Rate
Based on maximum soil rental rate established for the three predominant soils within the snow fence and snow catch area
From 10 to 15 years contract length
Additional Sign-up Bonus
$100 to $150/acre first year of the practice

USDA is an equal opportunity employer and provider

Eligibility

- The north or west sides of lanes, roads, railroads and public facilities; and
- Land that was cropped four out of the six years from 1996 to 2001

Photo courtesy of Lynn Betts, NRCS

More than 100 pheasant took shelter in this Boone County windbreak during heavy snowfalls.

Figure 99: US Forest Service's Living Snow Fence pamphlet.

Iowa's Cooperative Snow Fence Program

Iowa Department of Transportation

June 2005

Figure 100: Cover of Iowa's Cooperative Snow Fence Program (Iowa DOT).

Iowa's Cooperative Snow Fence Program

While we can't keep it from blowing, there are ways to influence the wind that carries tons of blowing and drifting snow. Periodically, severe winter storms will create large snow drifts that close roads and driveways, isolate farmsteads and increase snowplowing. Many of these drifting problems happen in the same place year after year.

Although there are no foolproof methods of wind and snow control, properly designed and maintained snow fences can reduce or eliminate these problem areas. This publication discusses the benefits of snow fence, then examines the types used by the Iowa Department of Transportation. Finally, it provides information about how you can get involved in the DOT's Cooperative Snow Fence Program.

> ***"National research has found that it costs 100 times more to plow snow than to trap it with a snow fence."***
>
> **Source:** Strategic Highway Research Program.

Public benefits of snow fence

- Reduces blowing and drifting snow on roadways
- Stores snow at low cost
- Reduces the accident rate during snowy, windy conditions
- Creates safer travel conditions
- Decreases freezing and thawing effects on the roadway
- Lowers snow removal cost
- Increases visibility

Benefits to landowners

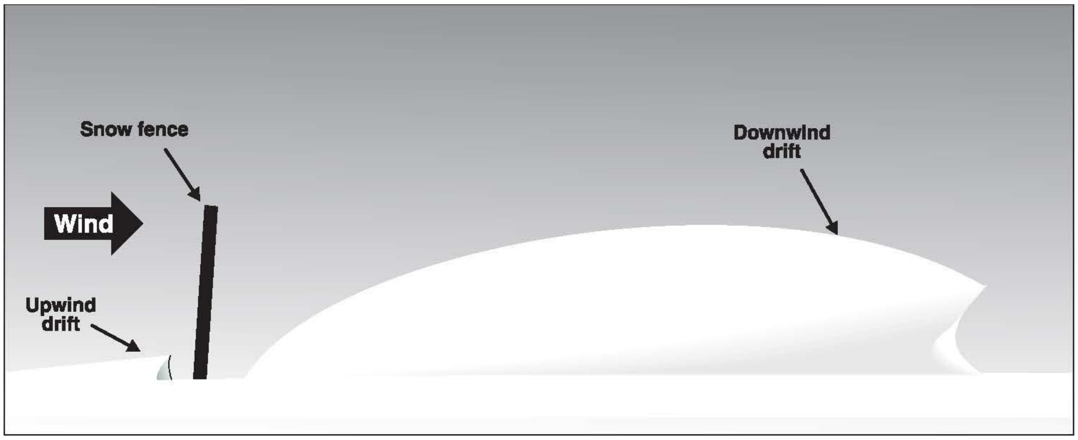
- Improves access to farmsteads and rural areas
- Helps reduce soil erosion
- Provides a service to your community
- Conserves wildlife
- Can increase yield by retaining moisture and reducing drying effects of the wind

1

Figure 101: First page of the document describing Iowa's Snow Fence Program.

Purpose of a snow fence

The purpose of a snow fence is to keep as much snow off the roadway as possible for safety and cost efficiency. Drifts that would normally fall on the roadway now form at the location of the snow fence.



How does a snow fence work?

Snow fence forces the wind to go around and through the fence, causing the wind to lose energy and speed. The snow particles suspended in the fast-moving air come to rest as the speed slows. This forms a drift behind or in front of the snow fence. The height of the fence, and amount of snowfall common to the area, determines how much snow a fence can trap.

Characteristics of snow fence

To be effective, snow fences must be properly designed and located with respect to the highway in need of protection. Not all roadways will benefit from snow fence. Snow fence is used by the DOT at critical locations where it can effectively trap and control blowing and drifting snow.

A fence placed in the wrong location may not do an adequate job of protecting the road, and may even cause snow to accumulate on the roadway.

Height

Any standard size fence will help stop drifting snow. However, the taller the fence - the more snow will be trapped. One row of eight-foot fence is recommended for maximum efficiency. Multiple rows of shorter fence can also be used. One eight-foot fence can trap as much snow as five rows of four-foot fence. Height should be sufficient to store blowing snow during an average to above average snowfall year. The average snowfall for Iowa is 32 inches; the range is 21.9 to 42.4 inches.

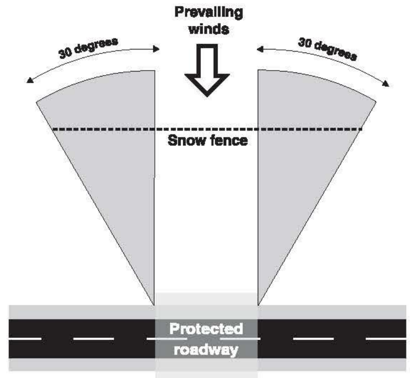
Length

Snow fence length determines the maximum amount of area that can be protected from blowing and drifting snow. Snow storage at the ends of a barrier is significantly less than near the center. It is recommended that the ends of the fence extend approximately 30 degrees beyond the desired protection limits to allow for wind variability.

2

Figure 102: Second page of Iowa's Cooperative Snow Fence Program.

Set back distance
Fences should be set back from the edge of the roadway a distance of 35 times the height of the fence. For instance, if the snow fence is eight feet tall, it should be placed 280 feet back from the edge of the roadway. (8' high x 35 = 280-foot set back.) Living snowfence should be set back from the edge of the roadway a distance of 15 times the expected height of the mature fence.



It is recommended that the ends of the fence extend 30 degrees beyond the desired protection limits.

Placement
The fence should be placed as parallel to the road and perpendicular to the prevailing wind direction as possible.

Helpful fence hints
- Fences should contain 40 to 50 percent open space to be most effective.
- Horizontal gaps are the preferred design.
- A gap of six to eight inches is needed between the ground and the fence to reduce the tendency of fences to become buried in drifts, which reduces storage capacity.

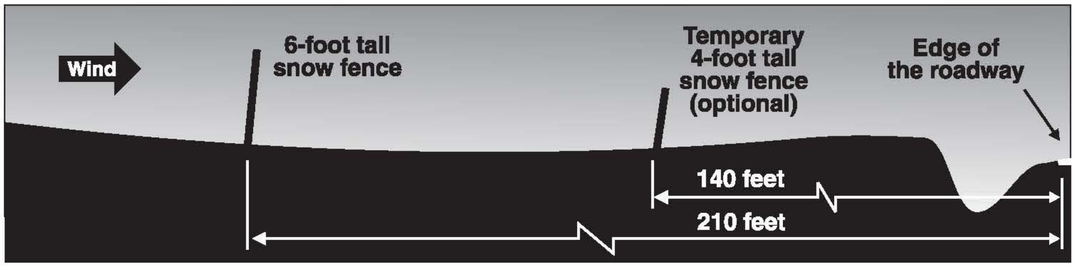
Types of snow control
- Structural, either permanent or temporary
- Standing corn
- Living, using either trees, shrubs, tall grass, or combination of types

Type	Description	Advantages	Agreement length
Structural, permanent	Six- to eight-foot tall fence consisting of two wooden posts, lightweight plastic fence and 2" x 4" supports.	Very low maintenance. Takes up as little as one-foot width of land.	10 year minimum.
Structural, temporary	Four-foot tall portable plastic fence or wooden fence.	Installed after harvest and removed before planting.	Fall to Spring.
Standing corn	One section of eight to 16 rows of corn.	Can reduce soil erosion. Public service organizations benefit from picking by hand. Wildlife habitat.	Fall to Spring.
Living trees, shrubs or native grasses	Two or more rows of trees or shrubs, or a combination of both.	Wildlife habitat. Reduces soil erosion. Hunting ground.	10 year minimum.
CRP living snowfence	Two or more rows of trees or shrubs, or a combination of both with 75-100 foot native grass buffer.	Wildlife habitat. Reduces soil erosion. Hunting ground.	10-15 years per CRP program guidelines.

3

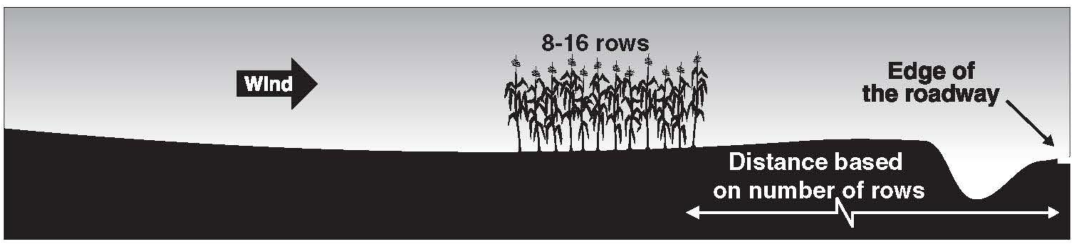
Figure 103: Third page of Iowa's Cooperative Snow Fence Program.

Structural snow fence



The conventional slatted, four-foot high snow fence and the six-foot high board fence have been used in Iowa in the past. The preferred height for a single row fence is six feet. The height of snow fence required depends on the annual snowfall. Most places in Iowa will receive great benefits from a four- to six-foot high fence.

Standing corn



This type of snow barrier affords the landowner more control over the materials used on their property since they plant their own fields. (However, advance planning is required because the rows of corn need to be planted parallel to the roadway.) In the past, landowners have arranged to have service organizations pick the corn by hand and sell it to benefit their organizations. Events such as this may be tax deductible and also offers a community service for the area.

Living snow fence

Living snow fence is pleasing in appearance and requires little maintenance. Living snow fences work the same as those already mentioned. They too need to be placed back from the roadway a distance of 15 times the mature height of the plant.

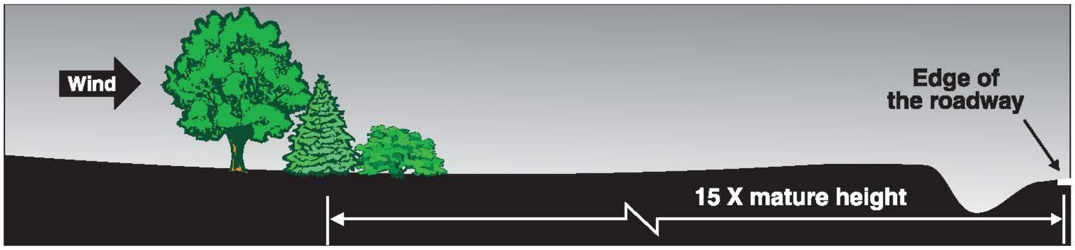
Species are selected and placed to create the space needed for a snow fence when the plants reach maturity. The goal is to establish a living fence that not only survives and grows fast, but also remains effective over a long period.

Deciduous trees, shrubs and native grasses

Windbreaks made of trees, shrubs and native grasses have been used for years. Not only do trees, shrubs and native grasses provide wind protection, but they add beauty to the roadway and create a habitat for wildlife.

4

Figure 104: Fourth page of Iowa's Cooperative Snow Fence Program



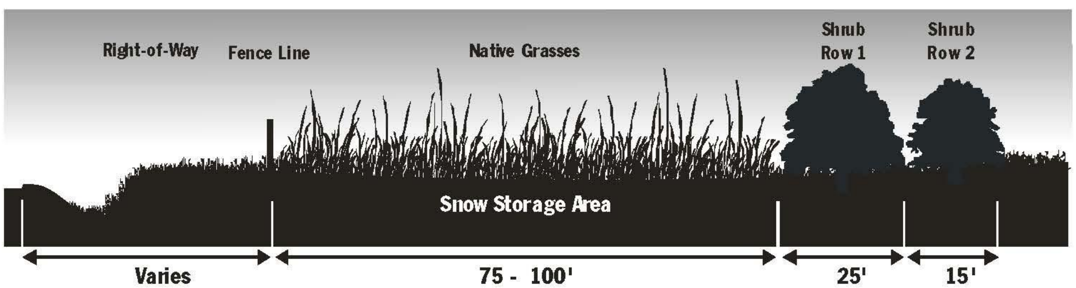
Trees and shrubs should be planted in rows running parallel to the roadway. Two rows or more provide the most effective wind protection. Native grasses should be at least 100 feet deep running parallel to the roadway.

Species selection is determined by the soil type and fertility, as well as the surrounding vegetation. Because soil types vary around the state, each living snow fence may be custom designed to suit that area.

The availability of funding for living snow fence varies from year to year.

Conservation Reserve Prograam (CRP) Living Snow Fence

The CRP now includes a living snow fence program that allows landowners to receive annual payments for up to 15 years if they agree to plant two rows of trees or a combination of trees and shrubs along with a 75-100 foot buffer of native grasses. More information about this CRP living snow fence program is available at the local Farm Service Agency, Natural Resource Conservation Service office or local Iowa DOT maintenance garage.



How to get involved

The Iowa Department of Transportation wishes to expand participation in the Cooperative Snow Fence Program. The program establishes agreements with private landowners for the use of snow fence. Landowners have been, and continue to be, the keys to the success of the program.

> ***"It's amazing to see how well snow fences can help prevent drifting problems and improve visibility. I can really see the benefits of snow fence along the roadway."***
>
> *Walter Phillips*
> *Pocahontas County farmer*

If you would like to learn more about the program and benefits of snow fences, contact your local DOT maintenance office listed on the back page.

5

Figure 105: Fifth page of Iowa's Cooperative Snow Fence Program.

Common Snow Fence Questions and Answers

Q. How could I benefit from installing a snow fence?
A. If you have a driveway or access road to your property that tends to drift full in the winter, making it difficult for you to travel, then a snow fence may be a solution. Snow fences can reduce or stop drifting all together.

Drifts are formed on roadways because an obstacle, such as a ditch or a building, has forced the wind to move around it, causing the wind speed to slow down. As the wind slows, the snow particles carried in the air have a chance to settle to the ground. Over time, a drift will form around the object.

Snow fences, whether they are structural, made of corn, or living provide the same results. They cause the wind speed to slow so the snow particles in the air have a chance to rest, forming a drift. However, the drift is now located at the snow fence instead of on the roadway or drive.

Q. What height snow fence should I use?
A. The appropriate height for a fence depends upon three factors: 1) how much snowfall is common for your area; 2) what type of snow fence is available; and 3) how much snow you want to trap. Any standard size fence will help stop snow from drifting. But, the taller the fence, the more snow that will be trapped. One row of eight-foot high fence is recommended for maximum efficiency. However, multiple rows of shorter fence can also be used. For driveways or access roadways, one row of four- to eight-foot tall fence is most commonly used.

Q. Where should a snow fence be placed?
A. Fences should be set back from the edge of the roadway a distance of 35 times the height of the fence. For example, if the snow fence is eight feet tall, it should be placed 280 feet back from the edge of the roadway. (8' high x 35 = 280-foot set back) The fence should be placed perpendicular to the prevailing winter winds and parallel with the road.

Q. Where can I purchase prefabricated snow fence or find materials to make my own?
A. Many local farm supply stores or larger hardware/lumber stores carry prefabricated snow fence and fence materials. Snow fence is made of wood, plastic and other materials that withstand the winter elements. For instance, general purpose plastic snow fence made of high density polymers is usually available in 4' x 100' orange-colored rolls.

The best snow fence for collecting snow is one made with horizontal pieces. Wind flow over a horizontal fence will slow quicker than over a vertical fence, causing more snow to deposit on the horizontal fence than the vertical fence. To get the best results, the fence material should have 40-50 percent open space and should be placed six inches above the ground. This allows the wind to pass through the fence while trapping snow particles at the same time.

PM 775 8-20-98

Figure 106: Sixth page of Iowa's Cooperative Snow Fence Program, "Common Snow Fence Questions and Answers."

Types of snow control

Type	Description	Advantages	Agreement length	Compensation (annual)
Structural, permanent	Six- to eight-foot tall fence consisting of two wooden posts, lightweight plastic fence and 2" x 4" supports.	Very low maintenance. Only takes up a one-foot width of land.	Five year minimum.	$.50 per linear foot.
Structural, temporary	Four-foot tall portable plastic fence or wooden fence.	Installed after harvest and removed before planting.	Fall to Spring.	None.
Standing corn	One to two sections of four to 12 rows of corn, each separated by 160 feet.	Can reduce soil erosion. Public service organizations benefit from picking by hand. Wildlife habitat.	Fall to Spring.	$.50 above market price.
Corn stalks	Left in the field after harvest. No-till field conditions.	Wildlife habitat. Reduces soil erosion. Hunting ground.	Fall to Spring.	None
Living, trees or shrubs	Three or more rows of trees or shrubs, or a combination of both.	Wildlife habitat. Reduces soil erosion. Hunting ground.	10 years.	Living Roadway Trust Fund. Contact Roadside Development.
Living, switchgrass (testing)	Twelve-foot strips of five-foot tall durable grass.	Wildlife habitat. Hunting ground. Low maintenance.	Six years.	$.50 above market price/linear foot.

PM 775 8-20-98

Figure 107: Seventh page of Iowa's Cooperative Snow Fence Program.


Wisconsin's Standing Corn Row Snow Fence Program

WISCONSIN DEPARTMENT OF TRANSPORTATION

July 2014

Revised 07-28-2014

Figure 108: Cover page of Wisconsin's Standing Corn Row Snow Fence Program (Cir. 2014).

Wisconsin's Standing Corn Row Snow Fence Program

There are many ways to influence the wind that carries tons of blowing and drifting snow. Periodically, severe winter storms will create large snow drifts that close roads and driveways, isolate farmsteads and increase snowplowing. Many of these drifting problems happen in the same place year after year. Although there are no foolproof methods of wind and snow control, strategically placed standing corn row snow fences can reduce or eliminate drifting problems in many areas.

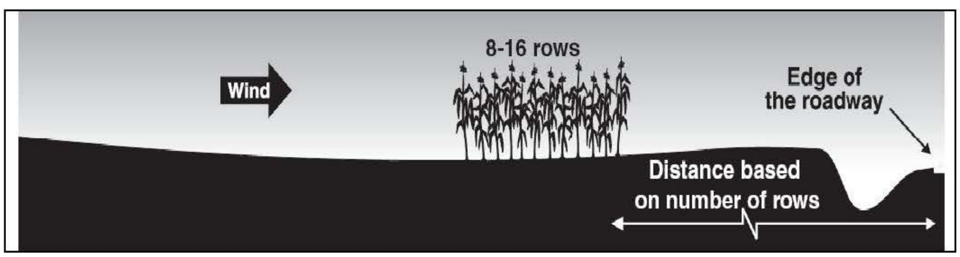
"National research has found that it costs 100 times more to plow snow than to trap it with a snow fence." **Source:** Strategic Highway Research Program.

Public benefits of standing corn row snow fence

- Reduces blowing and drifting snow on roadways
- Stores snow at low cost
- Reduces the accident rate during snowy, windy conditions
- Creates safer travel conditions
- Decreases freezing and thawing effects on the roadway
- Lowers snow removal cost
- Increases visibility

Benefits to landowners

- Improves winter access to farmsteads and rural areas
- Helps reduce soil erosion
- Provides a service to your community
- Conserves wildlife
- Can increase yield by retaining moisture and reducing drying effects of the wind



Revised 07-28-2014

Figure 109: First page of Wisconsin's Standing Corn Row Snow Fence Program.

Standing corn row snow fence requirements:

- Corn must be planted parallel to the roadway.
- Land owner must take precautions to prevent livestock from entering area and damaging standing corn.
- Land owner may hand pick the corn but the stalks must remain intact throughout lease period which ends on March 15th. (In the past, landowners have arranged to have service organizations pick the corn by hand and sell it to benefit their organizations. Events such as this may be tax deductible and also offers a community service for the area.)
- Area of standing corn cannot be disturbed until after March 15^{th}.
- Number of rows will depend on how far they are from the roadway. Regional staff will work with the land owner to determine the appropriate number of rows necessary to create effective snow fence.
- ORIGINAL SIGNED TAXPAYER IDENTIFICATION NUMBER (TIN) VERIFICATION FORM is required for reimbursement. Send the original with your signature to the local WisDOT office contact listed for your county.
- WisDOT will pay $0.50 more per bushel then the bushel price used at the time of the agreement signing.
- All agreements made from December 1^{st} through June 30^{th} will be honored based on the previous year's July price for the county the corn is located in. The price per bushel is determined based on the National Agricultural Statistics Service (NASS), Agricultural Statistics Board, U.S. Department of Agriculture.
- All July 1^{st} through November 30^{th} agreements will be determined based on the current bushel price at the local mill. Where the local mill is defined as where the agreement party typically takes their grain or the current NASS price for the county the corn is located in; whichever is higher.

How to get involved

The Wisconsin Department of Transportation wishes to expand participation in the standing corn row snow fence program. The program establishes agreements with private landowners for the use of standing corn row snow fence. Landowners have been, and continue to be, the keys to the success of the program.

If you would like to learn more about the program and benefits of standing corn row snow fences, contact your local DOT region maintenance office contact listed on the next page.

Revised 07-28-2014

Figure 110: Second page of Wisconsin's Standing Corn Row Snow Fence Program.

Appendix G: Lifecycle Cost Framework

Before you start, you will need this information:

Site Description: Example 1 is the 1 (of 100) ranked blowing snow problem area located Rapids City, SD Hwy 42, MRM 48. This site has a length of 0.101 miles (or 533 ft), is located adjacent to crop, pastureland, or hay and therefore LSF, structural snow fence, and temporary snow fence were considered as feasible options.

1. Select which blowing snow treatments are feasible at the location. The data elements needed for Example 1 are highlighted below.

Table 44: Step 1 of the Lifecycle Cost Framework to select feasible blowing snow treatments.

Data Needs	Structural Snow Fence	Temporary Snow Fence	Living Snow Fence	Standing Corn Rows	Earthwork Grading	Snow Ridging, Berming
Contracted Amount or Loaded Build Cost Per Foot	X		X		X	
Personnel Rate (per hour)	X	X	X		X	X
Equipment Rate (per hour)	X	X	X		X	X
Temporary Snow Fence Material		X				
Seasonal Maintenance Material Costs (ex: nails, rebar, weed cloth, etc.)	X	X	X			
Watering			X			
Land Lease/ Easement ($/year)	X	X	X	X		X
Crop Reimbursement Rate (per acre, bushel)				X		
Round Trip Distance to Site (miles)	X	X	X	X	X	X
Length of Blowing Snow	X	X	X	X	X	X

Treatment (ft or acres)						

2. Fill in data elements

Table 45: Set Costs/Amounts for Step 2 of the Lifecycle Cost Framework.

Set Costs/Amounts	**Cost**
Round Trip Distance to Site (miles)	14.3
Length of Blowing Snow Treatment (ft or acres)	533
Land Lease/Easement ($/year)	$850.00

Table 46: Structural Snow Fence Costs calculations needed for Step 2 of the Lifecycle Cost Framework.

Structural Snow Fence Costs	**Cost Per Unit (or hourly rate)**	**Number of Units**	**Total Cost**	**Notes**
Set Up Cost Per Foot	$15.00	533	$7,995.00	
Seasonal Snow Fence Maintenance - Personnel	$37.02	8	$296.16	
Seasonal Snow Fence Maintenance - Equipment	$2.01	8	$16.08	
Seasonal Maintenance Material Cost(s) Per Season (ex: lumber, nails, rebar, etc.)			$250.00	Enter lump sum cost of seasonal maintenance materials.

Table 47: Temporary Snow Fence Costs calculations needed for Step 2 of the Lifecycle Cost Framework.

Temporary Snow Fence Costs	**Cost Per Unit (or hourly rate)**	**Number of Units**	**Total Cost**
Snow Fence Set Up - Personnel	$37.02	40	$1,480.80
Snow Fence Set Up - Equipment	$2.01	40	$80.40
Seasonal Snow Fence Maintenance - Personnel	$37.02	16	$592.32
Seasonal Snow Fence Maintenance - Equipment	$2.01	16	$32.16
Fence Material (ex: plastic sheeting, posts, ties, nails, etc.)	$14.00	533	$7,462.00
Other Material Cost(s) (ex: nails, rebar, etc.)			$250.00

Table 48: Living Snow Fence Costs calculations needed for Step 2 of the Lifecycle Cost Framework.

Living Snow Fence (LSF) Costs	**Cost Per Unit (or hourly rate)**	**Number of Units**	**Total Cost**	**Notes**
Set Up Cost Per Foot	$15.00	533	$7,995.00	
Seasonal Snow Fence Maintenance - Personnel	$37.02	8	$296.16	
Seasonal Snow Fence Maintenance - Equipment	$2.01	8	$16.08	
Seasonal Watering			$0.00	May be DOT or an MOU w/ county conservation district will cover materials and costs.
Seasonal Maintenance Material Cost(s) (ex: weed cloth, additional plants, etc.)			$10.00	

3. Compare estimate cost per treatment lifecycle

Table 49: Step 3 of the Lifecycle Cost Framework is to compare the estimated cost per treatment lifecycle.

Blowing Snow Treatment	**Contract Cost/Build (material, personnel, equipment costs)**	**Maintenance (Life Cycle)**	**Land Lease/Easement or Reimbursement Cost**	**Crop Reimbursement**	**Total Cost**	**Life Cycle (Yrs)**	**Cost Per Year of Service**
Structural Snow Fence	$8,000.00	$11,244.80	$850.00		$20,094.80	20	$1,004.74
Temporary Snow Fence	$9,273.20	$1,873.44	$850.00		$11,996.64	3	$3,998.88
Living Snow Fence	$15,000.00	$16,112.00	$850.00		$31,962.00	50	$639.24
Standing Corn Rows				$0.00	$0.00	1	$0.00
Earthwork Grading	$0.00				$0.00	100	$0.00
Snow Ridging, Berming	$0.00	$0.00	$0.00		$0.00	1	$0.00