Research and Assess the Farmer and MnDOT Economic and Environmental Costs and Benefits of Living Snow Fences, Including Carbon Impacts

Final Report

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Executive Summary

A living snow fence (LSF) is a type of windbreak designed to keep blowing and drifting snow off roadways, a transportation efficiency and safety concern. The Minnesota Department of Transportation (MnDOT) administers a program working with landowners to maintain standing corn rows and install LSFs in areas where blowing and drifting snow is a problem.

In 2011, MnDOT paid a total of $50,974 for LSF (tree and shrub) contracts and $42,786 for standing corn row contracts. The 2011 budget for snow and ice removal was $81,085,501 (Appendix M). MnDOT spent 0.12% of the budget for preventative LSFs to landowners. MnDOT currently has contracts with 86 landowners on these sites representing 2.3% of the problematic sites. Approximately 3,800 sites have been identified in Minnesota to be problem snow sites.

Establishing standing corn rows and LSFs improves driver visibility, road surface conditions, and has the potential to lower costs of road maintenance as well as accidents attributed to blowing and drifting snow. LSFs can also sequester carbon and can avoid carbon emissions during snow removal operations. MnDOT has paid farmers to leave standing corn rows to protect identified snow problem roadways at $1.50 per bushel above market price which may not be sufficient incentive for leaving standing corn rows. Also, with MnDOT's memorandum of understanding with the United States Department of Agriculture (USDA) to plant LSFs through the Conservation Reserve Program (CRP) and the Environmental Quality Incentives Program (EQIP), now is an opportune time to review MnDOT's annual payment structure to farmers and make appropriate changes. The opportunity comes from the low adoption rate (2%) of a program with clear transportation and safety benefits. Quantifying the social constraints and the economic benefits and costs will allow the development of a new LSF payment program with the goal of increasing adoption rates in snow problem areas with positive economic net benefits.

This project has 1) Identified agency constraints to implementation of the current LSF program; 2) Evaluated farmers' willingness to establish LSFs and identify farmers/landowners constraints to adoption; 3) Estimated potential income from carbon payments; 4) Working closely with MnDOT engineers and plow operators, estimated the safety and snow removal costs and carbon emissions avoided by MnDOT through establishing LSFs; 5) Developed a calculator to estimate payment ranges to farmers that include consideration of safety and snow removal cost savings.

Five representative study sites were selected to conduct initial landowner focus group interviews. The areas selected were chosen to represent the variety of diverse conditions throughout the state of Minnesota. The sites included: International Falls, Breckenridge, Owatonna, Worthington, and Marshall. A total of 45 Minnesota landowners participated in five focus group discussions between January and February, 2010.Following the focus group interviews, landowners participating in the MnDOT LSF program were interviewed to get their input.

Focus group participants revealed a variety of perceived costs and constraints, and also described the conditions that would likely increase landowner adoption of the program. Specifically the life cycle costs of the LSF were most frequently mentioned including the costs associated with implementation, maintenance, rejuvenation, and removal costs. Other costs identified included the opportunity costs, costs related to changing land values, and some participants concluded the compensation was insufficient to cover all costs. Specific constraints that emerged in the discussion included risk, hassle and time constraints, and concerns about the contract. The

biggest constraints to adoption of the practice were the risks associated with the maintenance of the LSF planting including replacing lost trees and the landowner's liability to maintain the fence and the associated costs. Other constraining factors included the hassles presented by the LSF planting and additional time required to negotiate the hassles. Concerns about the rigidity and the length of the contract were final constraining factors discussed by participants.

As with other case studies documented in the literature, no universal variables influencing adoption emerged during the focused discussions. However, landowners in this study did identify several factors that positively influenced adoption of the LSF practice. These factors identified are awareness of the program, relative advantage, perception the program promotes the landowner's objectives, and incentives or compensation.

An online survey was distributed to key agency staff to better understand the perspectives of these individuals and the role played by each agency and its staff. A total of 160 agency staff completed the survey, representing the following agencies: MnDOT, Farm Service Agency (FSA), Soil and Water Conservation Districts (SWCD), and Natural Resource Conservation Service (NRCS). Results across the various agencies surveyed indicate that there is great interest in the LSF program and high confidence that the program is effective. The agency staff has the technical training and competency needed to promote and implement the program; however resources such as time and funding are more limited.

Several opportunities emerge to improve the program and increase landowner adoption of the practice, specifically several opportunities exist to address the costs and constraints the landowners encounter. Recommendations for improving the program include, but are not limited to, developing more flexible contracts, offering adjustable payments, adding more competitive incentives, providing alternatives for maintenance, creating a system of insurance against risk, and decreasing landowner liability.

Landowner costs were also documented for standing corn rows and LSF plantings with trees and shrubs. Farmers who had established snow fences in the past had the following suggestions for improving the LSF payment mechanism and agreement:

- Payments need to be adjusted for inflation in land values over time (increased). Two mechanisms can be used to achieve this 1) fixed historical inflation rate which increases the payment over the length of the contract and 2) adjustable inflation rate tied to a public index which changes every year based on changes in land prices. CRP annual payments are flat over the contract and so the transportation agency would have to take on a higher share of the total annual payment over time.
- After the establishment of snow fences, there are high maintenance costs during the first, second and third years. MnDOT should consider compensating the farmers for the first 3-4 years with a higher payment to cover these elevated maintenance costs and move back to a lower rate following that period.
- Flexible criteria for determining annual payment may be required because the cost of maintenance may differ from one area to another and from one farmer to the next. Payment for maintenance activities like watering could be considered.
- Better mechanisms for targeting landowners for snow fence promotion and educational materials should be considered. Approaching landowners with concrete payment information and personal visits should be encouraged.

- Paying for the entire area between the LSF the edge of the right of way will reduce the hassle of farming around the LSF and also provide a larger conservation area with associated environmental benefits. (In earlier contracts it was not possible but it is being offered now).
- MnDOT should consider paying the cost of removing the LSF trees at the end of agreement if the landowner does not sign a new contract.
- Consideration of bonus payments for locations with high potential benefits (super-elevated curve, high accident rates, etc.)

Farmers have provided a number of suggestions related to technical improvement of the standing corn rows as well as the mechanism for payment to the farmers.

- The payment mechanism should adopt a formula which is based on yield, production costs, inconvenience factors, income or financial benefit received, and the price of corn. Paying all the farmers at the same rate in the same region was one of the main suggestions.
- Farmers would prefer a single strip of standing corn rather than the recommended 2 strips. This might improve adoption but may limit the effectiveness of the standing corn rows in catching and storing snow.

The research team recommends that the agency promote LSFs planted to trees and/or shrubs over standing corn rows because of the lack of benefits during the soybean year in a corn/soybean rotation.

Trees in agricultural or forested landscapes sequester carbon dioxide from the atmosphere, a primary greenhouse gas, and store it as carbon in the form of biomass. Carbon sequestration of LSFs can provide an additional benefit beyond addressing blowing and drifting snow issues. It can also avoid emission of greenhouse gasses (i.e., carbon) back to the atmosphere due to reduction in road maintenance activities linked to controlling blowing and drifting snow. Such positive impact of LSFs will result in a reduction of fuel use for the trucks and other equipment used to deal with blowing and drifting snow.

The Living Snow Fence Payment Calculator is a computer program (Excel) tool which allows the user to enter inputs regarding a snow problem area or site plus enter characteristics about the site. This tool has custom features specific to MnDOT. However the tool is usable by any agency or County Engineers but will require more user input and/or construction of databases. One custom feature is district wide snow problem area prioritization maps. These allow for state and district wide prioritization based on the benefit cost ratio. The calculator can then be used for a more detailed analysis of individual snow fences. The calculator analyzes landowner costs and computes possible payments for LSFs and standing corn rows.

The output section of the tool provides a review of opportunity cost, transportation agency benefits, social benefits and minimum payment options. This tool will help agency staff work with local landowners to arrive at a realistic, economical and cost effective payment for land practices (LSF or standing corn rows) protecting state and local highways.

Based on this study and the information available to the authors, MnDOT could see net economic returns of over $1.3 million dollars per year if 40% of the sites inventoried blowing and drifting snow problems would be contracted to LSF practices.

A detailed list of recommendations is included in Chapter 7.

Chapter 1
Introduction

1.1 Introduction

Living snow fences which are rows of trees and shrubs planted to keep blowing and drifting snow from accumulating on roadways, have demonstrated their ability to address blowing and drifting snow problems. By having established living snow fences running in lines parallel to roadways and perpendicular to prevailing winds, highway departments are able to achieve several objectives during and after blowing snow events: 1) maintain a relatively snowdrift free highway surface during blowing snow events thus maintaining a steady flow of traffic; 2) minimizing the occurrence of "blow ice," ice forming on the roadway when snow blows across the surface, thus decreasing the potential for accidents when drivers cross the ice; 3) lowering the cost of maintaining snow and ice free roadways during and following blowing snow events; and 4) lowering the number of serious accidents attributed to snow and ice on roadways.

Another option for avoiding blowing and drifting snow problems is leaving standing rows of corn in the winter that function as snow fences. Both options are supported by MnDOT and will be discussed in this report. In the report "Living Snow Fences" will be referred to as **LSF**, and "Standing corn rows" will be referred to as **SCR**, and when referring to both, the term "snow fence(s)" will be used.

In addition to the benefits provided to highway departments, there are other present and potential benefits of snow fences. Snow fences often provide habitat for wildlife while also functioning to sequester and store carbon from the atmosphere. The reduction of atmospheric carbon is increased by the emissions avoided when highway departments can limit the time and fuel consumption of their maintenance activities related to snow and ice removal and treatment. Living snow fences, if planted and managed as biomass for energy, could also provide a source of renewable energy while protecting road surfaces from blowing and drifting snow (see Chapter 2 for a literature review of LSF).

Because of the benefits provided by LSF and SCR, MnDOT, in coordination with the Farm Service Agency (FSA), the Minnesota Association of Soil and Water Conservation Districts (MASWCD) and the USDA Natural Resource Conservation Service (NRCS), implemented an LSF and SCR program starting in 2002. Between 2002 and 2008 FSA worked with MnDOT and NRCS to establish and maintain 20 miles of living snow fence in collaboration with nearly 50 private landowners (USDA FSA, 2008). Agricultural landowners who participate in the LSF program are required to enroll in the CP-17A-Living Snow Fence Practice within the Continuous Conservation Reserve Program. Participants then receive establishment cost share and annual compensation for a period of up to 15 years; the compensation includes the acreage enrolled in the Continuous Conservation Reserve Program, payments from MnDOT to mitigate the inconvenience of farming around the fence, and compensation for the costs of establishing and maintaining the living snow fence (MnDOT, 2009). Non-agricultural landowners are eligible for Environmental Quality Incentive Program (EQIP) cost share and payments from MnDOT.

Despite fairly generous payments to landowners, adoption of LSF and SCR has been limited, addressing only a small percentage of identified problem areas in the state. A MnDOT funded survey of blowing and drifting snow problem areas revealed 3,841 snow traps along 1,233 miles

of MnDOT-maintained highways while between 2002 and 2008, the program was only able to address 50 problem areas and 20 miles of roadway. Obviously much more needs to be done to address the blowing and drifting snow problem that MnDOT faces. In order to help address the issue of adoption, MnDOT sponsored this research study to help estimate the impact and costs of implementing living snow fences to protect MnDOT administered Minnesota roadways.

The study addresses three important questions related to promoting greater adoption of LSF and the benefits they provide: 1) What are the constraints that landowners perceive as they consider adoption of living snow fences? 2) What are the total costs that landowners must take on when implementing living snow fences? and 3) What are the direct and indirect benefits of LSF and the value of those benefits to MnDOT and as public goods? Being able to quantify the costs and benefits of LSF to landowners, MnDOT can come up with a payment that is fair to landowners based on real costs in implementing LSF including additional payments that might be required to incentivize farmers in adopting the practice. By knowing the direct benefits that MnDOT receives from implementing an LSF, it will help MnDOT determine if the benefits in cost savings are greater than the payment to landowners. The value of the indirect benefits (public value) provided by LSF can be used as another decision criteria as MnDOT and its' partners consider changes to the LSF program.

In dealing with costs of the LSF program, this study took three approaches: 1) Working with landowners and focus groups, the costs of installing and maintaining living snow fences and standing corn rows were estimated. In addition, specific constraints related to risks and rewards from the installation and maintenance of the fences were elicited from landowners; 2) Working with MnDOT administrators, maintenance and safety people, benefits related to reduced costs for snow removal and application of chemicals were evaluated to estimate direct cost savings for MnDOT resulting from the installation and maintenance of snow fences; and 3) Indirect cost savings related to avoiding traffic slowdowns, avoiding serious accidents, sequestering carbon and avoiding emissions were estimated.

Those costs and benefits were incorporated into a Living Snow Fence calculator that, based on the location of a problem area, can be used to estimate: 1) the costs incurred by landowners in establishing and maintaining LSF; 2) MnDOT's direct cost savings associated with installing LSF on specific problem stretches of roadway; and 3) the indirect and public benefits of LSF above and beyond the direct cost reductions to MnDOT operations. The calculator is meant to be a tool that MnDOT can use to make decisions when considering deploying (or removing) a LSF and determining the appropriate compensation to the prospective landowner.

The specific issues addressed by this study include:

- **Costs of snowfence adoption**: The research on costs was conducted through interviews with farmers who have adopted snowfences to better understand their costs in establishing and maintaining snowfences. This varied depending on the type of snowfence and the level of maintenance provided. This information was used to develop the cost calculator.
- **Constraints to the adoption of snowfences**: This work was accomplished through focus groups and individual farmer interviews to identify reasons why a farmer/landowner might not be willing to adopt a snowfence. This information has been used to make recommendations for ways to promote greater adoption of snowfences.

- **Avoided maintenance and safety costs**: We worked closely with MnDOT engineers to estimate two types of avoided costs. The avoided costs associated with removing blowing and drifting snow and costs avoided from crashes caused by blowing and drifting snow based on MnDOT data on those costs. We identified problem areas for blowing and drifting snow and calculated the avoided costs based on MnDOT records.

  This work included meetings with MnDOT engineers and plow operators to discuss how and why additional costs are incurred on problematic roadways.

- **Calculating carbon emissions from maintenance and sequestration by living snowfences**: We used the additional fuel costs associated with snow removal in the absence of a snowfence to determine the additional carbon emissions occurring when snowfences are not available. We also calculated the potential carbon sequestration accomplished by establishing living snowfences. This was done by estimating tree/plant growth in a LSF and converting that annual growth to carbon sequestered. Carbon calculations were based on a review of secondary information.

- **Development of a payment calculator**: To develop the payment calculator we used: a) data on costs of establishment and maintenance of snowfences; b) avoided road maintenance and avoided safety costs, and 3) carbon emissions avoided and carbon sequestered estimating a value for each of those landowner costs and public/MnDOT benefits. The calculator lists those costs/benefits separately to demonstrate where those costs/benefits occur and assist the MnDOT decision making process.

1.2 Report Organization

The report is organized into several chapters that represent individual tasks related to the overall objectives of identifying costs, benefits and constraints to adoption of living snow fences in order to develop a decision support tool for MnDOT to administer their program for LSF and SCR. This chapter introduces the work and the following chapters outline the methods and results obtained from the individual tasks. The final chapter integrates the information and presents recommendations based on the findings of the study.

Chapter 2 reports on the results of our initial Focus Group meetings with landowners and an online survey distributed to MnDOT employees and agency representatives that assist MnDOT with snow fence implementation. Five representative study sites were selected to conduct initial focus group interviews. The areas selected were chosen to represent the variety of diverse conditions throughout the state of Minnesota. The sites included International Falls, Breckenridge, Owatonna, Worthington, and Marshall. A total of 45 Minnesota landowners with and without living snow fences participated in five focus group discussions between January and February, 2010. The focus group discussion was meant to identify the costs, benefits and constraints that landowners feel limit or help promote adoption of snow fences. The focus group discussions identified general costs and benefits of living snow fences and standing corn rows while a more detailed accounting of costs and benefits was included in subsequent chapters.

A total of 160 agency staff completed the online survey, representing the following agencies: MnDOT, FSA, SWCD, and NRCS. The agency survey elicited information on the agency staff persons' perception of the value of LSF and their familiarity with the MnDOT program and ability to promote and implement LSF in their particular work area. In addition, the agency staff were asked if they had sufficient resources and time to implement the LSF program.

The focus of Chapter 2 was to 1) understand the costs and constraints to landowner adoption of LSF to be able to design programs that address constraints and adequately compensate landowners for implementing snow fences; and 2) to understand the interest and ability of agency staff to promote and implement snow fence programs. The information generated by the focus groups and survey will play a crucial role in designing more effective programs leading to greater adoption of snow fences.

Chapter 3 takes as its base the information generated in the focus groups and surveys from Chapter 2 and concentrates on better estimates of the specific costs of snow fences including the detailed costs of establishment and maintenance; costs related to the inconvenience of farming around snow fences; and issues landowners had with the payment mechanism. Information for Chapter 3 was gathered through on-farm interviews of landowners that have adopted living snow fences and agency records of costs as well as discussions with agency representatives in the project areas. The information in Chapter 3 was used to help develop the cost structure for snowfences used in the payment calculator as well as to add farmer interview data to clarify results presented in Chapter 2.

Chapter 4 explores the impact of living snow fences on Greenhouse gas emissions and the estimated value of that impact. It includes 1) greenhouse gas emissions avoided by LSF by reducing the use of equipment and fuel to address blowing and drifting snow problems; and 2) the greenhouse gases sequestered in the vegetation (trees, shrubs and grasses). The information on greenhouse gases is incorporated into the LSF calculator.

Chapter 5 details the transportation agency benefits of the snow fences. This chapter includes calculations related to cost savings realized when snow removal equipment does not need to be mobilized, and when they are able to reduce the amount of sand and salt applied to the roadway. The final part of Chapter 5 provides instructions for a tool designed to analyze the impact of LSF on snow conditions and the application of sand and salt based on AVL (Automatic Vehicle Logger) equipment recently installed on MnDOT plows. This equipment will allow MnDOT to pinpoint areas of roadways where they are having blowing and drifting snow problems and estimate the impact on roadways protected by snow fences. Since the equipment was recently installed and is still in a testing phase, it was not possible to get accurate data to reliably estimate snow fence impacts but should be in the future.

Chapter 6 presents the Living Snow Fence Payment Tool User Guide. The tool was the main goal of this study and incorporates information from the previous chapters and tasks. The User Guide demonstrates how to use the tool which is a spreadsheet program. Although the tool was designed for MnDOT and uses MnDOT data, it is set up so County highway departments can enter data specific to their roadways. Thus, the tool has application for county highway departments and could likely be adapted for highway departments by other highway agencies as needed.

Chapter 7 presents recommendations for follow up activities and options for improving the LSF program based on the findings of the study.

Chapter 2
Costs of and Constraints to Living Snow Fence Adoption

2.1 Introduction

A living snow fence is a type of windbreak designed to manage high winds and blowing and drifting snow. MnDOT administers a living snow fence program working with landowners in areas where blowing and drifting snow is a problem. Data is lacking to determine if the current compensation provided to the landowners is appropriate; therefore, the purpose of this study was to estimate the costs and benefits associated with living snow fence plantings and to determine what constraints exist to the adoption of living snow fences.

This project centers around rural Minnesota landowners who have implemented living snow fence plantings, landowners who have not implemented plantings, and key agency staff including MnDOT, FSA, NRCS, and Soil and Water Conservation Districts (SWCD). This study addressed the following research questions:

- What are the costs of living snow fence adoption? Specifically, what are the costs in establishing and maintaining the plantings?
- What are the constraints to the adoption of living snow fences? Specifically, what are the reasons a landowner might not be willing to implement a planting?

Winter storms across the state of Minnesota, and the blowing and drifting snow that result, present a variety of transportation and safety concerns. During a typical Minnesota winter, blowing and drifting snow results in reduced driver safety, degradation of road quality, hazardous driving conditions, road closures, crashes, and significant costs for removal of snow. Secondary impacts of blowing and drifting snow include shipping delays, reduced commerce, lost salaries, and lost tax revenue (MnDOT, 2009; Shulski & Seeley, 2009). The implementation of living snow fence plantings is a solution to blowing and drifting snow problems; the fences improve driver visibility and road surface conditions. Living snow fences can save lives by minimizing snow drifts and hazardous conditions, save money by reducing costs associated with road maintenance and snow removal, and save time by avoiding road closures. In order to determine appropriate compensation for private landowners who participate in the living snow fence program, the purpose of this project was to better understand the environmental and economic costs and benefits associated with living snow fences.

2.1.1 Chapter Summary

A mixed method approach was used including data gathered through focus groups and data collected in an online survey. A qualitative focus group approach was used to better understand the factors that influence Minnesota landowner's opinions, behaviors and motivations regarding living snow fence plantings. Five representative study sites were selected to conduct the focus group interviews. The areas were chosen to represent the variety of diverse conditions throughout the state of Minnesota and the sites included: International Falls, Breckenridge, Owatonna, Worthington, and Marshall. A total of 45 Minnesota landowners participated in five focused discussions between January and February, 2010. In addition, an online survey was distributed to key agency staff in order to better understand the perspectives of these individuals and the role played by each agency and its staff. A total of 160 agency staff completed the survey.

Focus group participants revealed a variety of perceived costs and constraints, and also described the conditions that would likely increase landowner adoption of the program. Specifically the life cycle costs of the living snow fence were most frequently mentioned including the costs associated with implementation, maintenance, rejuvenation, and removal costs. Other costs identified included the opportunity costs, costs related to changing land values, and some participants concluded the compensation was insufficient to cover all costs. Participants in the focus groups discussed several factors as constraints to adoption of the living snow fence practice. Specific constraints that emerged in the discussion included risk, hassle and time constraints, and concerns about the contract. The biggest constraints to adoption of the practice were the risks associated with the living snow fence planting including replacing lost trees and the landowner's liability to maintain the fence and the associated costs. Other constraining factors included the hassles presented by the living snow fence planting and additional time required to negotiate the hassles. Concerns about the rigidity and the length of the contract were final constraining factors discussed by participants. As with other case studies documented in the literature, no universal variables influencing adoption emerged during the focused discussions. However, landowners in this study did identify several factors that positively influenced adoption of the living snow fence practice. The factors that emerged in the focus group discussion were similar to influencing factors that are documented in the literature. Specifically landowners identified the factors influencing adoption of living snow fence plantings as the following; awareness of the program, relative advantage, perception the program promotes the landowner's objectives, and incentives or compensation.

2.2 Living Snow Fence Literature Review

To gain an understanding of past research regarding windbreaks and living snow fences, a literature review was conducted. This review is divided into three sections: 1) windbreak structures and impacts, 2) farmer adoption of innovation, and 3) MnDOT Living Snow Fence Program.

2.2.1 Windbreak Structures and Impacts

Windbreaks are a category of Agroforestry practices that have been used for centuries. Windbreaks, also called shelterbelts, hedgerows, or fence rows, are rows of trees, shrubs, grass, or standing crop rows planted between agricultural fields to block the force of the wind (Cook & Cable, 1995). Scotland was one of the first countries to adopt windbreaks to protect agriculture production when the Scottish Parliament encouraged planting of tree belt fences between fields (Droze, 1977). In the United States, the "dust bowl" of the early 1930s was the catalyst for widespread planting of windbreaks across the country. The Prairie States Forestry Project was authorized by the U.S. Congress in 1935 and thousands of miles of windbreak fences including 200 million trees were planted in the Great Plains (Baer, 1989).

Windbreaks produce a variety of economic, ecological, and social impacts. Economic benefits include crop protection, increased crop yield, reduced erosion and improved crop water use. In addition windbreaks can protect livestock from harsh weather, shelter working areas on the land, and shield homes to assist in reducing heating and cooling costs (Mize, Brandle, Schoeneberger, & Bentrup, 2008). Living snow fences are a type of windbreak that can be used to manage high winds and blowing and drifting snow. In addition to the economic benefits listed above, living snow fences result in additional savings by reducing the energy and labor needed for snow removal. Snow is captured and stored in the living snow fence structure and the costs of snow

removal, plowing, labor, and maintenance are reduced (Brandle & Nickerson, 1996). The performance of the living snow fence depends on the design and the location of the windbreak. A low density living snow fence, or a porous fence, will have open spaces between the plantings and it will spread the snow across the protected area (Bradle, Hodges, & Zhou, 2004). The porous living snow fence can help capture the moisture provided by snow and provide additional water to protected crop fields or range lands. A high density living snow fence will have multiple rows of plantings and a large amount of solid material in the fence. This structure will capture and store snow in a restricted area and reduce the amount of blowing and drifting snow on roads (Brandle & Nickerson, 1996).

Windbreaks and living snow fences have a variety of environmental impacts; these impacts are different depending on planting location, the structure of the windbreak, and the plant species used. Although environmental impacts will vary site by site, the environmental benefits of windbreaks are widely considered to include enhanced habitat diversity, refuge for birds and insects, erosion control, increased moisture retention from snow, and protection for wildlife during harsh weather (Brandle et al., 2004). Porous living snow fences do increase moisture on crop lands as a result of distributing snow over crop fields. However, these fences and other windbreak plantings do compete for water resources with adjacent crops and this can have a negative impact on crop yield.

There are some quantitative studies documenting the social benefits associated with windbreaks. Living snow fences perhaps provide the most important social benefit of all windbreaks; living snow fences save lives by reducing blowing and drifting snow on roadways. The Minnesota Division of Emergency Managements estimated 142 fatalities caused by hazardous driving conditions associated with blowing and drifting snow between 1984 and 2002 (MnDOT, 2009). Strategic placement of a living snow fence along problem areas can reduce the amount of snow that blows and drifts onto the road, and thus improves safety conditions and potentially saves lives. Living snow fences save tax payer money as they reduce the cost and time needed for snow removal, maintenance and plowing (Kuhn, Hanley, & Gehringer, 2009). Cook and Cable (1995) conducted a study to quantitatively test if windbreak plantings contribute to scenic beauty. Using the Scenic Beauty Estimation Method, they found that windbreaks add positively to the scenic beauty of a landscape (Cook & Cable, 1995). Federal and state programs often help fund windbreak plantings and claim that the benefits go beyond economic and environmental to provide services to the general public as well are. Those claimed public benefits and services include scenic beauty, and this was the first study to scientifically document that the windbreak plantings do in fact contribute to scenic beauty.

While the benefits of windbreaks and living snow fences have been extensively studied and documented, little research has been done to determine the costs associated with these plantings. Mize et al. (2008) identify the three phases of a windbreaks' life cycle as establishment, functional, and mature/senescent. Each phase includes unique costs to the landowner including cost of seedlings and labor for installation during the establishment phase, cost of maintenance during the functional phase, and removal of plants or branches during the senescent phase. Additional research to identify and document the costs of windbreak plantings is needed.

2.2.2 Farmer Adoption of Innovation

The economic, environmental, and social benefits of living snow fences have been well documented. However, the actual use of living snow fence plantings is limited and many

landowners have not adopted the practice (Brandle et al., 2004). A significant body of research exists regarding landowner adoption of conservation programs and agroforestry practices such as living snow fences. Although some patterns and trends that influence landowner willingness to adopt conservation agriculture have been documented, universal variables explaining adoption or non-adoption have not been documented. In a review and synthesis of 31empirical studies seeking to understand the reasons for landowner adoption and non-adoption of conservation practices, Knowler and Bradshaw (2007) found few if any universal variables that regularly explain adoption of conservation agriculture. Efforts to promote adoption of living snow fences and other Agroforestry practices among landowners cannot be achieved with a prescribed influencing variable approach. These efforts must be done on a case by case basis to reflect the particular conditions of the individual locales (Knowler & Bradshaw, 2007). Strong and Jacobson (2006) reported similar findings in their assessment of Agroforestry adoption among Pennsylvania landowners. A variety of obstacles to adoption and benefits to adoption as well as opportunities to remove the barriers and promote the benefits were discussed. The opportunities and benefits were dynamic and unique depending on the individuals and the specific locale. Although no prescription to increase adoption was reported, Strong and Jacobson determined that the "key to outreach success and adoption will be to engage these landowner groups according to their unique interests and values, and to demonstrate the potential Agroforestry has to enhance existing objectives."

Despite the fact that no universal variables influencing adoption have been documented, there are several factors that have influenced adoption in many cases. Some of these factors include knowledge or awareness of the program, relative advantage, trialability, perception the program promotes the landowner's objectives, and incentives among others (Pannell, 1999). Adoption of any new program, such as living snow fences, has been described as a process with multiple phases and the first phase is exposure to the program and gathering information and knowledge about the program (Pannell et al., 2006; Rogers, 1995). This phase may include demonstrations of the program and technical visits to introduce landowners to the program. Extension agency staff play a key role in expanding landowner knowledge and awareness of conservation programs. Extension workers can identify program benefits from the farmers' perspective, raise awareness of the program, promote stewardship on the individual level, reduce uncertainty, and increase social network capacity (Pannell, 1999).

Relative advantage refers to the degree to which the new conservation practice is perceived as better or providing more benefits than the practice it supersedes (Rogers, 1995). For each landowner, the relative advantage of implementing a living snow fence is unique and depends on a range of economic, environmental and social factors. These factors include in-put costs, impact on profits, compatibility within the existing system, the risks involved, and the cost or profitability of the existing land use which the living snow fence would replace (Pannell et al., 2006). Conservation agriculture practices with high relative advantage will be adopted by landowners more readily.

When landowners can conduct a trial of the conservation program, they gain important information about the feasibility of the program and are better able to make a decision to adopt the practice. The risk and the initial investment are lowered with a trial of the program; landowners are then able to observe the results and assess the benefits (Pannell, 1999).

Adoption is more likely to occur when the landowners perceive that the program promotes their own individual objectives. Morris and Potter (1995) reported that the most active adopters of

conservation agriculture practices were the landowners whose personal objectives were similar to program objectives. Frequently this occurred when participants felt that the environmental protection and conservation goals of the program matched with their own objectives for land conservation and stewardship (Morris & Potter, 1995). Landowners are not passive participants in conservation agriculture; instead they are actively working within unique individual frameworks of existing goals and objectives. Agroforestry practices are more likely to be adopted when they contribute towards the achievement of these existing goals and objectives (Strong & Jacobson, 2006).

Although there is no prescriptive variable to determine adoption or non-adoption, there is strong evidence that economic considerations are the most important factors in the adoption decision making process (Cary & Wilkinson, 1997; Sniden & King, 1990). These economic considerations are frequently in the form of an incentive, or payment, to participate in the conservation agriculture practice. Kingsbury and Boggess (1990) used a contingent valuation approach to attempt to estimate landowner willingness to participate in the Conservation Reserve Enhancement Program in Oregon. As with other studies, an exact value to predict willingness to participate was not documented; however, the yearly payment was found to significantly influence the participant decision under all circumstances (Kingsbury & Boggess, 1990). Landowners provide a service to the public by adopting conservation agriculture practices on their property; however, there are costs of providing this service that often fall to the landowner. The services provided must be internalized, at least in part, to the benefit of the landowner, or the landowner will have little incentive to adopt Agroforestry practices that provide such services (Alavalapati, Shrestha, Stainback, & Matta, 2004). Environmental valuation economics are a tool that can help determine appropriate annual payments and incentives to influence and encourage landowner adoption of conservation agriculture practices.

2.2.3 MnDOT Living Snow Fence Program

Snow fences have been documented to reduce blowing and drifting snow (Brandle et al., 2004; Brandle & Nickerson, 2006), reduce time and cost needed for road maintenance and snow plowing (Kuhn et al., 2009), improve visibility and road surface conditions (Tabler, 2003), and reduce auto accidents by up to 70 percent (Tabler, 2006). Living snow fences are defined as plantings of trees, shrubs and native grasses located along roads or around communities and farmsteads (MnDOT, 2002). Living snow fences that are appropriately located and correctly designed serve as barriers that trap snow as it blows across fields or roads; the snow is captured and the living snow fence piles it up before it reaches a road, waterway, farmstead or community (MnDOT, 2002). In recognition of the multiple benefits of snow fences, a Living Snow Fence Memorandum of Understanding (MOU) was renewed on September 5, 2008 at the MnDOT Headquarters. Multiple agencies, including the United States Department of Agriculture Farmer Services Agency (FSA), the Minnesota Association of Soil and Water Conservation Districts (MASWCD), MnDOT, and the United States Department of Agriculture Natural Resources Conservation Service (NRCS), signed the MOU and agreed to work in partnership to implement a Living Snow Fence Program to alleviate the problems associated with blowing and drifting snow in Minnesota and improve winter road conditions in the state (MnDOT, 2009).

Between 2002 and 2008 the FSA worked with MnDOT and NRCS to establish and maintain 20 miles of living snow fence in collaboration with nearly 50 private landowners (USDA FSA, 2008). Landowners who participate in the living snow fence program are required to enroll in the CP-17A-Living Snow Fence Practice within the Continuous Conservation Reserve Program.

Participants then receive annual compensation for a period of up to 15 years; the compensation includes the acreage enrolled in the Continuous Conservation Reserve Program, payments from MnDOT to mitigate the inconvenience of farming around the fence, and compensation for the costs of establishing and maintaining the living snow fence (MnDOT, 2009).

2.3 Methods

A mixed methods approach was used including both focus groups and an online survey. First, focus groups with Minnesota landowners, both with and without living snow fence plantings, explored landowner behaviors and the perceived costs and constraints associated with living snow fence plantings. Second, an online survey was administered to staff members of the agencies that had entered into a Living Snow Fence Memorandum of Understanding. These agencies include the FSA, MASWCD, NRCS, and MnDOT. The discussion of methods used for this study includes both focus groups and the online survey. The following sections describe the methodology: approach, study setting, sampling, and data analysis.

2.3.1 Approach: Focus Groups

In order to better understand the factors that influence Minnesota landowner's opinions, behaviors and motivations regarding living snow fence planting, a focus group approach was used. Focus groups with landowners, both with and without living snow fence plantings, qualitatively explored the perceived costs and constraints associated with the plantings and captured landowner stories and perspectives in their own voices. Five focus group sessions were conducted between January and February, 2010. Focus groups were deemed to be more appropriate than individual interviews due to the public nature of and communal benefits provided by living snow fences. Each focus group had between three and eighteen participants and standard focus group procedures were followed for each session (Krueger & Casey, 2008). Participants were given a gas station gift card in the amount of $25 as a nominal incentive for attending the focus group. All participants were provided with a consent form and assured of confidentiality and anonymity.

A questioning route to guide the focused discussion was developed and reviewed by University of Minnesota social scientists and MnDOT representatives. The questioning route was pilot tested among members of the research team in order to ensure the questions were delivered in a conversational manner, easily understood by participants, and generated the type of information needed to address the research questions of interest. Approximately ten questions were used, and the questions were grouped in a funnel sequence that progressed from simple questions to more meaningful questions. This technique created a permissive environment and first eased the participants into the focus group setting and encouraged everyone to speak; then later narrowed participant attention in on areas of research interest (Krueger & Casey, 2008; Goldenkoff, 2004). The opening questions were designed to get people thinking back to how they first heard about living snow fences, first impressions of the program, and to describe what they know about the program. Next, transition questions probed landowners to explain what agency they would like to work with to learn more about living snow fences and who should establish and maintain the planting. A set of key questions focused on values and benefits associated with living snow fence plantings, explored the costs of the program and constraints to participating, and finally generated discussion and ideas that could improve the program and elicited participant perspectives on appropriate compensation for landowners who participate in the program. Finally, closing questions summarized the key themes from the discussion, and asked whether

there was anything else important that should have been discussed but was not. Each session lasted about an hour and a half, and refreshments were provided during the focus group. Four of the five sessions were digitally recorded and transcribed verbatim. The recording equipment failed during one focused discussion, and the transcript was instead constructed from the research team's notes. The data set for this study consists of the audio recordings, the written transcripts, and the research team's notes from each session.

2.3.2 Study Setting: Focus Groups

Five representative study sites were selected to conduct the focus group interviews. The areas were chosen to represent the variety of diverse conditions throughout the state of Minnesota. The following factors were considered in site selection: area contained counties with MnDOT living snow fence plantings, area contained counties without MnDOT living snow fence plantings, age of oldest MnDOT living snow fence planting, area contained interstate highway roadways, crop cover in the areas, and regional roadways contained critical areas or road closure areas (Table 2.1).

Table 2.1: *Focus group site selection (from targeted areas of the state)*

	Counties w/ MnDOT LSF	Counties w/o MnDOT LSF	Oldest MnDOT LSF	Interstate HWY	Critical area/ Road Closure		Crop Cover	No MnDOT LSF on Private Lands
					T1	T2		
Worthington	Nobles Jackson	Nobles	X	X		X	Corn Soybeans	
Marshall	Lincoln Lyon Redwood	Lyon	X			X	Corn Soybeans	
Breckenridge	Wilkin Ottertail	Wilkin	X	X	X		Corn Soybeans Sugar beet	
International Falls	Koochiching	Koochiching					Forest Hay	X
Owatonna	None	Steele		X	X		Corn Soybeans	X

International Falls was selected to represent the northern area of the state and is unique because the crop cover is some hay and primarily forest cover. Breckenridge was selected to represent the sugar beet region and large farms. However, there was some concern about being able to successfully recruit farmers to participate in the focus groups in this area due to the fact that many of the farmers travel south during the winter months. Marshall was selected to represent a corn and soybean production area. In addition, this area is unique because Lincoln County has several wind towers and the cropland is not considered as productive as other areas in the state. Many acres of land in this area are enrolled in the Conservation Reserve Program. Worthington was selected to represent the interstate highway and is unique because there are areas of the highway that are controlled access. Finally Owatonna was selected as the fifth site, due to the

lack of living snow fence activity and establishment. Residents in this area are likely to be familiar with the living snow fence plantings along Interstate 35.

2.3.3 Sampling: Focus Groups

Because the intent of this study was not to generalize, but to provide insights about how landowners in the focus groups perceive living snow fences, a random sample was not required. An existing list sampling procedure was used and regional SWCD offices assisted with participant recruitment for the focus groups. The SWCD offices identified landowners, both with and without living snow fence plantings, in local snow problem areas identified by MnDOT's Geographic Information System study. Landowners from this list were contacted by phone and also sent a letter of invitation to the focus group. The letters were personalized with the individual's name and address and also with the date, time, and place for the focus group meeting. After a week, all landowners were called again in an effort to answer any questions and confirm attendance at the focus group meeting. As anticipated, many of the landowners in Breckenridge were absent during the winter and only three landowners were successfully recruited for this site. All individuals in the sample across focus groups shared the common characteristic that they lived in a snow problem area identified by MnDOT and the SWCD regional office.

2.3.4 Data Analysis: Focus Groups

The data were analyzed through multiple audio reviews of the recorded discussions and meticulous reading and re-reading of the focus group notes and written transcripts. Each focus group session was first summarized in a table to document the key themes and perspectives that emerged during the session. The five tables were then synthesized to facilitate a side by side comparison among the sessions. Finally, across cases, the textual data were organized in categories and sub-categories; during this coding process similar themes were identified across focus groups and were grouped under a representative name. Analysis was facilitated with the qualitative text analysis software NVivo (QSR International Pty Ltd 2009).

2.3.5 Approach: Online Survey

The research team developed an online survey to collect information from key agency staff related to the costs and constraints associated with living snow fence plantings. The purpose of the survey was to better understand the role played by these key staff from agencies including MnDOT, Farm Service Agency, Soil and Water Conservation Districts, and the Natural Resource Conservation Service. The survey was developed and administered using the online site Survey Monkey.

2.3.6 Sampling: Online Survey

The link to the online survey and a template email was distributed to district administrators in MnDOT, the FSA, SWCD offices, and the NRCS. These administrators collaborated with the research effort by distributing the survey to staff in these agencies. Forty two MnDOT staff and one hundred eighteen other agency staff completed the survey between April 1 and April 16, 2010.

2.3.7 Data Analysis: Online Survey

Survey analysis consisted of descriptive statistics and organizing survey data into charts and tables. Preliminary analysis was assisted by the Survey Monkey program and further analysis was performed in Microsoft Excel.

2.4 Results: Focus Groups

A total of 45 Minnesota landowners participated in five focused discussions between January and February, 2010. These group interviews in five locations throughout Minnesota revealed that landowners perceive a variety of costs and constraints associated with living snow fence plantings. Participants described the actual and perceived costs of establishing and maintaining a living snow fence and provided responses to explain the constraints to adoption of a living snow fence practice and the reasons a landowner might not be willing to implement a planting.

The results discuss data across cases from the five focus groups the results are organized into three sections to address the research questions of interest: 1) Costs of living snow fence adoption, 2) Constraints to living snow fence adoption, and 3) Factors influencing adoption of living snow fences.

2.5 Costs of Living Snow Fence Adoption

Focus group participants described a number of costs associated with living snow fence plantings. The most frequently mentioned costs were the life cycle costs of the living snow fence including implementation, maintenance, rejuvenation, and removal costs. Other discussion identified the opportunity costs, noted that changing land value results in costs, and some participants concluded the compensation was insufficient to cover all costs.

2.5.1 Life Cycle Costs

The costs incurred over the life cycle of the living snow fence planting were perceived to be the greatest costs. Focus group participants were in agreement that the initial in-put costs for implementation would add up. There were several questions and concerns associated with these costs, as one man asked: “Where will we get the plants and the shrubs and stuff? Those get to be costly and stuff. I know there are different organizations there, but how do you go about finding the funding for the shrubs?” In addition to the shrubs, a woman identified the geo-textile matting as an in-put cost; she explained “that matting is a large cost. And what I have heard with CRP is that they don’t cost share on that, and that can hold a lot of people back, because matting isn’t cheap. It’s got an extended life . . . but it is still quite a cost.”

Although several cost-share options are available for the implementation of the living snow fence, most of the maintenance costs are the responsibility of the landowner. Several focus group participants were concerned about maintenance costs adding up to a large sum over the life cycle of the snow fence planting. The maintenance costs, including mowing, weeding, watering, and tree and shrub replacement over the life of the snow fence, were the most frequently discussed costs. One individual described his concerns related to the costs of replacing trees and shrubs over the years:

> “I wouldn’t mind planting a few in between you know, if they died, just to keep it up, but just where to get the tree to replace it and who buys it? I mean if you lose 20, 30, or 100 trees or something like that, that could be quite a bill you know. If you sign this contract for 15 years and they come and tell you ‘you gotta plant a

> hundred trees', well you know, then you just got socked with a pretty good bill there if I replanted them myself."

Another aspect of life cycle costs was rejuvenation; after a number of years the shrubs and trees in the living snow fence planting have to be cut back in order to facilitate continued growth. One man described the costs of cutting a 700 foot row of shrubs down to two or three feet; it took him a "day and half of labor with a chainsaw and a bobcat. . . . Equipment and labor, you are probably talking about $50 per hour." Other participants shared the perspective that the ongoing costs of rejuvenation would be problematic: "Rejuvenation is the problem, more so than probably the first five years of maintenance would be."

At the end of the living snow fence life cycle, the removal costs represent a final cost that concerned landowners. Some plant species, such as hybrid poplar, have a life span of approximately 25 years and when the snow fence planting senesces the landowner will incur costs to remove the dead trees or shrubs. This was an issue for several participants, and one man stated quite succinctly that his "biggest concern would be at the end."

2.5.2 Opportunity Cost

For many participants, the living snow fence was viewed as an opportunity cost because land would be taken out of production. Essentially the living snow fence would be "taking viable farm land out of production for an extended amount of time," and the lost opportunity of crop production resulted in a cost to the landowner. Although she thought the living snow fence program sounded like a good idea, one woman felt the opportunity cost was too much. She reflected in the discussion: "Four hundred dollars for four acres, and that's for a year? And our renter is gonna make maybe $600 or $800? . . . . How can you justify that? . . . No, we're not gonna do it."

2.5.3 Changing Land Value Costs

The changing value of land and cash rental rates was mentioned by many participants; overall, landowners felt that the living snow fence planting would cost more than what the landowner could earn for straight cash rent. One landowner summed up what would hold him back from participating in the living snow fence program; quite simply it "would be the cost. When you can get 175 dollars cash rent and you are only getting 100 or 80 or whatever." While landowners agreed that the payment up front for the living snow fence might look appealing, it was unlikely to match the changing land value over the length of the contract. The payment "looks pretty nice" at the beginning, "but you break it down over a fifteen year period, that's not really a realistic number" in the long run. Several participants shared stories about the costs of enrolling land at a set payment for fifteen years, including the story of a neighbor who enrolled 26 acres and now "he's not very happy." Since land values have changed, "right now he is wishing he would not have" entered into the fifteen year contract.

2.5.4 Costs Greater than Compensation

For some participants, the compensation was insufficient and the costs were perceived to be consistently greater than the proposed payment. For these participants, the compensation was not worth it and the cost was ultimately described as prohibitive. One participant announced that the compensation offered "isn't quite enough. If the rental rate would be a little more, there would be more of them going into it. When you can get $200 per acre cash rent and they will only pay you $100, it's kind of hard to put it into CRP." Another man could not identify the

appropriate payment that would justify the costs, he explained that it is "really hard to put a number on because every situation and every field and every case is gonna have its own amount of pain and agony that goes with it."

2.5.5 Constraints to Living Snow Fence Adoption

Several categories of constraints emerged in the focus group interviews including risk, hassle and time constraints, and concerns about the contract. The risks associated with the living snow fence plantings, including plant die off and liability, were described as the biggest constraints to adoption of the practice. The hassles presented by the living snow fence planting and additional time required to negotiate the hassles were other constraining factors. Finally, concerns about the rigidity and the length of the contract inhibited landowner adoption of the practice.

2.5.6 Risk

In every focus group session, the topic of tree and shrub mortality, or plant die-off, was discussed. This was perceived as the greatest risk associated with the program and was described in detail by many participants. Although the factors that influenced plant mortality were not always agreed upon, the participants were in general agreement that tree and shrub die-off was a serious issue to consider. One participant commented: "Sometimes things just change, don't they? 'Cause I remember growing up and heading to [town] and it was all nice and green, and for whatever reason now they all seem to be dying. I don't know why." Others reflected on their personal experience with plant mortality and one man felt certain that many trees would not survive in a snow fence planting. He explained his perspective; "it spooks me that I'd be responsible to replace these trees. I've planted thousands of trees and I know dang well a lot of them die!" Not all landowners felt so certain that plant die-off was going to occur, some discussed the need for proper planning and selecting a resilient species to plant in order to increase the survival rate. However, even with proper planting and care, the shrubs and trees face risk that the landowner cannot control. A landowner described deer as such a risk: "I think what really bothers me is the part that you plant the trees and everything goes good, there isn't any that die, if you do it right. But what if deer get in there or whatever and kill the whole bunch of them? The landowner is responsible; he could be paying the whole thing over again." The conversations related to plant mortality produced concern and uncertainty. One landowner described the risk:

> "I planted a couple thousand White Spruce and I was surprised how many of them died within the first three years. And now after fifteen, sixteen years they are starting to come up, now they are taking off, but there are a lot of bare spots. Maybe I'm just unique, but that's why I'm a little skeptical."

Although the implementation of the living snow fence planting is frequently cost-shared, the maintenance costs in the current program are the responsibility of the landowner. Participants expressed a variety of concerns related to maintenance, and the greatest risk that emerged was landowner liability for the planting. Participants agreed that since plant die-off was likely to occur, liability for replacing the plants was a constraining issue. One woman mentioned that if more than a few trees die off she could end up with "quite a bill," and she would like to have "an insurance policy. At least so you weren't liable to replace them." Other landowners expressed similar perspectives; they were not against the planting per se, the risk of liability was a prohibitive constraint. One man stated he would be willing to implement the planting, just "as long as I'm not liable in the future." Another individual was willing to forego any compensation

in order to be released from future liability. He explained; "I'd be more interested in them maintaining you know, and me not being liable for it, then me getting paid to have it there."

2.5.7 Hassle and Time

Across cases focus group participants agreed that there were many hassles and time constraints associated with living snow fence plantings. Some of the factors that emerged in discussion included the hassle of farming around the planting, hassles with machinery, hassles, with herbicide application, and the hassle of maintenance. All of these various hassles would have to be addressed and the impact on the landowners' time was described as the greatest constraint.

The plantings were described as bothersome by one woman; "I feel planting shrubs or trees would be very disruptive for farmers trying to farm around that. And especially with all the big machinery." The issue of the machinery and large equipment was reiterated by several other participants. One man discussed his first hand experience farming land between the road right of way and his planting, he explained that with the large equipment "There is some difficulty in farming it; you have to treat it as a separate field between the road and the living snow fence." Another man who had a snow fence planting on his land noted that he had taken the large equipment into account and situated the planting so the machinery could still be used. However, after a few years it was a problem; he explained that he "got new equipment and now it doesn't fit, and three years after that, it changes again. And so I don't know how you go about making that work, taking the strip out of the field." Others who did not have personal experience expressed doubts that farming around the planting would be feasible, one landowner wondered out loud if "one of those big farm equipment, can they get around that? Well I don't know. I am opposed to putting in trees and shrubs."

Herbicide application and spraying was another hassle that landowners identified. The farm crops require herbicide application, but if the spray dripped onto the shrub planting it could cause damage. A landowner described the issue: "It's right for spraying on the one side of it, but it ain't on the other. So how you gonna handle that? I don't know, there's hassles to it."

For some participants these hassles were perceived as prohibitive. Several people commented that the living snow fence plantings seemed to work well and greatly benefited drivers and the local community; however, individually they did not adopt the practice because of the associated hassles. One man summarized this perspective as other laughed in agreement, he stated: "I am probably like everybody else, I like the looks of but on somebody else's ground! Let them deal with it. When you're going down, you like a clean road. But it's no fun working around."

Ultimately these various hassles represented a serious constraint on the landowners' time. In the focused discussions, participants explained that in already full schedules, there simply was not more time available to deal with the hassles presented by a living snow fence planting. While many people supported the practice, few felt that they had the time to implement a planting on their land. One participant explained his perspective: "Personally for myself I got enough irons in the fire to be worried about a wind break." Another woman doubted she could even find time in the day to attend to the plantings, with existing work and commitments she did not have an hour to spare during the day. She noted that "the trees need 2.5 gallons of water. And if you have 150 trees, where are you going to get how many gallons of water? How would you even get it out to the field and who has that kind of time? I work, my husband works, and then after work?" For this woman, the hassle of watering and maintenance was viewed as a major time constraint, one that has prevented her from considering the living snow fence program. Others in

the focus groups shared a similar outlook; the time and responsibilities associated with farming and managing the land were all the landowners could take on in a day. One retired farmer looked back and explained why he was not interested in the program: "I am not going to go to the hassle of planting trees and make sure they live and all the rest of it. That's not my headache. I was farming at the time, and that's enough for me." For those participants that supported the practice, but did not have time to manage the planting themselves, some wondered if the state or other agency could manage the planting and relieve the time constraint from the landowners. One man explained: "It sounds like a good idea and I would just say go for it and then you guys do it. I'm busy enough chasing other things around in my life, you know, it's not like I want something else to do."

2.5.8 Contract

Concerns about the length of the living snow fence contract and the rigidity of the agreement emerged as another category of constraint. The fact that the living snow fence contract is typically a fifteen year agreement was viewed as problematic in all of the focus group meetings. The problematic factor was linked to the fact that land values and other variables change over fifteen year, while the compensation provided to the landowner through the contract would remain constant. Therefore, the contract was viewed as restrictive by some: "That's the thing, once you're locked in it's the same payment for 15 years, and a lot can change in just five years." Landowners agreed that land rental rates had increased over the past years, and an individual confined by a contract would not be making maximum profit on his or her land. One landowner noted that in the contract "there needs to be adjustments. Because it doesn't matter where we are at, things have changed. The only thing that seems go up is cost." Several participants agreed that without adjustments of some kind, the current contract was a serious constraint that held landowners back from participating in the living snow fence program. One landowner suggested a subsidy approach: "From the farmer's the standpoint, there should be something in there, some fair rates in there so the farmer doesn't feel he is being locked into 15 years at $200 an acre. And that if land rates go up to $300 an acre you're gonna subsidize something." Although the fifteen year contract was viewed as a constraint, landowners agreed that an adjustable, more flexible, or shorter contract would be more appealing; one participant commented "my thoughts are you gotta have something flexible in there with the 15 years."

Shorter contracts were another proposed solution to overcome the constraint presented by the fifteen year agreement. The proposed suggestions for shorter contracts included the idea of "one year contracts. Because there is too much variability on land prices right now." Not everyone felt the contracts needed to shorten to just one year, however, the landowners were in agreement that the length of the current fifteen year contract was a constraint to enrolling in the program. Participants discussed land values and what land was worth fifteen years ago compared to today and overall agreement emerged that a landowner who had entered a contract fifteen years would "probably be regretting that today." Across cases, the length and rigidity of the contract was consistently identified as a reason a landowner might not be willing to implement a living snow fence planting. One participant summarized his perspective on the contracts by saying: "Those contracts should probably max out at 3 years now a days." Other participants mentioned that the constraining length of the contract could be negotiated by making the agreement more flexible and allowing for periodic adjusted. There was agreement in the group that this suggestion would improve the contract: "An adjustment every five years would be an example with the fifteen year

contract, so the farmer has some insurance that he is going to get some extra compensation along the way if he signs up for this 15 year program."

2.5.9 Factors Influencing Adoption of Living Snow Fence Plantings

Similar to existing literature and case studies, no universal variables influencing adoption emerged during the focused discussions. However, several influencing factors that have been documented in the literature were described by focus group participants. The factors influencing adoption of living snow fence plantings include awareness of the program, relative advantage, perception the program promotes the landowner's objectives, and incentives or compensation.

2.5.10 Program Awareness

The process of adoption begins with exposure to the program and gathering information and knowledge about the program (Pannell et al., 2006; Rogers, 1995). Many of the landowners were not aware of the living snow fence program before participating in the focus group discussion. At the beginning of one session, an individual spoke for the group saying "I don't think any of us know what it is to tell you the truth." Similar comments were made in other groups, and in each discussion there was at least one person who was not familiar with the program. In another session a landowner commented "I don't know how many other people were aware of the program. I wasn't aware of the program until I received your letter."

Agency staff and extension staff play a key role in raising awareness about the program and focus group participants were in agreement that the way to receive information about the living snow fence program was from a local contact in person. Although some landowners had heard about the program on the radio or through other media, it was clear that one on one contact and conversation was the best way to approach a landowner about implementing a snow fence planting. A couple with a well established living snow fence recalled how they were first exposed to the program in a personal conversation: "M. from the Soil and Water Conservation District approached us about the possibility to see if we were interested." Another landowner shared a similar experience that led to the implementation of his planting, he explained that his first awareness of the program was when "a guy came up here and said we needed a tree line along the road because it filled in." In addition to the personal interaction, a local contact was viewed as more credible because "they walk your property already and they've got a map of it, they'd be the most influential to tell you what you need on your property." Across cases there was consistent agreement that landowners prefer to learn more about the program from someone local: "You want somebody from here, you wouldn't want somebody from Minneapolis or Duluth or whatever."

Landowners also discussed the importance of targeted recruitment; participants felt more receptive to an individualized approach where specific landowners were approached with details about the program. One participant explained what would work best for him:

> "If you were to send out to the landowners, a laid-out program with the cost on that particular piece of property, it's not that hard to do. You may rein in more than just your advertisements, if you have a dollar amount right in front of you as a land owner, you are more likely to get involved in it. At least, I respond to that, more so than I do a program that is approached in the paper or whatever."

Other landowners agreed that they would be interested in the program if they were specifically targeted and could see better how the living snow fence would impact their individual situation.

Participants also discussed the importance of targeting outreach and education toward landowners who live adjacent to stretches of roadway that have severe blowing and drifting snow problems.

2.5.11 Relative Advantage

Relative advantage refers to the degree to which the new conservation practice is perceived as better or providing more benefits than the practice it supersedes (Rogers, 1995). Focus group participants were in agreement that under certain conditions the living snow fence could provide a greater benefit, and landowners would be more likely to adopt the practice under these conditions. Some land areas are marginal for crop production due to salinity, alkalinity, soil compaction, and high water table. Enrolling this land area into the living snow fence program provided more benefits than attempting to produce crops on the same land. A landowner explained the relative advantage in a case like this, "the benefit would be to take the marginal land out of production." Another landowner explained that he implemented the planting because of the relative advantage of a living snow fence compared to poor crop production; he noted "that was a piece of ground I'd just as soon went to trees anyway, so it was ok." Other participants weighed the relative advantage; for productive lands often the benefits were not improved, but for marginal lands there was a clear benefit. Ultimately it was the unique location of the piece of land that determined the relative advantage: "You don't like putting good ground in! And where they need it on the interstate, that is some of the best ground going. Whereas if it was a pasture, it would be kind of a no brainer."

2.5.12 Promotes Landowner Objectives

Adoption of the living snow fence practice is more likely to occur when the landowners perceive that the program promotes their own individual objectives. Focus group participants that identified conservation as a personal value or objective were more likely to adopt the practice. For example, one landowner with a living snow fence explained that "in our case, we have always been pro-conservation so we saw the advantages not only for snow, but also for wildlife and habitat improvement." Another woman noted that her personal objective was to have trees and more wildlife on her property, and the living snow fence was a way to achieve her individual goal. She went on to say "we are really thrilled, we have wildlife, pheasants, ducks, lots of little birds, and it is slowing the wind and the snow down. The trees are holding a lot of snow. And I was just thrilled that I could have trees there!" Other participants identified a desire to do the right thing or make a difference in the community as their individual objectives, and the living snow fence program promoted those objectives. One participant explained that it was not the living snow fence itself that appealed to him, but rather the opportunity to help others. He stated: "There is really nothing that would make me really want to. But just that it is a problem area and I could help out, I guess is what it comes down." Not all participants were so interested in helping others; one participant summed it up succinctly by saying "if it is to your own personal benefit, you may be more inclined to participate."

2.5.13 Incentives and Compensation

The literature examining landowner adoption of Agroforesty practices identifies economic factors such as incentives and compensation as the most important variables influencing landowner adoption of the practice (Cary & Wilkinson, 1997; Sniden & King, 1990). Participants in this study indicated that incentives, specifically financial compensation, were very important factors in their decision to adopt or reject the practice. Money and compensation were

the most frequent responses to the question "what would it take to make you want to participate in the living snow fence program?" Some participants elaborated by explaining that considerable compensation would be required, and one man announced that he felt "it would take a gold nugget from the sky to entice them to give up acreage and grow a living snow fence." Another expressed similar feelings and explained, laughing, that the right price for him would be "all we can get, and a little more!"

Several participants emphasized a fair payment, and noted that the living snow fence must provide an additional incentive in order to appeal to landowners. One landowner commented: "The compensation needs to be more than reasonable, because based on the way land rates are today, we need to make sure it is a fair shake for the farmers too." Compensation that commensurate with land rates at market value would be required to keep the payment fair to landowners. Overall landowners agreed that an addition incentive above land rates at market value would make the program more attractive to them. Participants discussed the need for "some kind of premium," and agreed that "there's got to be some incentive" for landowners to enroll in the program. Although the specific parameters of this premium incentive were not defined, there was consensus among participants that this would make the program more enticing and increase rates of adoption. In summary, participants agreed that "there has to be some bump up there if you want pretty good participation. And I am not saying what the bump is, I don't really know, but I think most people would want some factor beyond just the prevailing rental rates." One individual suggested what this factor might look for him, he explained: "I think it would be a good incentive on my part, just to make me more interested, even if the check I got was a tax free check." Whether it was a tax free check or other incentive, some compensation beyond land rates at market value made the program more appealing to landowners.

Participants identified the length and restrictions of the contract as constraints that prevented them from participating in the program, and at the same time discussed shorter more flexible contracts as factors that increased the likelihood of program adoption. Overall landowners felt that adjustable contracts that were shorter in duration were needed to compete with the changing market value of land rental rates. Suggestions for improving the contract included the idea that "the payment would be variable," the contract "would be negotiable," and over the course of the agreement the contract "would keep the payments annual and everything re-doable." These concerns about the contract were discussed in each focus group and one participant summed it up by saying: "some kind of flex payment is my sticking point."

2.6 Results: Online Survey

A total of 160 agency staff completed the online survey and represented the following agencies: MnDOT, FSA, SWCD, and NRCS. Participants responded to both open-ended and closed-ended questions and indicated the degree to which their agency was involved in MnDOT's living snow fence program. Respondents described the costs of the living snow fences, as well as the constraints to the program from both the agency perspective and the perceived landowner constraints. Participants also indicated the level of technical competency they possessed as well as access to funding and resources for the Living Snow Fence Program. Finally respondents noted perspectives and ideas that they felt could help improve the program and increase the rate of landowner adoption.

2.6.1 Survey Questionnaire Results: MnDOT Staff

Forty two MnDOT staff completed the online survey; of the respondents fully 90% are promoting the living snow fence program. The program is being promoted frequently, and 87% of respondents indicated they promote the program once a year, more than once a year, or all the time. To promote the program, participants used a variety of and multiple techniques. Specifically respondents promote the program by talking to landowners, soliciting landowners, using various media outlets, identifying snow problem areas, answering questions, and proposing solutions.

MnDOT staff reported a high level of confidence in the living snow fence practice; respondents indicated certainty that the fences are effective in reducing snow removal costs and also effective for improving hazardous road conditions (Figure 2.1 and Figure 2.2).

How confident are you that living snow fences are effective at reducing snow and ice removal costs?

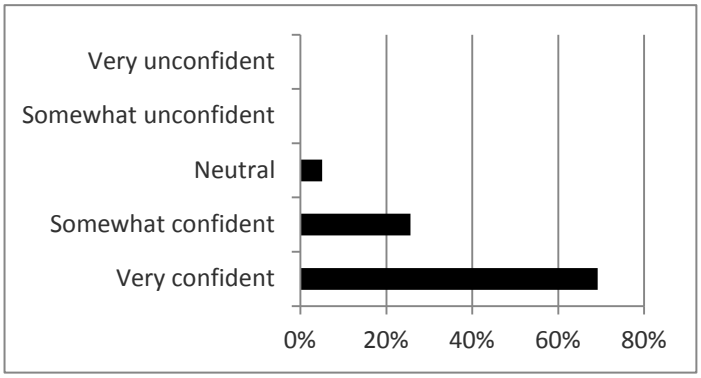


Figure 2.1: Living snow fences reduce snow and ice removal costs

How confident are you that living snow fences are effective at reducing crashes due to blowing and drifting snow?

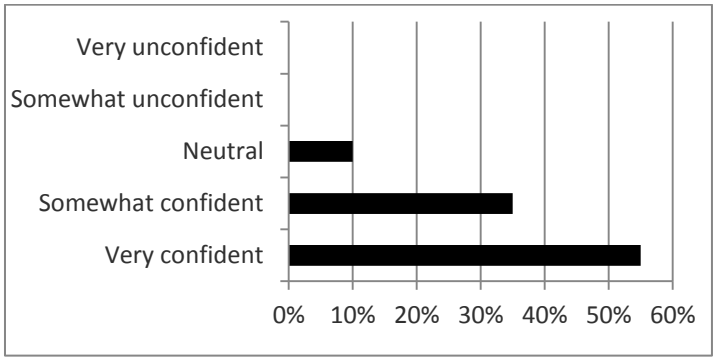


Figure 2.2: Living snow fences reduce crashes

The MnDOT staff who completed the survey indicated that, in addition to promoting the living snow fence program and expressing a high level of confidence in the program's effectiveness, they had the technical knowledge required for the program (Figure 2.3).

Do you have the technical knowledge, skills and ability of how living snow fences function to promote their use within MnDOT and agency partners?

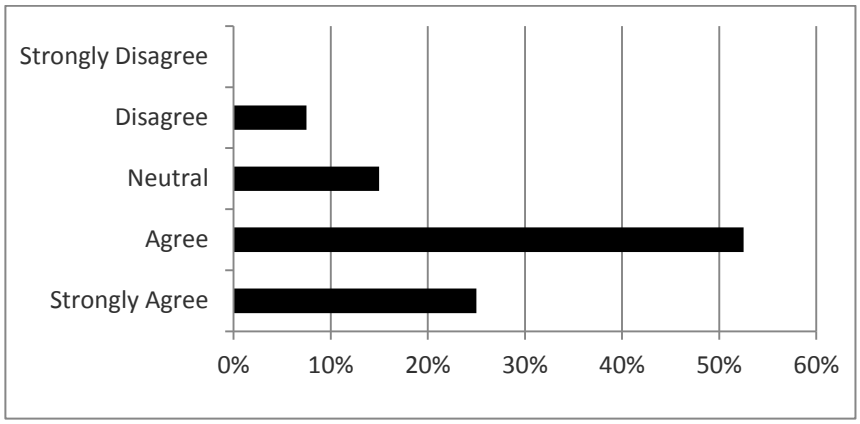


Figure 2.3: MnDOT agree and strongly agree that they have technical knowledge

Nearly three quarters of MnDOT staff reported constraints to promoting the living snow fence program. Notably these constraints were not training or technical knowledge; instead the constraints detailed including lack of time to work on the program, insufficient funding, and lack of landowner interest in the program. MnDOT staff the training and technical capacity needed to promote the program, the constraints exist in lack of resources such as time or funding and in low interest on the part of the landowners (Figure 2.4).

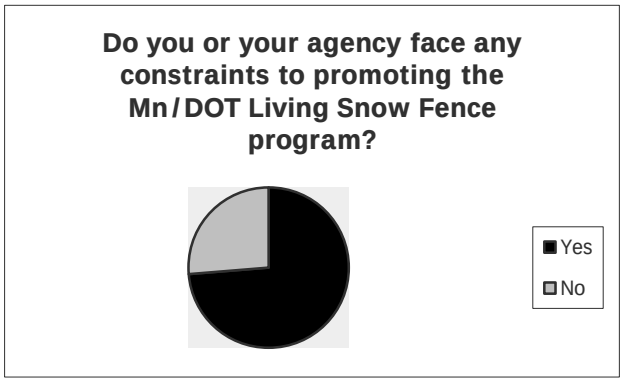


Figure 2.4: MnDOT constraints

While MnDOT respondents were very interested in promoting the program and had the necessary capacity, fully 53% felt they did not have the equipment, materials, labor and expertise necessary to plant a living snow fence on private lands. In addition, 70% of respondents were neutral or felt that their MnDOT District did not have the equipment, materials and trained work force available to annually maintain a living snow fence on private lands. Sources for continued and ongoing funding for the living snow fence program were perceived as somewhat stable at best, indicating a degree of uncertainty regarding funds for the program (Figure 2.5).

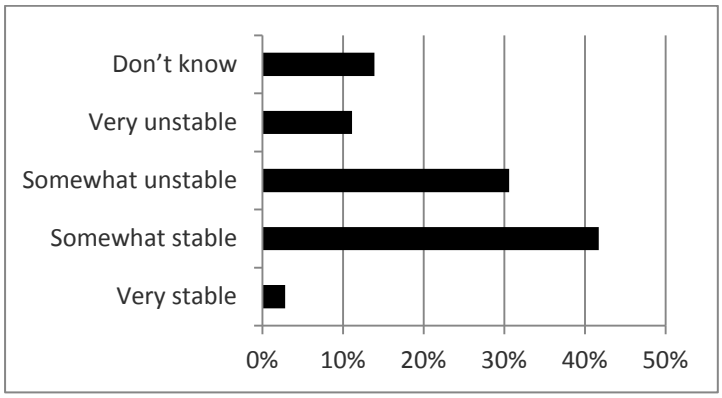


Figure 2.5: MnDOT funding sources for living snow fences

Two questions on the survey inquired about the GIS snow trap inventory; repsonses to these questions indicate that the agency staff who know about the inventory are using it, but that many other agency staff are not familiar with the inventory. Nearly 40% of respondents reported they had never heard of the GIS snow trap inventory; thus, there is an opportunity for educating MnDOT staff about this inventory.

2.6.2 Survey Questionnaire Results: Agency Staff

A total of 118 key staff from agencies including the FSA, SWCD, and NRCS completed the online survey. The majority of respondents indicated they are promoting the living snow fence program and the program is promoted once a year or more than once a year by most people. The living snow fence program was rated about average in terms of priorities by 56% of respondents. The majority of agency staff respondents (60%) agreed or strongly agreed that they have required technical knowledge of the program; however, only 36% feel their agency is equipped to do plantings.

The MnDOT website was used most frequently (by 70% of respondents) to identify the local MnDOT District contact to work with on the living snow fence program. Again, the website was the most useful source for agency staff to learn about the living snow fence program and nearly 80% of respondents indicated they used the website to learn more about the program.

The large majority of respondents (95.6%) reported they have not met with the MnDOT District Living Snow Fence Coordinator this year to prepare living snow fence plans. In addition, nearly all (99.1%) respondents confirmed they had not ever been invited to participate in a road safety audit to look at ways to reduce crashes. Again, there is an opportunity here for education and outreach to these key agency staff.

Agency staff rely on a variety of and multiple sources to find information on MnDOT's blowing and drifting snow problem areas. The most frequently used source is GIS maps; notably, nearly 20% of respondents indicated they do not know where to look to find information about blowing and drifting snow problem areas (Figure 2.6).

Where do you go to find MnDOT's blowing and drifting snow problem areas?

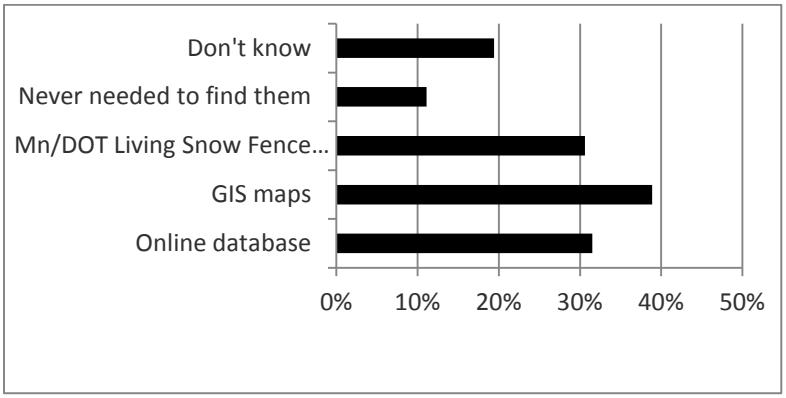


Figure 2.6: Information sources for problem areas

In the online survey, agency staff respondents addressed the costs of living snow fence plantings and reported some doubts in continued and future funding for the project. Participants reported an average to low level of confidence that MnDOT will have funding to install Living Snow Fences in the next year (Figure 2.7).

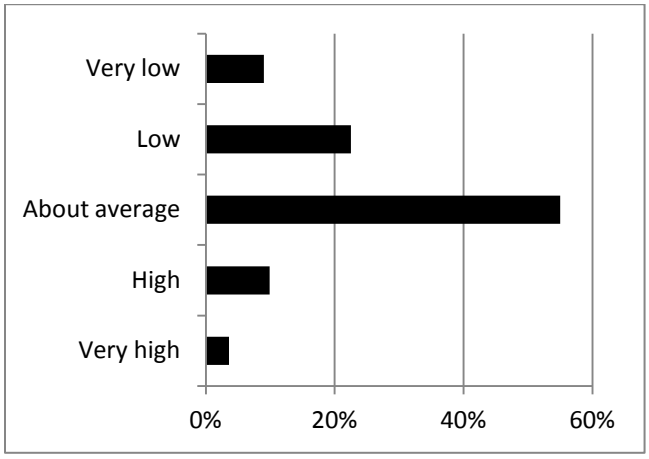


Figure 2.7: Agency staff confidence in MnDOT funding for living snow fences

Similar to MnDOT staff, the majority of all agency staff agreed that they and their agencies faced constraints to promoting the living snow fence program. Over half of the FSA, SWCD, and NRCS staff reported constraints (Figure 8). The agency staff respondents were in agreement that lack of technical knowledge was the least constraining factor, and identified lack of support from partnering agencies as the second-least important constraint. For these respondents, the most significant constraint was lack of landowner acceptance of the program.

Figure 2.8: Agency staff constraints

Finally agency staff commented on the Toward Zero Death mission and indicated the role they and their agency might play as part of this mission. Only 3% of repsondents reported being very familiar with the Toward Zero Death mission and 20% were somewhat familiar. Fully 77% of respondents indicated they were not familiar with the mission. Across the FSA, SWCD, and NRCS survey participants, 67% agreed that their agency did not have a role to play in reducing vehicle crashes. This reponse suggests yet another opportunity for outreach to educate these agencies in the various they can in fact play an import role in reducing vehicle crashes and contribute to the Toward Zero Death mission.

2.7 Conclusions

The purpose of this study was to identify and describe the costs of and constraints to adoption of the MnDOT living snow fence program. Focus group participants revealed a variety of perceived costs and constraints, and also described the conditions that would likely increase landowner adoption of the program. Specifically the life cycle costs of the living snow fence were most frequently mentioned including the costs associated with implementation, maintenance, rejuvenation, and removal costs. Other costs identified included the opportunity costs, costs related to changing land values, and some participants concluded the compensation was insufficient to cover all costs. Participants in the focus groups discussed several factors as constraints to adoption of the living snow fence practice. Specific constraints that emerged in the discussion included risk, hassle and time constraints, and concerns about the contract. The biggest constraints to adoption of the practice were the risks associated with the living snow fence planting such as plant mortality and liability. Other constraining factors included the hassles presented by the living snow fence planting and additional time required to negotiate the hassles. Concerns about the rigidity and the length of the contract were final constraining factors discussed by participants. As with other case studies documented in the literature, no universal variables influencing adoption emerged during the focused discussions. However, landowners in this study did identify several factors that positively influenced adoption of the living snow fence practice. The factors that emerged in the focus group discussion were similar to influencing factors that are documented in the literature. Specifically landowners identified the factors influencing adoption of living snow fence plantings as the following; awareness of the program, relative advantage, perception the program promotes the landowner's objectives, and incentives or compensation.

Results across the various agencies surveyed indicate that there is great interest in the living snow fence program and high confidence that the program is effective. The agency staff have the technical training and competency needed to promote and implement the program, however

resources such as time and funding are more limited. Several opportunities emerge to improve the program and increase landowner adoption of the practice, specifically several opportunities exist to address the costs and constraints the landowners encounter. Recommendations for improving the program include, but are not limited to, developing more flexible contracts, offering adjustable payments, adding more competitive incentives, providing alternatives for maintenance, creating a system of insurance against risk, and decreasing landowner liability.

Chapter 3
Fencing Drifting Snow Naturally: Farmer/Landowner Economic Input Costs Associated with Installing Living Snow Fences and Leaving Standing Corn Rows in Minnesota

3.1 Introduction/Background

Establishing snow fences along major highways to address blowing and drifting snow issues has been one of the priority areas for MnDOT in recent years. This move has been driven by a better understanding of, and realization of a need for more cost effective and environmentally friendly ways of protecting public roads from snow blockages during the winter.

As part of this initiative, MnDOT has been collaborating with farmers to establish two main types of living fences at the edge of their farmlands in the documented blowing and drifting snow problem areas – 1) planting and maintaining living tree and shrub rows along the road; and 2) maintaining standing corn rows during the winter. A number of agencies are involved in this process (USDA Farm Service Agency (FSA), USDA Natural Resources Conservation Service (NRCS) and Soil and Water Conservation Districts (SWCD)).

Figure 3.1: MnDOT living snow fence sign

There is limited monitoring of the costs of activities that are carried out by the involved agencies and the farmers in establishing and maintaining the fence. Payments are based on established rates for planting and maintaining the snow fences. MnDOT has been compensating the farmers for: i) planting and maintaining the snow fence on a cost share basis; ii) the hassle of farming around the fence; and iii) compensation for storing snow on the property. There has been a concern that the annual compensation may not accurately reflect the actual costs and the inconvenience that the fences have created for the farmers.

In addition, there has been limited adoption of living snow fences/standing corn rows by landowners. MnDOT is interested in extending this program to a larger number of problem areas and therefore this research aims to identify the actual economic costs associated with the living snow fences to develop an economic calculator so that the farmers are fairly compensated as a way to promote greater adoption of living snow fences in Minnesota to help mitigate blowing and drifting snow problems and the associated cost and safety impacts.

3.2 Methodology

Interviews with farmers who had participated in the MnDOT living snow fence program followed focus group meetings in five different communities with blowing and drifting snow problems scattered around the state. We were able to discuss economic issues in the focus group meetings which provided insight and the basis for the follow-up interviews with individual landowners.

This research mobilized two main methods of collecting information – in-person interviews with the farmers, and the analysis of financial documents generated by various agencies including

MnDOT. First, for the purpose of identifying actual costs of establishment and maintenance, and also the extra inconvenience due to the fence, we used lists of landowners who had participated in the MnDOT snow fence program to identify participants for the interviews. We called landowners, set up meetings with them, and conducted 17 face to face and 4 telephone interviews with farmers who had installed snow fences through the MnDOT program. Interviews took place in MnDOT Districts 4, 7 and 8. Those districts cover southern and west central Minnesota in a band from the South Dakota border to the Twin Cities Metropolitan area including farms along I-90 and north to the Fergus Falls area. MnDOT has collaborated with landowners to establish 68 living snow fences and 18 standing corn rows by the winter of 2011-2012. The criteria for recruiting interview participants were primarily the geographical coverage of various parts of Minnesota and the willingness of landowners to participate in interviews. Second, we collected financial documents related to living snow fences and analyzed their content to find out the amount and processes adopted by MnDOT for providing financial compensation to the farmers. Agency representatives from the Soil and Water Conservation Districts and the Farm Service Agency were also interviewed and information was verified for cross-checking and clarification. The SWCD's work with landowners to apply for cost sharing and government assistance programs and the FSA administers federal programs. Current LSF (tree and shrub) and standing corn contract information is found in Appendix P and Appendix Q.

3.3 Sources of Information

All of the cost information was collected from two sources. Most of the cost data came directly from interviews with landowners and the numbers presented represent the range of values landowners provided. The second source of information were the rates provided by FSA and MnDOT to determine how they cost share the different practices that are covered under the snow fence program, CRP and EQIP. As mentioned below in limitations, since most of the snow fences were established through agency programs, farmers do not register costs but accept those provided by their contract. They were able to give us estimates of the time and resources required to perform maintenance activities since they usually performed the maintenance or hired someone to do it although, in most cases, they performed the maintenance activities.

3.4 Limitations

a. Variations in management of the snow fences impacts costs. Landowners differ significantly in the level of maintenance provided. Therefore it is hard to estimate the specific cost of planting and maintenance activities but we have provided a range of the costs indicated by landowners.

b. Most landowners do not register the time they spend on the snow fences but did offer their estimates of that time. Since the cost share is provided based upon pre-determined cost figures from FSA, farmers accept that. Several landowners, when asked about the costs associated with planting and maintaining the snow fences, referred us to the SWCD or other government agencies that set up the contracts, cost share and payments. If there were interest in getting more accurate figures for the costs associated with planting and maintaining snow fences it would probably require taking more detailed information at the time the snow fences are planted and maintained.

c. The farmers interviewed had already accepted the utility of the snow fences and therefore may have a different perception of the costs of the fences since they are not negotiating a

payment. It is likely that farmers who are not in the program might estimate the costs at a higher rate.

3.5 Results

3.5.1 Distribution of MnDOT Sponsored Snow Fences in Minnesota

There are more than 68 living snow fences established by landowners in Minnesota with the collaboration and financial support of MnDOT. The average acreage of a snow fence ranges from 0.5 to 7 acres. The main species planted in those snow fences include red cedar, plum, honeysuckle, red-osier dogwood, and lilac. The snow fences can be as old as 15 years and there are also several which were established in 2009. The majority of the living snow fences were established over the last five years with the active involvement of MnDOT and other state and federal agencies. The Conservation Reserve Program (CRP) support has played an important role in providing funding for landowners who enroll in the living snow fence program.

Similarly, the average size of standing corn rows ranges from 0.5 to more than 4 acres with 8-12 rows of corn. Farmers have followed the specifications set up by MnDOT in terms of technical details on the number of rows and spacing between the two main strips of standing corn. The MnDOT agreement also specifies how long the standing corn rows must be maintained in the spring.

3.5.2 Cost of Establishing Living Snow Fences (initial investment and annual fixed cost)

Land rent, site preparation, planting and application of geo-textile fabric to control weeds are the four main activities requiring substantial investment when establishing a living snow fence. A combination of payments from MnDOT and the Conservation Reserve Program or the Environmental Quality Incentives Program cover the cost of establishing snow fences and the annual rent of the land as per the agreement, and the protection/maintenance of the snow fence is the responsibility of landowners. (See Appendix F for explanation and examples)

3.5.3 Annual Rental Payment

Landowners receive an annual payment which represents a combination of payments from MnDOT, CRP and EQIP depending on each specific situation. The annual rent is decided based on the FSA county land rental rate in the sign up year of the agreement. In 2011, the FSA published land rents per acre varied from a low of $55 in Otter Tail County in northern Minnesota to a high of $215 in Sibley County in southern Minnesota although some farmers mentioned rents up to $250/acre. In addition to the land rental rate is MnDOT provides a payment package to compensate landowners for storing snow and for the inconvenience of farming around the living snow fence or standing corn rows. Income tax from the land is paid by the landowners, and it is calculated on the basis of the productivity of the farm. Living snow fence owners suggest land rent and income tax could vary from year to year depending on crop and land prices and therefore MnDOT's payment mechanism should develop a flexible calculation method to adjust for fluctuations in land values and taxes. Farmers that have implemented living snow fences in the past under a fixed rental rate have seen the local rental rates rise which could mean that they are making less net income off of the land dedicated to a living snow fence than if they rented or farmed the area.

Issues/suggestions by the farmers-

- MnDOT should pay the land rent according to the FSA rental rate every year or at least include a periodic adjustment to the rate to better reflect changing land values. The payment mechanism ideally should adjust to changes in the market rate annually. This would attract more farmers by reducing the risk they face with changing land and rental values and also becomes an incentive to stick with a long term commitment to maintaining living snow fences
- So far rents have increased but that may not always be the case. If land values were to be adjusted, if rental prices declined, farmers may be reluctant to accept a lower payment. If farmers were to renew on a shorter time scale such as every 5 years they could potentially have the option to opt for a fixed rental rate or a rate tied to the FSA county rental rate or another acceptable standard.
- MnDOT could consider compensating the farmers for paying any additional income tax for the land where trees are planted for the fence or look into the possibility for a tax exemption for the land dedicated to living snow fences. Tax rates are determined at the county level so you would have to get information on changes from each county.

3.5.4 Site Preparation

Site preparation, especially when plowing is required, is a major operation in the establishment of living snow fences. Heavy plowing is required for land that was in pasture prior to planting trees. If trees are planted on land previously in crops, costs of site preparation would be lower. As the trees are planted in a narrow strip, heavy equipment is not used for plowing and it often takes longer than normal plowing operations. There are three main activities under site preparation – laying out the planting, site preparation, and the application of herbicide.

Table 3.1: *Site preparation costs for living snow fence – tree planting*

Site preparation	*Labor time range/acre*	*Price ($)*	*Material/ Machine/acre*	*Price/ hour ($)*	*Total cost per acre ($)*
Lay out planting (a)	0.5 hour for two people	10			10
Tillage (b)	1 – 1.5 hour	10 – 15	1 – 1.5 hour	25 - 37	35 - 52
Herbicides (c)					15 - 20
				Total cost for site preparation	**60 - 82**

Legend for Table 3.1:

(a) If the planting is done separately after laying out the planting by other parties, this activity requires extra time of the landowner

(b) Farmers practice different tillage activities. Some of them plow the land once which takes less than an hour for an acre whereas some farmers till the land at least for three times as a preparation

(c) Not all farmers use herbicides when they prepare the plantation site

MnDOT pays in an average of $30 - $38 per acre to the contracting companies for site preparation. This payment rate is different in different areas (data is from receipts that the farmers provided and interviews). This preparation does not include the time required for laying out the planting and herbicide application. Site preparation under MnDOT program includes one-time tillage.

3.5.5 Planting

The cost of planting seedlings in a prepared site involves three main costs – rental of a planting machine (tree planter), price of the seedlings, and planting grass if planted in between tree rows. Most living snow fence owners do not have direct experience with tree planting therefore, the planting is usually carried out by contracting agencies, SWCD's for example. However, government agencies have pre-established cost schedules that they use for reimbursement based on previous studies of the costs of establishing plantings. Financial records reviewed showed that tree planting is the main cost item involved in the establishment of living snow fences. The actual cost varies according to the tree species selected for the planting and the type of plant that is purchased. Bareroot seedlings planted in the spring can be pennies per plant while potted, container or larger more established plants can cost many dollars per plant. For example, a Red Cedar potted (1 gallon) seedling may cost five dollars whereas a plum tree bareroot seedling may cost only one dollar. The spacing between trees and rows will also vary depending upon the species selected for planting.

MnDOT, working with the EQIP and CRP ensures the landowner is compensated for the full cost of planting trees in the living snow fence program. Since the payments are often worked out by the local FSA/SWCD offices, farmers do not necessarily know the exact costs of establishing a LSF planting, but they have ideas on how much time they might need if they do the planting by themselves. The average cost of planting trees and native grasses in between tree rows is estimated at $464 by the farmers. MnDOT pays $282 to $872 for an acre of an LSF planting to the landowner. This variation in the cost is due to the difference in the price of tree seedlings (which depends on the species selected), with or without native prairies, selection of the grass mixture, and tree density in the rows. For example, $282 per acre is paid if the tree rows are of plum trees without planting native grasses between the rows.

3.5.6 Geo-Textile Fabric

Plastic mats are used to control weeds and they are put on the ground immediately after or before the planting. The size of the mat depends on the species planted and number of rows in a fence. Landowners estimated the cost of mats at $117/acre and labor charge for a piece (per tree) to fix on the ground is 25 cents. However, they do not purchase and fix the mat by themselves therefore their estimation of the cost may not be actual or accurate. MnDOT pays $836 to $1125 for 1000 feet of the mat, which includes purchase of the mat and fixing the mat to the ground. The size of the mat and the total cost per acre depends upon the number of rows and spacing between rows. Therefore the cost of mat fixing in one acre of the land could range from $1000 to $2500.

Table 3.2: *Summary of living snow fence planting cost*

Cost items	***Average cost per acre ($)***
Site Preparation	60 – 82
Planting	464
Mat	950 – 2500 (836 – 1125 for 1000 feet)
Total	**1474 – 3046**

3.6 Living Snow Fence Maintenance Costs

The cost of maintenance varies depending on geographical locations which is determined mainly by the farming practices adapted by the farmers and also species planted in the snow fence. Apart from the general protection from damages to the farm, there are mainly four different maintenance activities - mowing, watering, replanting, and spraying – which are practiced by most of the farmers who have planted trees in their farmland. Mowing is less common (except hand picking of some weeds) in areas where trees are planted adjacent to CRP grasslands or uncultivated pasturelands. It is important to note that the level of maintenance provided by landowners can have a marked impact on the survival and subsequent growth of the LSF. One farmer we visited had watered and mowed around his LSF on a regular basis and had established a healthy windbreak in a relatively short time. In other cases, less maintenance and attention was provided and the survival and growth of those LSF were reduced compared to the landowner who provided regular maintenance and watering.

3.6.1 Mowing

Mowing is one of the more common and most important activities for the first three years to keep weeds suppressed and maintain healthy growth of the fence. Mowing is used if the living snow fence is established in a farmland, whereas hand-picking of main weeds is a common method in the case of pasture lands. Usually, mowing is done at least three times in the first year of planting and reduced to two in the second and third years after planting. Farmers continue handpicking of some invading weed species especially thistles in the remaining years, but mowing is not necessary especially if grasses are planted in between tree rows. In either case, the time required for handpicking of the weeds goes down to one hour per acre per year from the fourth year onward. But in most of the cases farmers suggested that there is basically no mowing or weeding required in the living snow fences following establishment. Similarly, some farmers were concerned about reduced wildlife abundance and therefore they prefer to leave weeds un-mowed to provide shelter for the wildlife.

Table 3.3: *Mowing costs*

Mowing/acre	*Labor time*	*Labor Price ($/hr.)*	*Mower time*	*MowerPrice ($/acre)*	*Total cost of mowing/acre*	*Labor Hand pulling in Grassland ($/hr.)*
First year – 3 times	20 minutes x 3 = 1 hour	10	1 hour	40	50	10
2nd and 3rd year – 2 times	20 minutes x 2 = 40 min	7	40 min	30	37	10
Total annual mowing cost/acre (first three years)					**37 - 50**	**10**
Total annual mowing cost/acre after third years					**10**	**10**

3.6.2 Watering

Watering is very important to tree establishment especially in the first few weeks and months after planting. Many farmers mentioned that they had watered the snow fence for five to ten times a year between May to September during the first two years. Gravity irrigation either from nearby water sources or by transporting water in a tank is the most common watering method. The soil type (loamy or sandy), amount and timing of summer rains, number of tree rows and the species planted in the snow fence are the main factors that farmers have considered to determine quantity and frequency of watering. (In some areas water is purchased, in the chart below it is assumed that the water is free from a farm well or surface water source).

Table 3.4: *Watering costs*

Watering/acre	*Labor time*	*Labor Price ($)*	*Vehicle with a tank*	*Tank Price ($)*	*Total cost for watering/acre*
Watering (five to ten times) a year	5 – 10 hours	10/hour	5 - 10 hour	30/hour	200 - 400
Total annual watering cost/acre (first two years)					**200 - 400**
Watering cost/acre after third year					**0**

3.6.3 Replanting

Replanting in a spot where a previously planted seedling dies is the responsibility of the landowner. Re-planting of seedling is done manually by hand where replanting of ten seedlings generally requires an hour. In a normal situation an acre of living snow fence requires an hour of replanting work (ten seedlings per acre). Originally planted seedlings may die due to drought, rodents, deer, frost or some other injury. The rate of mortality as in any planting will depend upon the species, abundance of wild animals and the condition of soil moisture.

Table 3.5: *Replanting costs*

Replanting	*Labor time*	*Labor Price ($)*	*Seedling*	*Seedling Price ($)*	*Total cost for replanting/acre*
Replanting by hand	1 hour	10/hour	10	1 – 4/ seedling	20 - 50
Replanting cost (once in second or third years)					**20 - 50**

3.6.4 Spot Spraying

Spot spraying is one of the regular activities performed to control weeds and undesired species in and around the snow fence every year. This is done every year not only in the fence area but also on the rest of their farms. As spot spraying is done only once a year in snow fence areas as well as nearby farmlands it is a routine activity and therefore is not an extra inconvenience for the farmer.

Table 3.6: *Spot spraying costs*

Spot Spraying	*Labor time*	*Price ($)*	*Total cost for spot spraying/acre*
Spraying time/acre	20 min	10/hour	4
Chemicals	0.2 liter		10
4 wheel sprayer	20 min	30/hour	10
Spot Spraying cost (annual)			**24**

3.7 Inconvenience Cost of Living Snow Fence

The existence of living snow fence rows in farms has created various kinds of inconveniences to the farmers. Such inconveniences have either increased their cost of production or become an extra hassle for them when taking care of the living snow fence. Living snow fence owners have suggested that the increased cost of production (due to increased time investment or decreased production of crops) needs to be financially compensated, whereas some landowners think that the hassle created by the snow fence is balanced out by the environmental benefits (including hunting) and snow free road access provided by the snow fence. Some of the major inconvenience costs of living snow fences are delays in planting crops due to the high moisture content in the field from snow drifts, extra time required for mobilizing equipment, reduction in production, paper work, and damage to crops and the LSF planting caused by wild animals.

3.7.1 Loss of Crop Production Around Snow Fence Area

The loss of crop productivity directly around (first few rows) the planting is 10–15% of the total annual production. The reduction in production is due to improper/less effective plowing around the snow fence, variation in moisture content (this increases production sometimes), and imbalanced application of fertilizers/pesticides. The farmers believe that the affect of tree rows becomes visible after the tenth year following establishment, and this effect spreads around the fence covering roughly the same area as the snow fence rows, i.e. one acre of living snow fence reduces 10 – 15% of total production in nearby one acre of farmland. The area of the farm that has reduction in production due to the effect of the snow fence is equal to the size (acreage) of the living snow fence.

The loss of production is higher at both ends of the fences because machinery has to turn around at those points and farmland is taken out of production in those turn-around areas. Note that LSF research documents a reduced crop yield closest to the LSF planting but increase yields (bell curve) feathering out to field averages are recorded as you move away from the planting.

3.7.2 Difficulties in Mobilizing Farm Equipment

A snow fence planting can require additional maneuvering when operating farm equipment (plowing, combining, spraying) and therefore requires added time to conduct farming activities. This added time in farming around the snow fence increases the cost of production. Tillage takes an extra ten minutes per acre; cross plowing, a common plowing practice is not possible in the narrow strip of land between the fence and the highway right of way. Cross plowing requires extra turning of the machinery. Similarly, combining takes an extra ten minutes for every acre due to the fence as the fence acts as a barrier and extra turning is required to cover all crop lands. Likewise, spraying the crop takes more time and may be limited near the snow fence because if the spray drifts to the trees in the fence, the spray can kill the trees.

Table 3.7: *Increased cost of production*

Activities	*Extra time required/acre*	*Price ($) (Labor and machine)*	*Total extra cost ($)/acre*
Tillage	10 min	40/hour	10
Combining	10 min	40/hour	10
Spraying in the crop	10 min	40/hour	10
Increased cost of production due to each acre of the fence			**30**

There may be ways to mitigate some of the inconveniences presented by living snow fences.

Following are some suggestions for addressing the inconvenience issues:

- Establishing a long stretch of Living Snow Fence would reduce such disturbances and the hassle of farming around the fence
- The main inconvenience of the snow fence is running equipment in the field, and this inconvenience could be reduced by planting trees in square sized plots. Many fields are irregular in shape due to telephone lines or other obstacles, using a living snow fence to "square off" those boundaries might actually reduce some inconveniences.
- Ideally for maintenance and safety issues, there should be a non-ending line of snow fence, which will require working together with other farmers.
- At least one farmer mentioned that having to farm the strip between the LSF and the right of way was difficult and would have preferred to put that strip into CRP. It would be worth considering including a payment for that strip in the LSF agreement which would avoid a lot of the inconvenience issues (the snow catch area between the snow fence and the right away can now be enrolled into CRP).
- Selection of species is very important; tall trees which readily shed branches require more maintenance by landowner. (more time is required for cleaning or picking up branches blown into the cropland.) The use of shrub species are recommended.

3.7.3 Delay in Planting Crops and High Moisture Content

Due to the storage of snow around snow fence areas the moisture content of the land is very high, which can delay spring plowing and field work. This delay can range from a few days to two weeks, but it depends on the weather conditions and the length of winter season. Shorter winters with low snowfall reduce the amount of snow stored into the spring and would result in earlier loss of snowcover therefore excess moisture as a result of the fence is less likely to be a problem.

11 Farmers in District 7 were surveyed in May of 2011 (6 with shrubs and trees and 5 with standing corn rows) to determine if the snow fences resulted in any problems with moisture and late planting in the Spring. (See Appendix H) One of the 6 with shrubs and trees indicated it was a problem but also said moisture had always been a problem in that field and that he had no problem farming around the area. 2 of the 5 farmers with standing corn rows indicated that there was additional moisture but only one of them indicated that it was a problem. For the most part,

farmers were happy with their snow fences and in some cases indicated the snow fence actually improved farming conditions.

The impact of snow fences will vary depending on the general moisture conditions in the field where it is placed but interviews with farmers with snow fences tend to indicate a minimal impact if any in most cases.

3.7.4 Dealing with Agencies

Dealing with the different agencies involved has been one of the least time consuming activities. Although it takes some time while working through contracting issues and establishing the snow fence the first year, landowners mentioned that often the local SWCD office helps with the paperwork and prepares it for the landowner minimizing the amount of time the landowner has to deal with agencies. One landowner mentioned that he didn't find out what he would be paid until he signed up and another mentioned that it took him a while to be paid. A number of other landowners suggested that having a concrete idea of what they would have to do and what they would be paid during the first visit would make it easier for them to sign up for a LSF. Sometimes, there are confusions about who to talk to if some problems arrives as a lot of agencies are involved and their working style is different.

3.7.5 Damages Caused by Wildlife

Living snow fences provide shelter to wildlife and there are concerns that wildlife using the snow fences for shelter may cause damage to the main crops around fence. The extent of such damages is relatively small compared to the environmental benefits it provides. Nonetheless, this may act as a constraint to landowners being willing to accept establishing a LSF. This may need to be a consideration when providing information to landowners and when developing payments for LSF.

3.8 Environmental and Other Benefits of Living Snow Fence

We found those farmers that had installed living snow fences valued environmental and other benefits from living snow fence. Some of the famers' reflections on the benefits of living snow fence included:

- Farmers like the natural scene and also trees which are an incentive for them to plant trees in addition to the compensation they receive from MnDOT.
- For some landowners, hunting is the main objective in establishing a LSF.
- Some farmers have been complimented by their neighbors for having grown trees/established snow fences along the road although some neighbors thought that the living snow fence has devalued the property in the area
- The living snow fence protects roads from snow which has been beneficial not only for others but also for the landowners that have established them; in some cases, the neighbors have appreciated the fact that the LSF has stopped the snow from drifting into the road.
- People have increasingly realized that the living snow fence has also reduced or stopped soil erosion.
- Wildlife abundance has increased - more pheasants, deer, geese, and songbirds.

3.9 Farmers Suggestions on the Payment Mechanism

Farmers who had established snow fences in the past had the following suggestions for improving the LSF payment mechanism and agreement:

- As the rent of the land is one of the main sources of income from the LSF, it should be adjusted according to the market value every year. In recent years, land rental rates have increased sharply. The contract should be flexible so that the payment could be adjusted every year or periodically (every 2 or 3 years).
- The adjustment of annual payment in the contract (including already existing contracts) to include the rent adjustment would also make it more likely that LSF owners would speak favorably of the program. We talked to one farmer who was happy with his LSF but said that he would not recommend it to others because he could have made more from renting the land to others.
- After the establishment of snow fences in year 1, there are a lot of maintenance costs during the first, second and third years. MnDOT should consider compensating the farmers for the first 3-4 years with a higher payment to cover those elevated maintenance costs moving back to a lower rate following that period.
- Flexible criteria for determining annual payment may be required because the cost of maintenance may differ from one area to another and also from one farmer to the next. An additional payment for activities like watering could be considered.
- Land taxes are an issue and may need to be considered in payments development.
- Better mechanisms for targeting landowners for snow fence promotion and educational materials should be considered. Approaching farmers with concrete payment information and personal visits should be encouraged.
- Paying for the entire area between the living snow fence the edge of the right of way will reduce the hassle of farming around the LSF and also provide a larger conservation area with the associated environmental benefits. (in earlier contracts it was not possible but it is being offered now)
- MnDOT should consider paying the cost of removing trees at the end of agreement. Otherwise, it could be a disincentive for farmers.

3.10 The Economics of Standing Corn Rows; Cost of Establishing Standing Corn Rows

Leaving standing corn rows along the road is found to be another effective measure of controlling snow drifting onto the road. MnDOT collaborates with farmers to leaves 8 to 16 rows of corn in two strips in snow problems areas and compensates farmers at a rate of $700/acre or more for leaving standing corn rows till April first of every year. Such rows act as barriers to reduce blowing and drifting snow and help keep the roads safe and drivable. The cost of establishing corn rows is not extra work for the farmer; they leave rows of standing corn and do not combine them in the fall although they may harvest corn by hand (without damaging the standing corn).

Table 3.8: *Cost of establishing standing corn rows*

Activities/materials	*Cost/acre ($)*
Labor for tillage (1hour)	10
Tillage machine rent (1hour)	40
Fertilizer	110
Corn seed	80
Labor for seeding	10
Corn Planter	40
Spray	10
Volunteer corn spray	5
Land rent	100 – 250
Total cost of establishing standing corn row	***405 - 555***

An acre of cornfield produces 180 to 220 Bushels and the price per Bushel has in the past ranged from $3.25 to $3.50 although corn prices are variable and are expected to be in the $6.00 range in 2011. In this sense, the compensation paid by MnDOT in the past has been equal or more than the value of the total production of the corn. In addition, farmers are encouraged to harvest the corn either manually in the fall or they may machine harvest after first of April every year.

3.10.1 Maintenance of Standing Corn Rows through the Winter

There is no maintenance cost in keeping standing corn though the winter other than not harvesting the core in the fall and keeping animals out of the corn (cattle).

3.10.2 Inconvenience Costs of Standing Corn Rows

The extra inconvenience costs associated with leaving standing corn rows through the winter is an additional hassle in spring to combine, additional plowing, possible late planting and the extra time required to farm around the standing corn rows. Standing corn rows makes combining more difficult in the fall and it also requires extra work if combined in the spring.

Table 3.9: *Inconvenience costs of standing corn rows*

Extra activities due to inconvenience	*Extra time required/acre*	*Price ($)/hour*	*Total inconvenience cost/acre*
Combining the corn rows in the spring	30 minutes	40	20
Cleaning the combine	30 minutes	10	5
Tillage in the spring	30 minutes	40	20
Spraying herbicides in the spring	20 minutes	40	15
Stalk chopping	30 minutes	20	10
Late planting in the spring (10 - 20% reduction in production of spring crop)			20 - 40
Total additional costs due to standing corn row			**90 - 110**

Landowners with large farms are less willing to put up with these inconveniences as the actual financial benefits they receive are much less relative to landowners with smaller farm sizes. In general the farmers who leave standing corn rows tend to operate smaller farms and have smaller equipment. However, some farmers leave standing corn around farmsteads to protect their homes in the winter. Some also see it as a good source of food for wildlife, which inspires them to keep the corn un-harvested. That way they don't need to deal with the harvesting hassle and at the same time the corn attracts wildlife. Hand-picking of the corn and/or combining in the spring are extra work and an inconvenience for the farmers although some do that as well.

3.10.3 Cost of Harvesting Corn in the Spring

The majority of the farmers interviewed harvested their corn in April using a combine and only a few have handpicked either in the fall or in spring. Others have left the corn un-harvested to provide a source of food to wild animals. In some cases, the stored snow has damaged the standing corn stalks making it unharvestable in the spring. Depending on the season, abundance of wildlife and locations, farmers who combined the corn in spring could harvest 60 – 80% of their average per acre corn yield.

Table 3.10: *Income after cost of spring harvested corn*

Harvest and sell	*Cost per acre ($)*	*Production per acre*	*Income per acre in spring ($)*
Harvesting corn in spring	30		
Total harvest in spring (60 - 80% of the 180 – 220 bushels)		108 – 176 bushels	
Elevator costs	80		
Income from the corn in spring ($3.25/bushel)			351 - 572
Total cost and income	110		351 - 572
Actual income after cost in spring per acre			**241 - 462**

The cost of harvest is the same as a normal harvest other than the need to get equipment out for a relatively small harvest. Hand harvest in the fall produces close to field averages of 180 – 220 bushels per acre. Farmers will often rent a combine from neighbors to save the time and effort of taking the combine out and putting it back in storage after cleaning. The custom combining rate is $30 per acre (range $22 to 40 per acre ISU custom rate survey), but the cost also depends on the distance the combine must be taken to reach the standing corn. In some cases, youth groups like 4-H, FFA, Boy Scouts, etc. are allowed/encouraged to hand-pick the corn in the fall or spring to raise funds for their activities.

3.10.4 Compensation Required to Offset Additional Costs and Production Loss from Standing Corn Rows.

Based on the information provided us by landowners and information from the Minnesota Crop Cost & Return Guide for 2011 (Lazarus 2010), we were able to calculate the cost to farmers of maintaining standing corn rows through the winter to block blowing and drifting snow. The calculations included: 1) the inconvenience cost of working around the standing corn rows; and 2) a 20% reduction in yields when the corn is harvested in the spring. Performing that

calculation for yields between 164 bushels per acre and 220 bushels per acre and at per bushel prices between $2.50 and $7.00 per bushel resulted in costs between $190 and $350 per acre per year when the standing corn rows are maintained. This would suggest that current payments of $700 per acre for maintaining standing corn rows more than compensates landowners for lost production assuming that landowners are able to harvest the remaining corn in the spring. If landowners do not harvest the remaining corn in the spring, their costs are approximately $765-$785 per acre to establish the standing corn rows assuming the remaining corn is plowed under in the spring.

Although payments to landowners who are able to harvest and market the remaining corn in the spring appear to be generous, there has still been reluctance by farmers to establish standing corn rows. Interviews suggested that part of the reason is the size of equipment used on the larger farms is an obstacle to adoption.

3.11 Environmental and Other Benefits from Standing Corn Rows

Landowners have identified a number of environmental and other benefits of standing corn rows. One of the main environmental benefits that were commonly cited by interviewed landowners is increased wildlife abundance especially birds and deer. Some farmers are hunters and the snow fence has been providing this opportunity. Similarly, farmers have realized that the standing corn rows have kept snow away from the road and it was easier for them to get access to work and travel. Most importantly, corn rows increase the moisture content and, depending on the general moisture conditions, the additional moisture may be important for their crops or cause delays in spring planting.

The standing corn rows owners have received a lot of positive feedback and appreciations from their neighbors and road travelers. They feel that it has "made a lot of difference" especially when the drifts kept getting taller and extending into the snow storage areas. In some cases, farmers called the owners to see what variety of corn was in the standing corn rows because it stands throughout the winter (farmers like strong standing corn stalks, there are some varieties which have weak stalks and lodge (fall over leaving the corn ear on the ground which is then unharvestable) before the corn ear is harvested). Some people have thanked the landowners for leaving the standing corn rows because they have noticed there was less blowing and drifting snow and icing where the standing corn rows are.

3.12 Suggestions on Payment Mechanism

Farmers have provided a number of suggestions related to technical improvement of the standing corn rows as well as the mechanism for payment to the farmers.

- From the experience of this winter's snow storm events, farmers have realized that the space between two strips of corn rows should be wider than that currently practiced
- The idea of protecting wildlife should be promoted as a part of living snow fence and standing corn rows. This might attract more farmers to join the program. As a part of the incentive, the DNR could compensate farmers for their efforts in conserving a food source for wildlife.
- One of the common suggestions from the landowners was that the adjacent farmers should be organized as a cooperative and an uninterrupted stretch of standing corn rows could be established. This would not only protect the road from drifting snow but also make harvesting cheaper and more efficient.

- The payment mechanism should adopt a formula which based on yield, production costs, inconvenience factors, income or financial benefit received, and the price of corn. Paying all the farmers at the same rate was one of the main suggestions. Payments are simpler with the flat fee. The rate could be determined for different regions of the state. One way to calculate payments would be to add 30% to the cost of production.
- Some farmers live many miles away from the standing corn rows, driving the combine to the site in the spring is an inconvenience and an expense. An additional compensation item could be inserted for distance from the site to where the machinery is stored. Possibly pay other farmers close to the standing corn rows to combine corn. (MnDOT could pay custom rates for mileage and combining) (See Appendix G for reference to custom rates)
- Farmers need to be informed that youth groups could hand-pick the corn in the fall and be given a donation, many farmers don't know this.
- Farmers would prefer a single strip of standing corn rather than the recommended 2 strips. This might improve adoption but may limit the effectiveness of the standing corn rows in catching and storing snow. It might be worth considering a change in the configuration of the standing corn rows.

Chapter 4
Greenhouse Gas Emissions and Payment Estimation and Documentation

4.1 Introduction

Trees in agricultural or forested landscapes sequester carbon dioxide in the atmosphere, a primary greenhouse gas, and store it as carbon in their biomass. LSF's can sequester carbon providing an additional benefit beyond addressing blowing and drifting snow issues. In addition to the carbon sequestered by living snow fences, 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. In the existence of a market the carbon sequestered can have value as a "carbon credit", but even without a monetary value the carbon sequestered represents an environmental benefit and contributes to reducing the greenhouse gases in the atmosphere which have been linked to global warming and climate change. Carbon markets are thought to be one of many innovative, market-based solutions to global climate change. These markets allow for the purchase of carbon "credits" by carbon emitters who need or wish to offset their emissions based on a government set "cap" or on a voluntary basis. The emitter could reduce carbon emissions or purchase credit(s) from a seller who is taking some action to reduce carbon emissions or sequester carbon. The following sections explain the impacts of LSF's on: 1) reducing greenhouse gas emissions; and 2) sequestering greenhouse gases already in the environment.

4.2 GHG Avoided

Snow fences, living or structural, reduce greenhouse gas emissions. Activities such as snow drift removal and sand/salt applications require fossil fuels. Snow fences reduce this activity and the associated greenhouse gas emissions, carbon dioxide being one of the principal green house gases released by fossil fuel consumption. This is the case for any type of properly designed snow fence and can include structural, living or corn row snow fences. In addition living snow fences reduce nitrous oxide emissions (a greenhouse gas) through a reduction in usage of nitrogen based fertilizers on acreage converted from agricultural uses. It is important to note that this is not a full life cycle assessment of snow fences but analyzes the major sources of GHG changes in this system.

4.2.1 Drifting Snow

Snow drifts on highways caused by blowing snow can require the use of heavy equipment to clear the roadway and make it safe for traffic. Equipment includes v-plows, snow blowers, bulldozers, loaders, dump trucks and plow trucks. This equipment may not be used during every drifting snow event and/or all of the equipment will not be used in a particular location. The table below outlines an estimate of the percentage of events that each type of equipment must be used. These pieces of equipment use fuel for the time they are in operation to clear the snow drift. The fuel usage varies by equipment and is the gallons of fuel used per hour or per mile of operation.

Table 4.1: *Drifting snow: 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	.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

Snow drifts can also vary in size and the amount of time it takes to clear the drift. Therefore we calculate the CO2 emissions on a snow problem per foot basis. Here we chose three common equipment types and a hypothetical usage of 2 hours to clear a 100 foot snow drift.

Table 4.2: *Example: CO2 emissions per foot by type of equipment for 2 hours to clear 100 feet*

	# of events	Hours	Total Hours	Gal/hour	Gallons	Gallons per foot	CO2 per foot (lbs.)
Tractor w/blower	10	2	20	0.4	7.8	0.1	**1.7**
Small Dozer	5	2	10	2.0	20.0	0.2	**4.4**
V-Plow	2	2	4	2.2	8.7	0.1	**1.9**
Total					**36.5**	**0.4**	**8.1**

4.2.1.1 Blow Ice

Blow ice caused by blowing snow that sticks to the roadway can require extraordinary sand/salt treatments. These treatments are in addition to normal baseline sand/salt applications on the roadway. The table below outlines the fuel usage per mile of blow ice.

Table 4.3: *Blow ice: fuel usage single axle plow truck*

	Fuel Usage	
Plow Truck	0.21	gal/mile

Using this figure and the mileage driven the amount of fuel used to apply the sand/salt to treat the blow ice can be estimated. These fuel usages can then be converted into a greenhouse gas emission estimate. According to the U.S. Environmental Protection Agency (US EPA) on average each gallon of diesel fuel releases 22.2 pounds of carbon dioxide. Using this figure the carbon dioxide emissions from snow drift removal and blow ice treatment can be estimated.

Table 4.4: *Blow ice: CO_2 emissions per foot/year*

	gal per mile	miles	Gallons	Gallons per foot	CO2 per foot (lbs.)
Single Axle Plow Truck	0.21	50	10.5	0.1	**2.3**

Table 4.5: *Drifing snow and blow ice: CO_2 emissions per foot per year*

	CO2 per foot per year (lbs.)
Drifting	8.1
Blow Ice	2.3
Total	**10.4**

Our estimate is that for an average 100 foot snow fence reduces carbon dioxide emissions by 10.4 pounds per foot. Most of this reduction comes from the reduced fuel usage to deal with the snow drift problem.

4.2.2 Nitrous Oxide

Living snow fences provide additional GHG avoidance through the elimination in the usage of nitrogen based fertilizers (nitrous oxide emissions) on the acreage where agricultural land is converted to a living snow fence. A portion of nitrogen based fertilizer when applied to cropland oxidizes and is emitted into the atmosphere. Nitrous oxide is a powerful greenhouse gas with a warming potential of 310 times that of carbon dioxide. The amount of nitrous oxide released depends heavily on the timing, quantity, and practice of nitrogen application and depends on the tillage practices.

USDA Natural Resources Conservation Service (NRCS) and Colorado State University, Natural Resource Ecology Lab (CSU NREL) have created an online tool, COMET-VR (http://www.comet2.colostate.edu/), that can be used to calculate the nitrous oxide emissions for specific parcels and includes inputs such as soil type, practice, tillage, and nutrient management. An example parcel calculation is shown.

State: Minnesota

County: Blue Earth

Soil: Loam

Current Practice: Corn/soybean rotation

Future Practice: Agroforestry: Windbreak

Corn/Soybean Tillage: Conventional

Nutrient Management:

Table 4.6: *Pounds nitrogen, applied to or given off by, crops*

	N fertilizer (lbs. per acre)	**Timing**
corn	113	Spring
soybean	26	Spring
windbreak	0	N/A

This example parcel has a reduction in nitrous oxide emissions of 2.0 pounds per acre per year (modeled using COMET-VR). Nitrous oxide has a greenhouse gas warming potential of 310 times that of carbon dioxide. That equates to 0.32 tons per acre per year of carbon dioxide equivalence.

4.3 GHG Sequestration

Grasses or plants in living snow fences have the ability to absorb or sequester carbon. As a plant grows, it accumulates biomass. This biomass grows incrementally using atmospheric carbon in photosynthesis. A rapidly growing young forest, for example, has a large yearly incremental increase in biomass and thus has a large capacity to sequester, or absorb, carbon from the atmosphere. This ability to absorb carbon is what makes forests an important source of credits from sequestration projects. Further, carbon absorbed through grasses in a living snow fence system is stored in biomass and in soil. Reduction of carbon dioxide in the atmosphere can also occur when carbon-neutral fuels such as trees or grasses are substituted for fossil fuels. One such example is substituting coal with forest or agricultural biomass in electricity generation. The same is true when emissions of carbon dioxide and other greenhouse gases are avoided by not having to use additional machinery (and therefore additional carbon dioxide emitting fuels) to deal with blowing and drifting snow problems.

4.4 GHG Payments

Carbon markets are thought to be one of many innovative, market-based solutions to global climate change. These markets allow for the purchase of carbon “credits” by carbon emitters who need or wish to offset their emissions based on a government set “cap” or on a voluntary basis. The emitter could reduce carbon emissions or purchase credit(s) from a seller who is taking some action to reduce carbon emissions or sequester carbon.

The Kyoto Protocol of 1997 imposed carbon emissions limits on its signatories. This meant that carbon-emitting enterprises in signatory nations were obligated to either remain within its emissions limits or purchase carbon credits from the European carbon market. Because the United States did not sign the Kyoto Protocol, it could not participate in the European market, so a voluntary carbon credit trading market was established. In 2003, the Chicago Climate Exchange (CCX) set up a working carbon credit trading market for U.S.-based emitters (Sustainable Ag Energy CoP, 2011). Because this market is voluntary, demand for credits is lower than in European markets, creating a disparity in carbon credit prices.

4.5 Updates on Carbon Credit Program/Market in the US

The carbon credit program that paid farmers and landowners millions of dollars for reducing greenhouse gasses through carbon storage land use practices (i.e., no-till or strip till farming, grasslands and forests) has virtually stopped primarily due to no U.S. climate legislation being established. Two major aggregators (i.e., North Dakota Farmers Union – NDFU and AgraGate) in the Midwest have been unable to generate revenue from the sale of carbon credits in 2010. During its existence, the carbon credit program brought additional income to U.S. landowners which had qualifying land practices. NDFU and AgraGate reported nearly 10,000 farmers and ranchers from 40 states have earned about $16 million through the program since it started in 2003 up to 2010. The carbon credit voluntary market peaked at $7.50 a metric ton in 2008 and went down to 5 or 10 cents a metric ton in 2010.

Lack of climate change legislation in the US is affecting the carbon credit program. Congress did not pass the proposed cap-and-trade climate legislation in 2010. The poor U.S. economy from the recession coupled with the possible increase in energy costs from a cap and trade bill led to the lack of support for this legislation. There may be carbon programs with regional cooperation among state and government entities such as the Western Climate Initiative, but these programs may not offer much opportunity for agricultural credits (David Miller, AgraGate, 2010).

Although the Chicago Climate Exchange is no longer operating as a trading platform for carbon, there are regional initiatives that do provide payments for carbon sequestration in the Northeast, the Western States and California. In addition to those regional and state efforts there is a voluntary market available to some landowners and MnDOT might even consider approaching one of the voluntary market participants to develop a project that would pay for credits.

Although not likely in the near future, there is still interest in carbon sequestration and using a carbon market to promote sequestration. That market may develop in the future and could be a way to provide an additional incentive to landowners. Whether a market develops or not, LSF's still represent a practice that will help sequester greenhouse gases and avoid emissions of greenhouse gases thereby helping to reduce the concentration of greenhouse gases in the atmosphere.

Chapter 5
Transportation Agency Benefits

Snow fences provide benefits to transportation agencies by 1) reducing snow drift removal costs and 2) sand and/or salt applications to treat blow ice. Blowing snow problem areas can have one or both of these problems. This chapter outlines the details of these cost savings for the transportation department.

5.1 Snow Removal Equipment

When blowing snow causes drifts on the roadway that cannot be removed with standard plow trucks, snow removal equipment must be brought in to keep the roadway clear. The extraordinary efforts are over and above those to plow a roadway without a blowing and drifting snow problem. Understanding how often there is a drifting problem, what equipment is brought in, and the time it takes that equipment to clear the roadway are necessary to understand the potential cost savings. In addition this equipment must reach the snow drift area which adds an additional cost depending on the location of the snow drift.

5.1.1 Drifting Snow Events

The number of drifting snow events ($\#_{\text{drifting snow events}}$) requiring each type of equipment can vary across snow problem areas and winters. Drifting snow events happen when blowing snow drifts on the roadway and create snow drifts that are too large for a standard plow truck to remove. This can be highly variable from year to year depending on winter conditions. Keeping local records in addition to road maintenance personal knowledge can be useful for transportation agencies to understand how often these events occur at each snow problem area.

5.1.2 Snow Drift Removal Time

The length of snow drifts can vary in size from a few feet to a couple hundred feet. Longer snow drifts will take more time to clear. Field data can be collected during peak drifting season to estimate the removal time of a drift. Knowing the average time that each type of equipment is used, the equipment usage time can be calculated.

5.1.3 Use of Snow Removal Equipment

The type of equipment used to clear a snow drift can vary by location and drifting event. Certain locations may only use some of this equipment while others may use all of them throughout the year.

5.1.4 Cost of Snow Removal Equipment

Use of snow removal equipment requires labor, fuel, and equipment costs. The average total cost per hour to operate each type of equipment was estimated from communication with MnDOT maintenance supervisors. The default values are indicated below on a total cost (fuel and equipment) per hour used.

Table 5.1: *Total per hour cost of snow removal equipment (fuel, equipment)*

Class	Description	Recovery Rate	Unit	Billing Rate
330	Truck 2-1/2 Ton – 3 Ton Dump	2.95	per mile	$3.58
344	Truck 4 Wheel Drive 8-10 Ton	6.88	per mile	$8.36
350	Truck 57M LB Chassis Cab Tandem Axle	2.75	per mile	$3.34
428	Mover Tractor 4 WD over 60 HP	55.87	per hour	$67.88
620	Motor Grader Over 70 HP All	60.42	per hour	$73.41
710	Cat. RD7 and D7 with Angle Dozer	30.96	per hour	$37.62
760	4 Wheel Drive Loader-Hough, Pettibone	54.41	per hour	$66.11
880	Dual Motor Rotary (Klauder) Sno Go	--	per hour	$175.00

5.1.5 Operator

In addition to the equipment costs, each piece of equipment must be operated by a transportation employee. The cost associated with this is $42.18 per hour for a general transportation employee. This cost includes fringe benefits and administration. Contact the MnDOT finance office for a current copy of equipment and labor costs.

5.1.6 Total Snow Removal Cost Savings

A properly designed living snow fence or standing corn rows can prevent snow from drifting on the roadway and potentially reducing extraordinary efforts. With the above information the total snow removal cost savings can be calculated using the following equation.

$$\sum \#_{\text{per year}} \left(EquipUsage_{\text{hours or miles}} EquipRate_{\$/\text{hours or miles}} + OperUsage_{hours} OperRate_{\$/hour} \right)$$

The number of drifting snow events multiplied by the average hours per drifting snow event for each type of equipment is multiplied by the cost to operate to get the average cost per event for each type of equipment at the snow problem area. This value is then summed up across the different equipment types. This gives the average annual snow removal equipment cost savings from the installation of a snow fence in a particular snow problem area.

5.2 Sand/Salt Applications

In addition to drifting snow, blowing snow can also cause icy road conditions (Blow Ice). Snow blowing on the pavement can stick to the relatively warmer pavement and refreeze. These poor conditions require sand and/or salt applications to return the road to bare pavement conditions.

Snow fences can provided cost savings for the transportation agency because they reduce the applications of sand and/or salt that are above and beyond the normal sand and salt application.

5.2.1 Blow Ice Events

The number of blow ice events requiring extraordinary effort can vary across snow problem areas and winter. A blow ice event is when blowing snow melts on the highway caused by a sunny or warming daily temperatures or heavy highway traffic and refreezing at night or when temperatures get colder. This is an event when sand and/or salt must be applied to snow problem areas in addition to the normal sand and/or salt applications on the roadway.

5.2.2 Sand and Salt Application

Sand and salt application can vary by road type, location, and agency protocol. This application is typically specified as pounds per lane mile. The application can be sand, salt, or a mixture. The sand/salt would be applied to the roadway at a length assumed to be the same as the length of the snow problem area.

5.2.3 Sand and Salt Application Costs

Sand and salt application requires truck and driver time along with the cost of the material. The costs per ton of sand and salt are estimated from MnDOT records.

Table 5.2: *Costs per ton of sand and salt*

Salt	$67.00	*per ton*
Sand	$5.50	*per ton*

5.2.4 Mobilization

In addition to the costs to treat the blow ice the sand/salt truck needs to reach the snow problem area. The distance can vary based on how far the truck travels from where it is stored and/or in the case of multiple blow ice treatments per trip, how much extra distance does the snow problem area add to the trip. The cost is on a per mile basis.

5.2.5 Total Sand and Salt Application Cost Savings

A properly designed snow fence can prevent blow ice from forming on the road. With the above information the total costs savings from sand and salt application can be calculated using the following equation.

$$\#_{\text{blowice events}}\left[\#_{treatments}\, rate_{lbs/lanemils}\left(\%_{sand}\, rate_{\$/\text{lbs sand}}+\%_{salt}\, rate_{\$/\text{lbs salt}}\right)d_{\text{lane miles}}+rate_{\$/mile}\, Truck_{miles}+rate_{\$/hour}\, Oper_{hours}\right]$$

The cost per pound of application mixture is calculated and multiplied by the application rate. This gives the sand/salt cost per lane mile. This is then multiplied by the number of lane miles and results in the sand/salt cost per blow ice event. This is added to the equipment costs and operator costs per event resulting in the average total costs per blow ice event. This figure is then multiplied by the average number of blow ice events.

5.3 Evaluation of Living Snow Fences: Tool Instructions for Processing of Plow Routes and Determining Study Pairs

5.3.1 Background

This ArcGIS tool will do the necessary processing on an input snow plow route and snow fence feature class. The tool assumes the existence of three data elements in a geodatabase:

a. Statewide Snow plow route line file from MnDOT
b. Statewide living snow fence polygon file from MnDOT named SnowFence
c. 30m Land Cover raster from 2000 from land.umn.edu

Because of the nature of the geoprocessing tasks performed, this tool requires the ArcEdit licensing level. It will not work with lower licensing levels nor with the student disk from ESRI.

The tool will ask for several inputs:

a. The geodatabase which contains the above information
b. The name of the plow route file within that geodatabase
c. The name of the land use raster file within that geodatabase
d. The MnDOT district which is to be processed in a given run
e. Azimuth degrees increment
f. Snow Fence buffer distance and units
g. Roadway buffer distance and units
h. If a new, cleared output file should be created or not

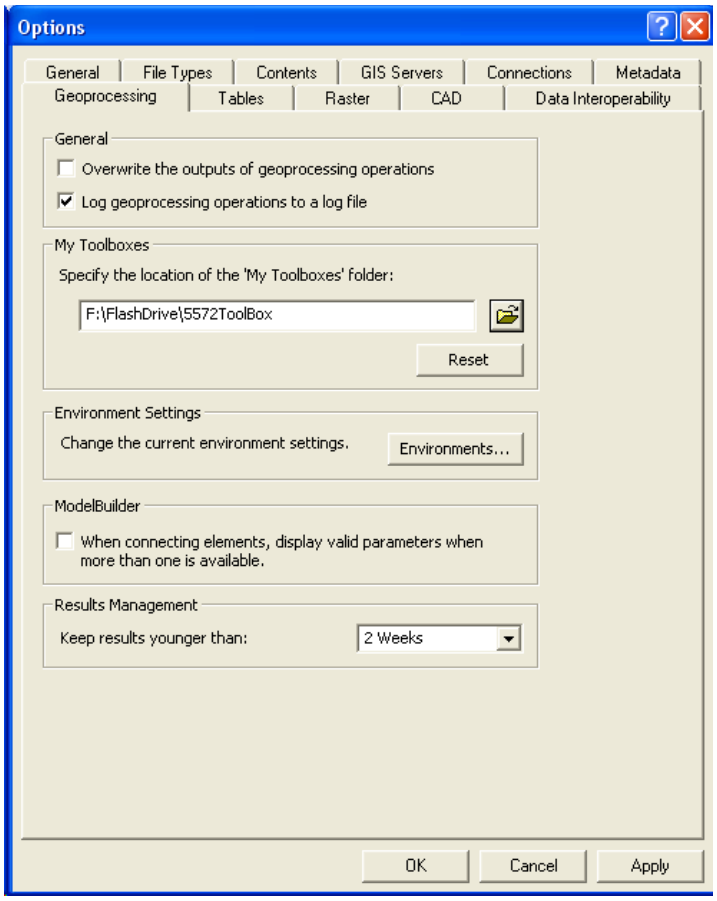
As an output, the tool creates a polyline file named CompPlowRoutes of the processed plow route which contains additional attributes:

- Azimuth in degrees of the roadway segment rounded to whatever increment was specified
- The predominant land cover classification code surrounding this roadway segment
- The FID of any living snow fence that is within the snow fence buffer distance from this roadway segment.
- The type of living snow fence

At the completion of processing, the road segments in the output file can be selected and the attribute values or other matching road segments can examined to identify road pairs for further evaluation.

5.3.2 Loading the Tool into your ArcGIS Software

- Navigate to the zip file that contains the tool and unzip it to the location of your choice.
- Open ArcCatalog
- In the main menu click Tools > Options > Geoprocessing Tab
- The following screen will display:



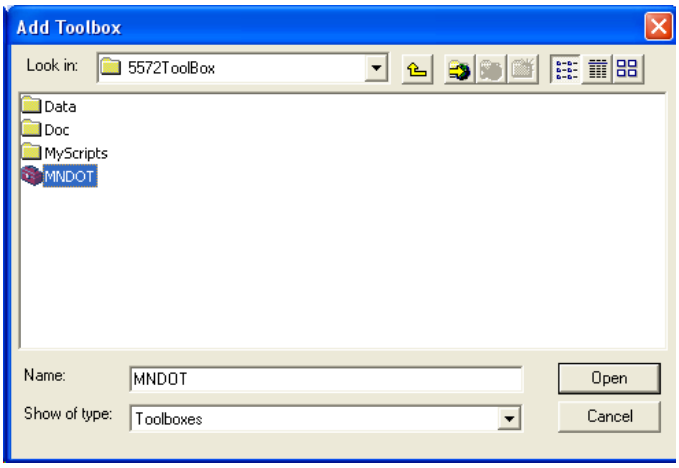
In the General section, check the box to "Overwrite the outputs of geoprocessing operations" and click **OK**.

In the My Toolboxes section, click on the Open Document Icon and navigate to the location that you unzipped the tool to in step 1 above (In the above example that location is F:\FlashDrive\5572ToolBox).

Add the tool box to ArcGIS

- In the ArcCatalog screen make certain the tool boxes are visible. If not, click on the  icon to display them. Right click on ArcToolbox and click Add Toolbox in the drop down menu.

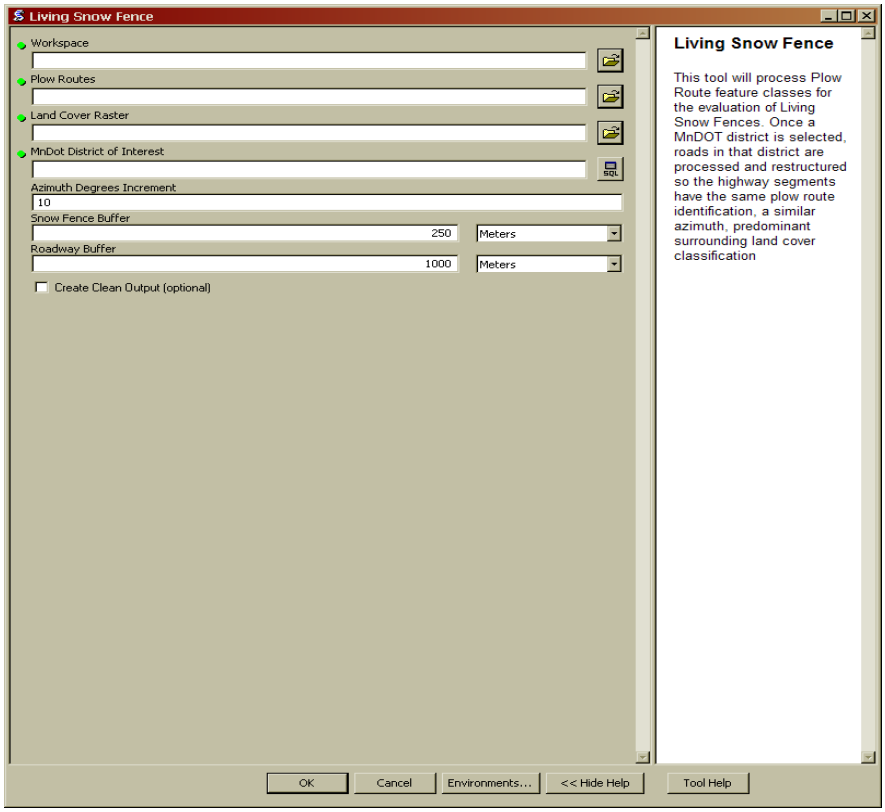
- The follow dialog box will open:



Navigate to the location at which you unzipped the tool and click on the MnDOT toolbox to highlight it and click on **Open**. The MnDOT toolbox should be added to your tool list and when expanded should look like the view on the left.

Note: the Find Azimuth and Find Maximum LC tools are used by the Living Snow Fence tool. You will not execute them directly.

To run the tool, expand the **Directional Tools** icon and click on the **Living Snow Fence** script. The Living Snow Fence dialog box will appear:

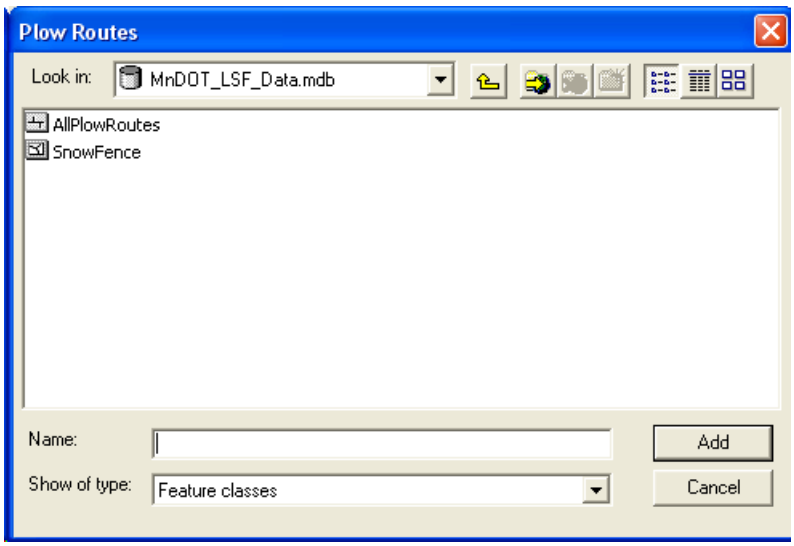


Note as you click in the various entry fields, the help windows will guide you with information for that field.

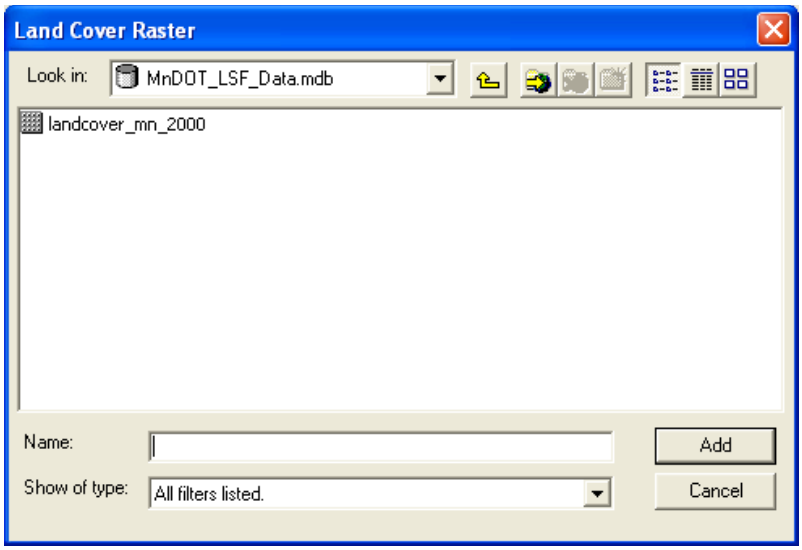
In the Workspace entry, navigate to the Data subdirectory where you unzipped the tool.

Single Click on the MnDOT_LSF_Data geodatabase choice and click **Add**.

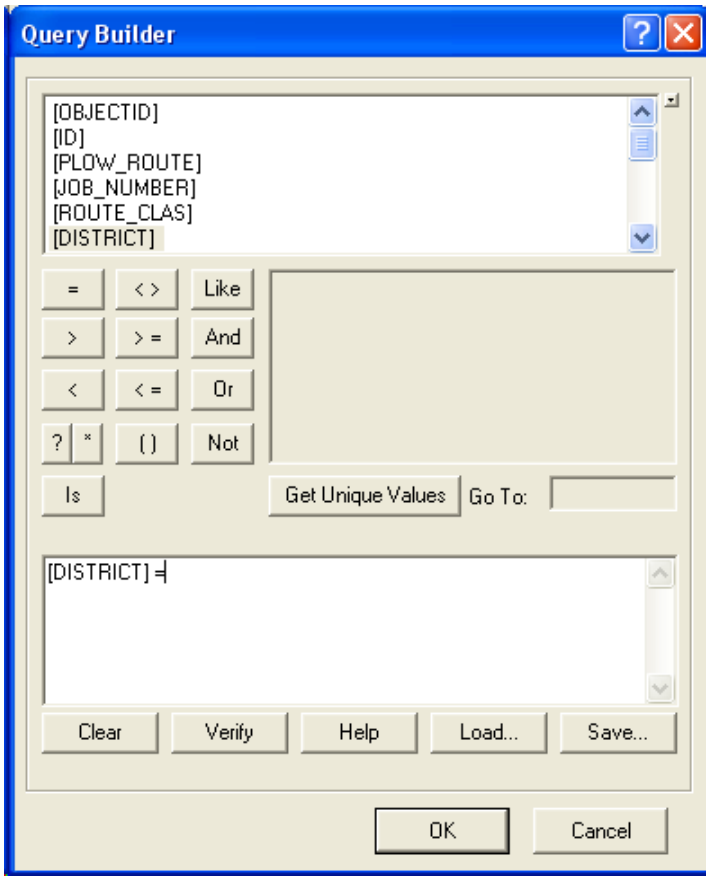
In the Plow Routes drop down, navigate to the desired plow route file, click on it and click **Add**



In the Land Cover dropdown, navigate to the landcover_mn_2000 entry click on it and click **Add**



In the MnDOT District of Interest entry, click on the **SQL** button:



Double click on **DISTRICT** in the field list

Single click on the = sign

Single click on the **Get UniqueValues** button

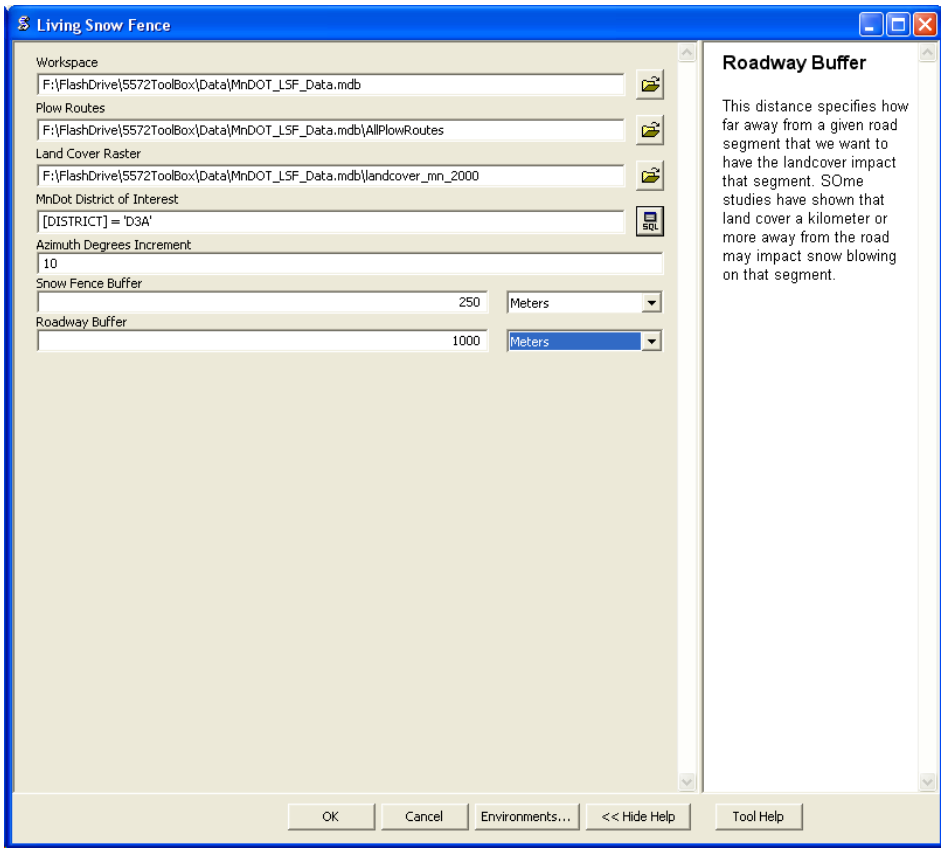
Scroll in the list of district until you see the desired district and Double click on it.

Click **Verify** to make certain the query you entered is valid. You should see:

Click **OK** to close this pop up.

Click **OK** to close the dialog box

At this point your screen should look something like below. The disk letters may be different, depending on the location you unzipped the tool to.



In the **Azimuth Degrees Increment** entry box, enter the number of degrees that you would like to have the roadway segment azimuths readings rounded to. This field defaults to 10 degrees, which means roads will have azimuths of between 0 and 170 degrees in steps of 10 degrees. If this number is made smaller, you may have difficulty finding road segments with the same azimuth reading for the test pairs.

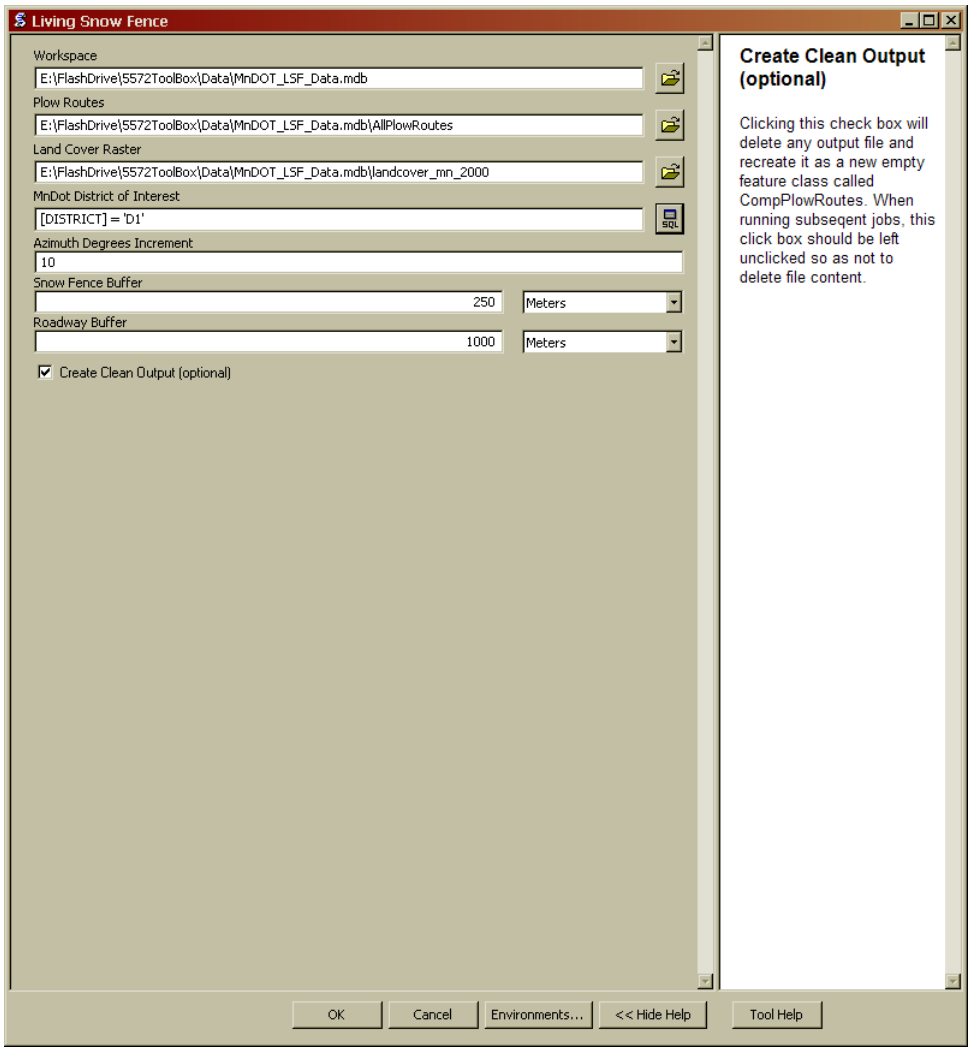
Enter a value for the **Snow Fence Buffer distance** and choose an entry for the **unit of measure** from the drop down list. This is the distance around snow fences that will see an impact from that snow fence. If the distance is too small, the snow fence may not impact a nearby roadway.

Enter a value for the **Roadway Buffer distance** and choose an entry for the **unit of measure** from the drop down list. This is the distance away from a given road that the surrounding land

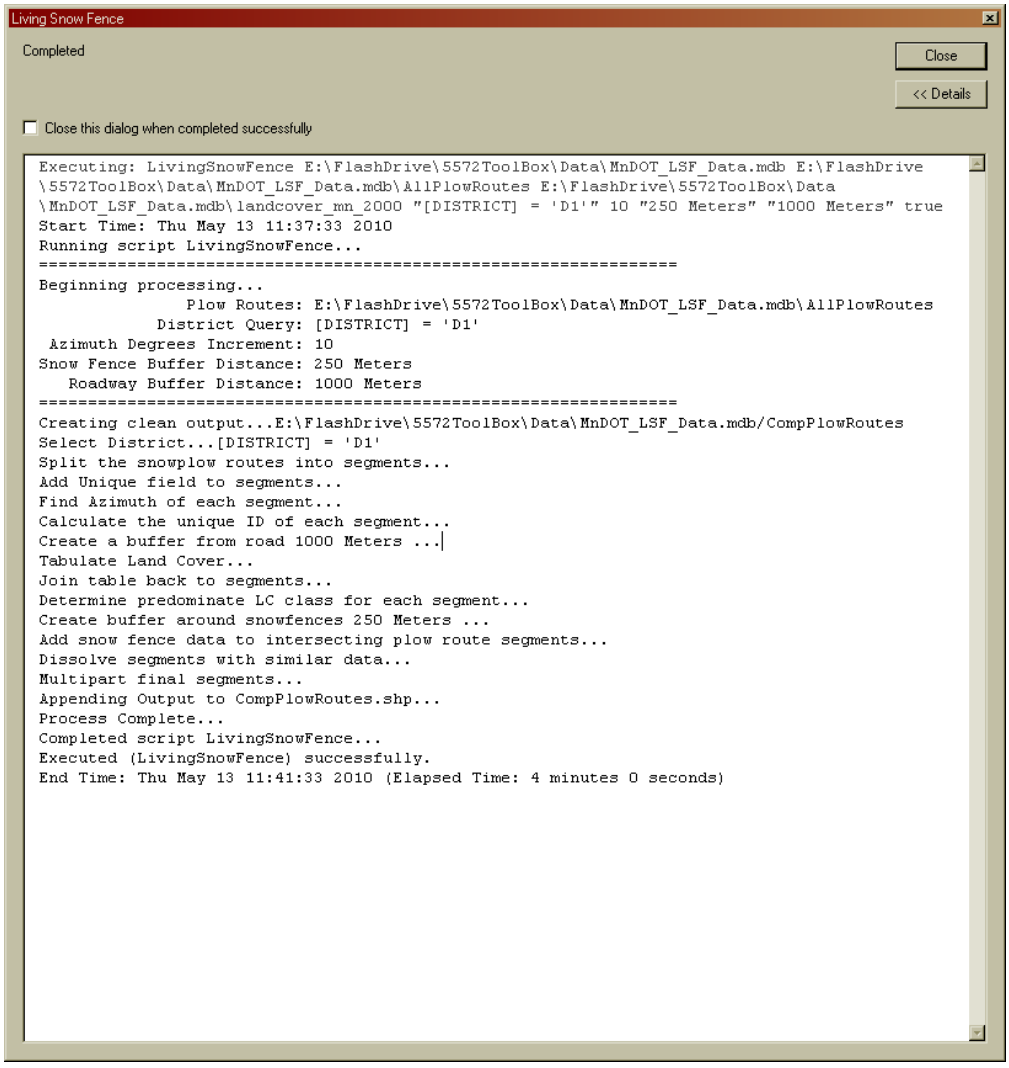
cover features have impact on the road. Studies have shown that features up to a kilometer or greater may have impact on the snow drifting on a highway.

If this is the first district being run in a series of multiple runs, click the **Create Clean Output** check box. This will delete and recreate an empty output feature class called CompPlowRoutes in the geodatabase. For the next districts being run on the tool you would want to leave this box blank so the district information already processed in prior runs is not erased.

Your completed tool dialog box will look something like below:

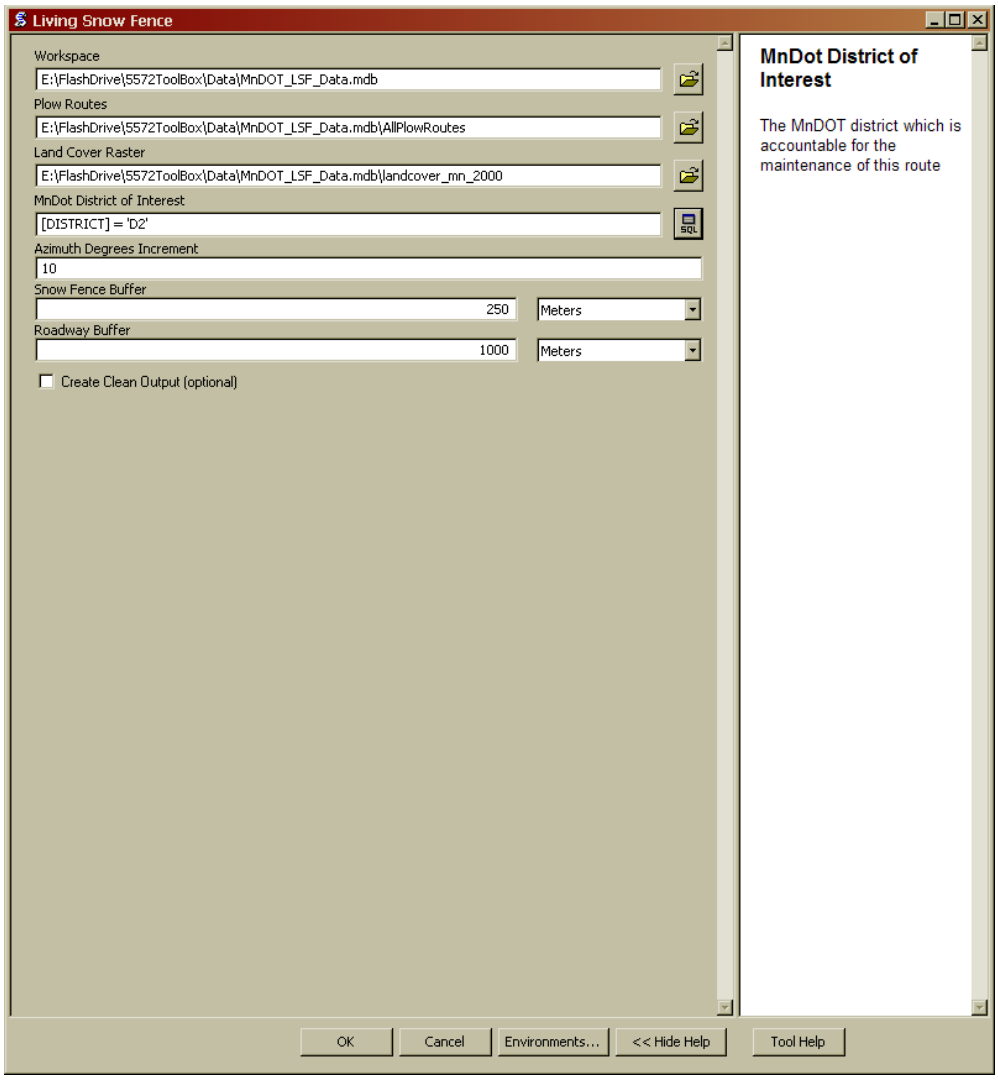


Click **OK** to run the tool. You will get status messages in the tool output dialog box:



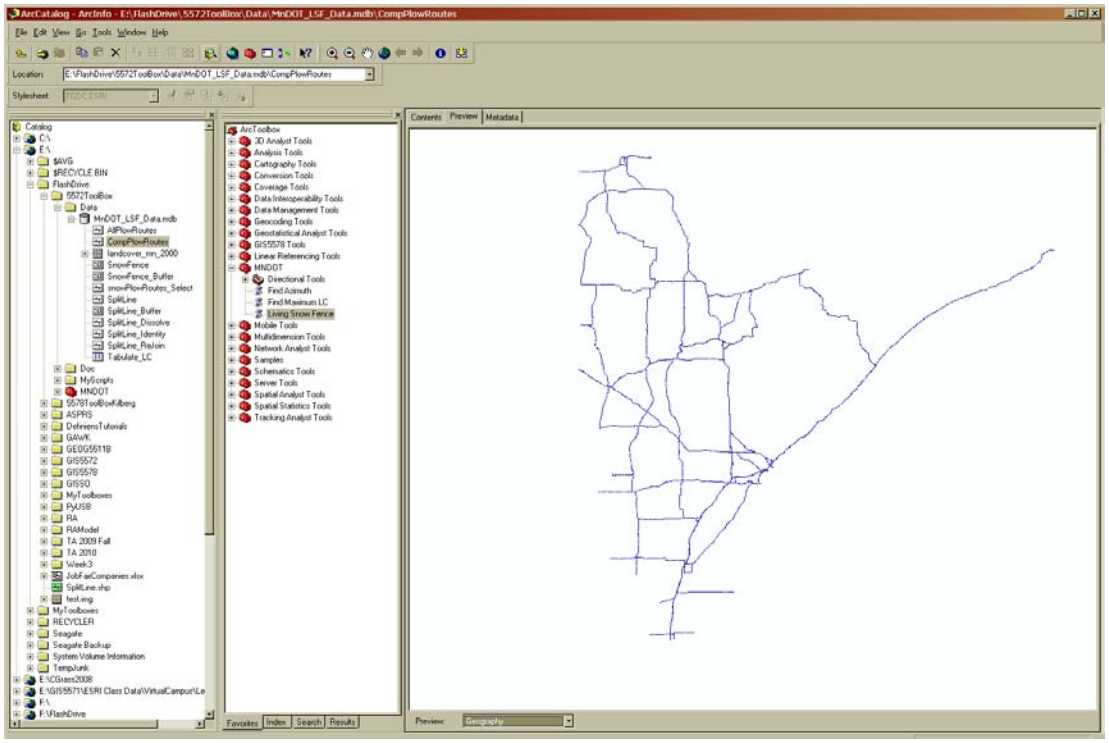
At this point, you can run the tool again to process the next district. Simply repeat the steps above but selecting the next District to process. The dialog box would look like below assuming you select District 2.

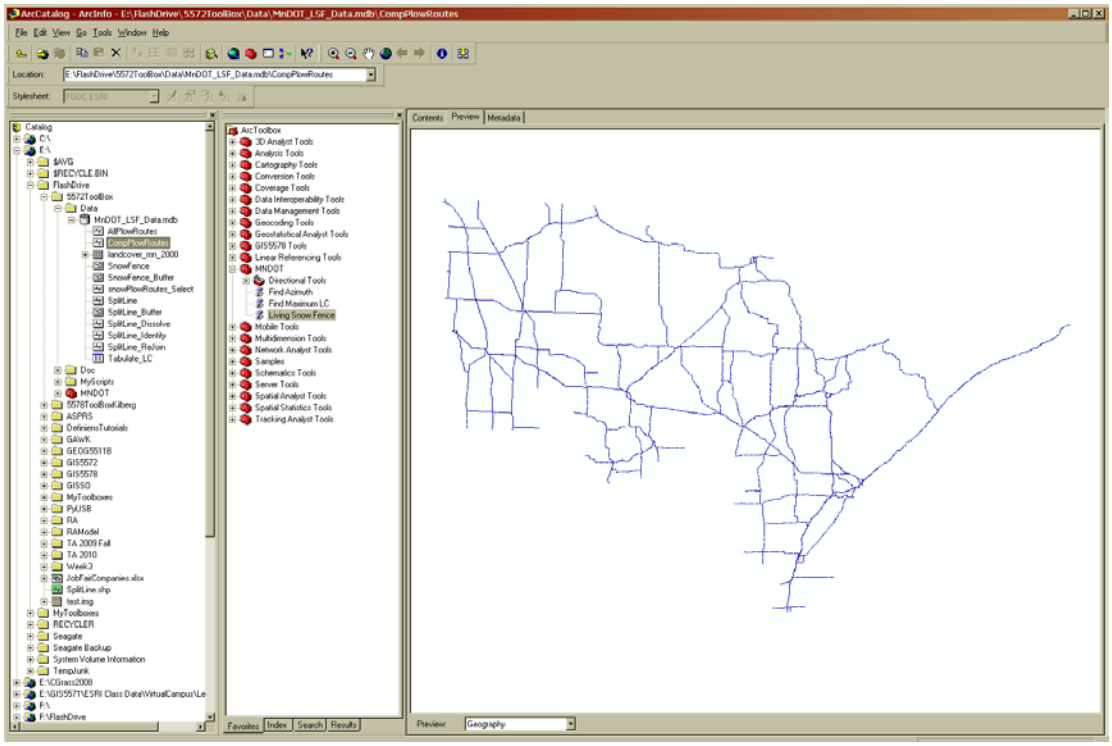
Advanced users can generate their own query to process multiple districts (or all districts) at one time but the processing time will increase accordingly.



The output of District 2 …

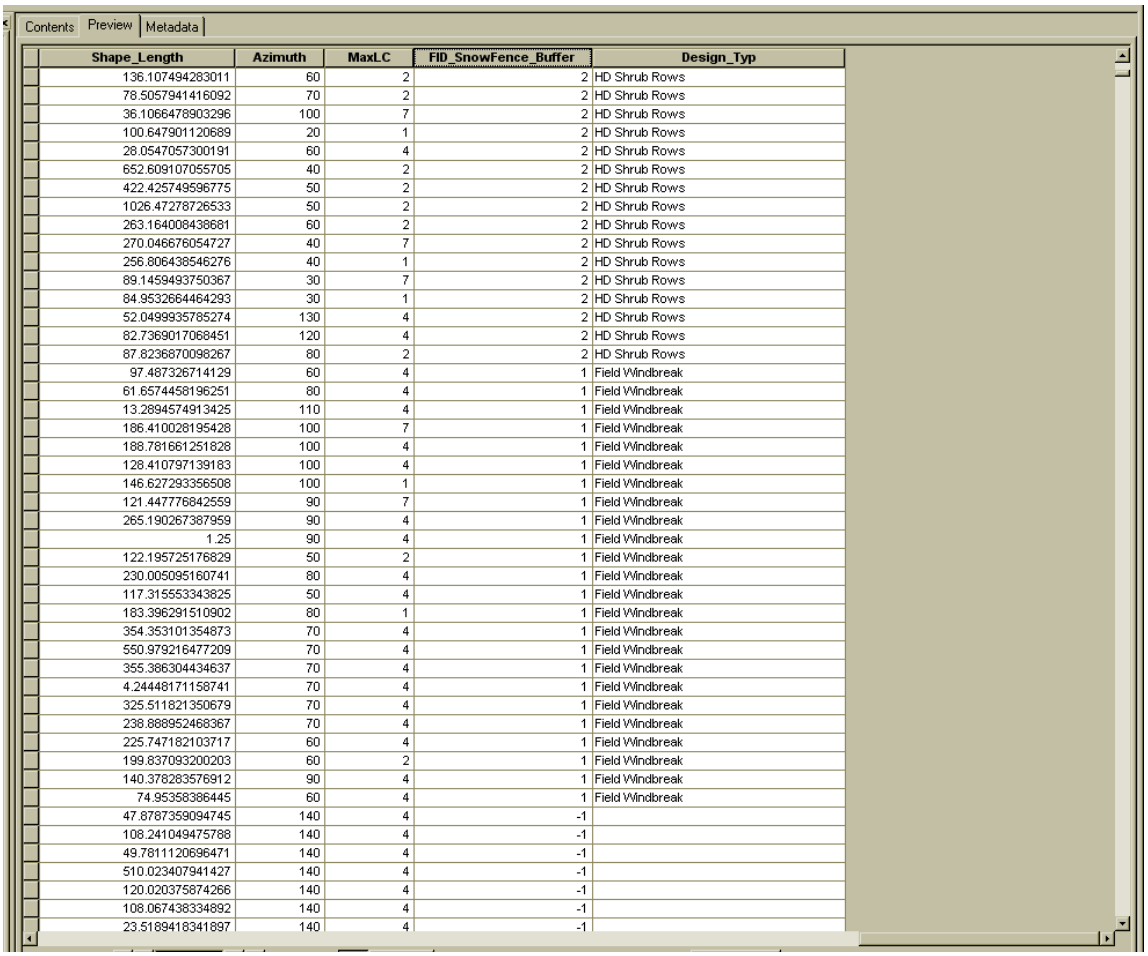
You can preview the results of the runs in ArcCatalog by navigating to the CompSnowRoutes feature class and clicking on the Preview tab. We can see below, what the data looks like for first District 1 only and then Districts 1 and 2 combined:





The following screen shows an example of the data that is added to the base Plow Route file at the end when a snow fence is found impacting this section of roadway. The azimuth field shows that azimuth between 0-179˚. The MaxLC field gives the predominant land cover class that

exists in a buffer drawn from the roadway out to the surrounding geography (as specified by the roadway buffer distance). The FID_SnowFence_Buffer is the ID of the snowfence buffer that intersected with this section of roadway and Design_Typ is a text description of the kind of snow fence it was.



Contents | Preview | Metadata

Shape_Length	Azimuth	MaxLC	FID_SnowFence_Buffer	Design_Typ
136.107494283011	60	2	2	HD Shrub Rows
78.5057941416092	70	2	2	HD Shrub Rows
36.1066478903296	100	7	2	HD Shrub Rows
100.647901120689	20	1	2	HD Shrub Rows
28.0547057300191	60	4	2	HD Shrub Rows
652.609107055705	40	2	2	HD Shrub Rows
422.425749596775	50	2	2	HD Shrub Rows
1026.47278726533	50	2	2	HD Shrub Rows
263.164008438681	60	2	2	HD Shrub Rows
270.046676054727	40	7	2	HD Shrub Rows
256.806438546276	40	1	2	HD Shrub Rows
89.1459493750367	30	7	2	HD Shrub Rows
84.9532664464293	30	1	2	HD Shrub Rows
52.0499935785274	130	4	2	HD Shrub Rows
82.7369017068451	120	4	2	HD Shrub Rows
87.8236870098267	80	2	2	HD Shrub Rows
97.487326714129	60	4	1	Field Windbreak
61.6574458196251	80	4	1	Field Windbreak
13.2894574913425	110	4	1	Field Windbreak
186.410028195428	100	7	1	Field Windbreak
188.781661251828	100	4	1	Field Windbreak
128.410797139183	100	4	1	Field Windbreak
146.627293356508	100	1	1	Field Windbreak
121.447776842559	90	7	1	Field Windbreak
265.190267387959	90	4	1	Field Windbreak
1.25	90	4	1	Field Windbreak
122.195725176829	50	2	1	Field Windbreak
230.005095160741	80	4	1	Field Windbreak
117.315553343825	50	4	1	Field Windbreak
183.396291510902	80	1	1	Field Windbreak
354.353101354873	70	4	1	Field Windbreak
550.979216477209	70	4	1	Field Windbreak
355.386304434637	70	4	1	Field Windbreak
4.24448171158741	70	4	1	Field Windbreak
325.511821350679	70	4	1	Field Windbreak
238.888952468367	70	4	1	Field Windbreak
225.747182103717	60	4	1	Field Windbreak
199.837093200203	60	2	1	Field Windbreak
140.378283576912	90	4	1	Field Windbreak
74.95358386445	60	4	1	Field Windbreak
47.8787359094745	140	4	-1	
108.241049475788	140	4	-1	
49.7811120696471	140	4	-1	
510.023407941427	140	4	-1	
120.020375874266	140	4	-1	
108.067438334892	140	4	-1	
23.5189418341897	140	4	-1	

Selections can now be done in ArcMap to locate non-snow fence segments that would have a similar Azimuth, MaxLC and PlowRoute Number as a given snow fence segment.

5.3.3 Notes on Creation of this Script

This script supports the MnDOT effort to gain an understanding of the value of living snow fences and their impact on road maintenance during winter weather events. The intent of this project is to examine data provided by MnDOT that describes roadways and the location and types of snow fences that have been identified to date. The code will process the roadway feature class and add attributes to the file such as direction (azimuth) of the road, predominant land cover surrounding the road and nearby snow fences. Project team members will then look for segments with similar attributes except one segment having a snow fence and the other not. These paired segments will be evaluated for the time and materials it takes to maintain each of them during events. Each time new snow fences are installed and identified or changes are made to road information, the team didn't want to have to manually re-process the files. This script allows the user to select a specific MnDOT district of interest (or multiple districts) and process the files when changes are made to the source data. As can be seen, there are many steps to the

process and manual actions were not deemed advisable. When the manual pair selection process is better understood, that will be incorporated into the script as well.

The script began life as an ArcGIS model builder which was used to walk thru the various processing steps and provided a prototyping environment to ensure the processing was as desired. A rather tricky portion of the model was to force the use of both an input and output feature class for the azimuth tool. Without this derived output, the tool would never be forced to run in the model. Also particularly vexing was the creation of a tool that would determine the predominant land cover classification out of 8 fields. There is no MAX function in the calculate field tool and a script had to be improvised for the tool to do that. I thank Tim Loesch profusely for his help in getting the model to run. This model was used as a graphic on the Living Snow Fence poster.

Once the model worked, a script was created. Considerable modifications were done in error checking and commenting as the script was fine tuned. Once working, the script was hooked to a tool dialog box in ArcGIS. This step was as complex and frustrating as it normally is when dealing with scripts. Over all, the model tool about 15 hours to create, the script took another 15 hours and hooking it to the dialog box and debugging that took another 8 hours. Writing this manual and write-up took another 5 hours. Total project time was about 43 hours.

Chapter 6
Living Snow Fence Payment Tool: User Guide v0.9

6.1 Introduction

This user guide has two purposes. The first is to explain how to use the living snow fence payment tool. The second is to explain how the tool functions. Being built for MnDOT, this tool has custom features specific to Minnesota and MnDOT. However the tool is usable by any agency but will require more user input and/or construction of databases. These details are outlined throughout the user guide.

6.1.1 Users

This tool has been constructed to be used by transportation agencies. Within the agencies it is expected that safety engineers and road maintenance supervisors would be the primary users. These users have access to the input sheet and the output sheets. They are restricted from the parameter and database worksheets by means of an administrator password. In addition the main file will be a read only file. Users can save inputs and outputs to another file name but will not be able to save over the master file. Tool and living snow fence program administrators will have access to all worksheets so that updates to the parameters and databases can be made periodically and any minor bugs can be fixed.

6.1.2 Agency Prioritization Maps

To compliment the living snow fence tool a set of prioritization maps are available for MnDOT. There is a map for all MnDOT snow problem areas in Minnesota and one for each MnDOT district. These maps allow users and administrators to prioritize snow problem areas and are based on MnDOT cost savings using state averages. The color coded values are the cost/benefit ratio for the MnDOT. A value less than one means the cost are greater than the benefits. A value greater than one means that the benefits are greater than the costs. The higher the benefit cost ratio the higher the priority should be. These maps also indicate the segment ID so that a more detailed analysis can be conducted using the LSF tool.

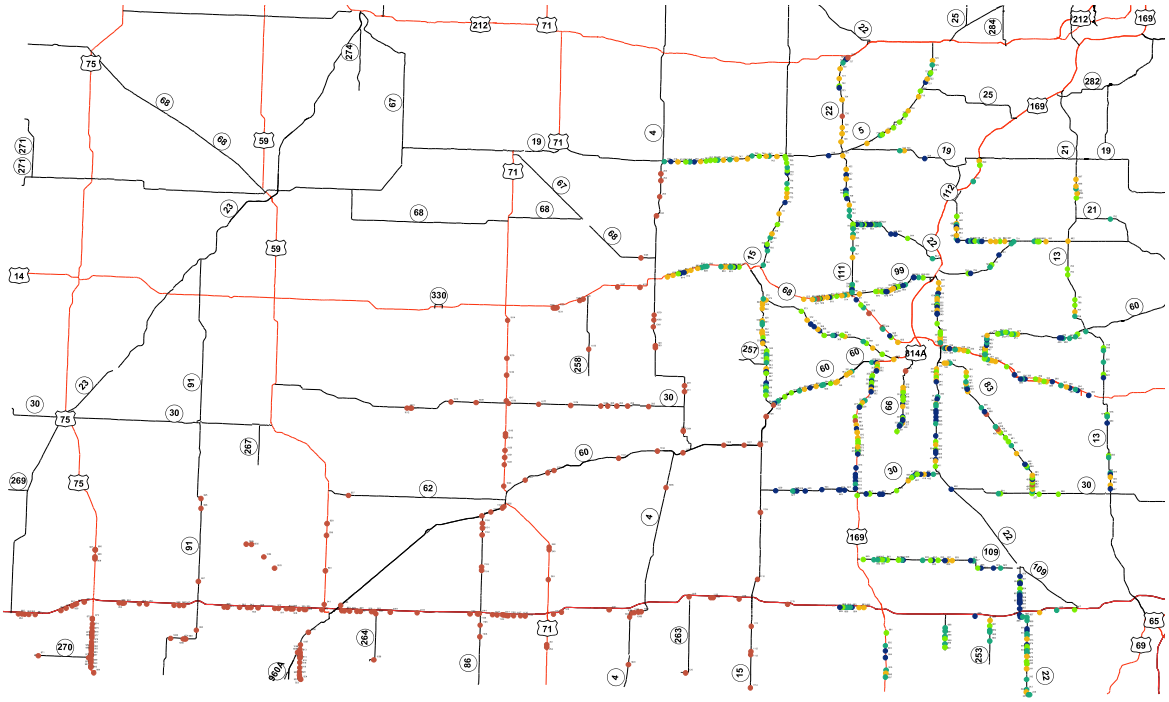


Figure 6.1: MnDOT identified snow problem sites

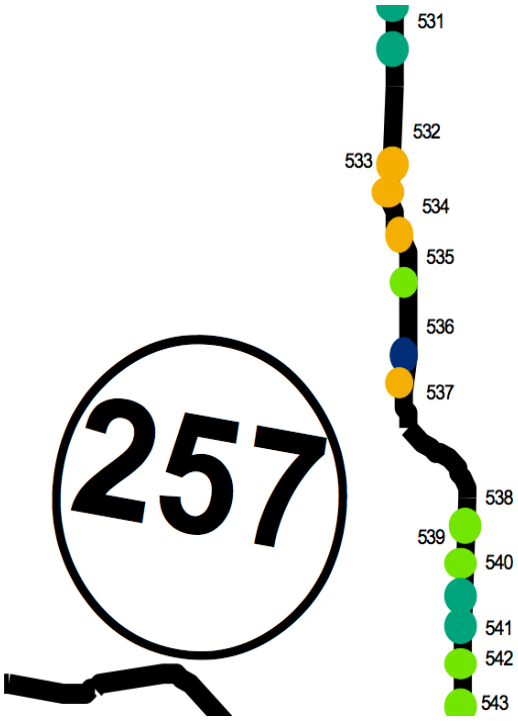


Figure 6.2: Color-coded cost/benefit highway maps – identified by site

6.1.3 User Input

In the input worksheet there are three categories of user inputs. These are color coded according to the category. The first (green) is required user inputs. Each time the calculator is used this data must be inputted. If data is missing then the tool will either not calculate certain costs and benefits or will not give results. Some of the inputs are restricted to certain values. Details are outlined in the following sections. The second (orange) is the data retrieved from the databases based on user inputs. This data is used in the tool to make calculations. If the retrieved data is incorrect it can be manually overridden by the user. The third (red) is retrieved informational data only. This data is not used by the tool but may be useful to the user.

Table 6.1: *Three categories of user inputs*

User Input			Retrieved Data			Informational Data		
Description	Input	Unit	Description	Input	Unit	Description	Input	Unit

6.1.3.1 Segment ID

This input is the unique identifier for the snow problem area. The segment ID is used to retrieve data from the snow prioritization database. For MnDOT this segment ID can be located from the agency prioritization maps.

6.1.3.2 Snow Problem Area Length

The length of the snow problem area is important in understanding the size of the drift and the length of roadway that is subject to poor driving conditions. If the transportation agency has a snow prioritization database then the length is automatically retrieved based on the segment ID. The length can also be manually overridden or inputted in the input worksheet.

Table 6.2: *Snow problem area length*

	Length	326	feet

6.1.3.3 Acreage

The LSF and corn row acreage is calculated based on the snow problem area length. It also assumes that the length of the snow fence must be longer than the snow problem area based on optimal snow fence design. The following default parameters are used to calculate the acreage.

Table 6.3: *Default parameters used to calculate the acreage*

LSF Width	40	feet
Corn Row Width	30	inches
Number of Corn Rows	16	#
Fence Setback from right-of-way	200	feet

These parameters can be updated on the parameter worksheet and require an administrator password.

6.1.3.4 Corn/Soybean Rotation

In areas with corn and soybean rotation, standing corn row fences can only be used the year that corn was planted. Users can choose the type of corn crop rotation adjacent to the snow problem area. Choosing “yes” assumes a corn and soybean rotation and costs and benefits of standing corn rows with be zero every other winter in the output. Choosing “no” assumes continues corn planting and so the standing corn row fence is assumed to be present every winter.

Table 6.4: *Cropping rotation*

Corn/soybean rotation	yes

6.2 Transportation Agency Benefits

Snow fences provide benefits to transportation agencies by reducing snow removal costs and sand and/or salt application. The total of these benefits are on the $ Output worksheet under the transportation agency benefits section

6.2.1 Snow Removal Equipment

When blowing snow causes drifts on the roadway that cannot be removed with standard plow trucks snow removal equipment must be brought in to keep the roadway clear. The extraordinary efforts are over and above those to plow a roadway without a blowing and drifting snow problem.

6.2.1.1 Drifting Snow Events

The number of drifting snow events requiring extraordinary effort can vary across snow problem areas. The user must input the average number of these events for the specific snow problem area.

Table 6.5: *Drifting snow events input*

Drifting snow events	per year

6.2.1.2 Use of Snow Removal Equipment

The type of equipment used to clear a snow drift can vary by location and drifting event. If the transportation agency has a snow prioritization database the type of equipment used is automatically retrieved from the database. This can be overridden on the input worksheet.

Table 6.6: *Snow removal equipment used*

	Y/N
V-Plow	Y
Bulldozer	Y
Snow Blower	Y

Even if this equipment is used at this location it may not be used for every drifting snow event. The user must input the average percentage of events that require the particular piece of equipment.

Table 6.7: *Average percentage of events equipment is used*

	hour(s)/ 100 ft.	**% of events**
V-Plow		
Bulldozer		
Snow Blower		
Traffic Control		

Snow drifts can vary in depth, width, and length. The user must input the time required to remove the drift per 100 feet of drift length. The length of the drift is indicated from the segment length.

6.2.1.3 Cost of Snow Removal Equipment

Use of snow removal equipment requires wage, fuel, and equipment costs. The average total cost per hour to operate each type of equipment was estimated from communication with MnDot supervisors. The default values are indicated below.

Table 6.8: *Hourly cost of snow removal equipment*

Snowblower	$200.00	*per hour*
Bulldozer	$175.00	*per hour*
V-Plow	$175.00	*per hour*
Traffic Control		*per hour*

These values can be up dated on the agency parameters worksheet. This worksheet is locked and requires the administrator password to make changes.

6.2.1.4 Snow Removal Equipment Mobilization

In addition to the costs to remove the snow drift the snow removal equipment needs to reach the snow problem area. The distance can vary based on how far the equipment travels from where it is stored and/or in the case of multiple drift removals per trip, how much extra distance does the snow problem area add to the trip. The user must input this information on the input worksheet.

Table 6.9: *Distance to snow drift problem area*

Snow Drift Mobilization	10	miles

The cost to mobilize the snow removal equipment includes all costs and is a per mile cost.

Snow Drift Mobilization Costs	*per mile*

These values can be up dated on the agency parameters worksheet. This worksheet is locked and requires the administrator password to make changes.

6.2.2 Sand/Salt Applications

In addition to drifting snow, blowing snow can also cause icy road conditions (Blow Ice). These poor conditions require sand and/or salt applications to return the road to bare pavement conditions.

6.2.2.1 Blow Ice Events

The number of blow ice events requiring extraordinary effort can vary across snow problem areas. The user must input the average number of these events for the specific snow problem area.

Table 6.10: *Number of blow ice events per year*

Blow Ice Events	10	per year

6.2.2.2 Sand and Salt Application

Sand and salt application can vary by road type, location, and agency protocol. The user must input the application rate for the sand/salt mixture. The user must also input the percentage of sand in the mixture. The percentage of salt is automatically calculated to make up the remainder of the mixture.

Table 6.11: *Application rate input for the sand/salt mixture*

Application Rate	300	lbs./lane mile
Sand	0%	
Salt	100%	

6.2.2.3 Sand and Salt Application Costs

Sand and salt application requires truck and driver time along with the cost of the material. The costs per ton of sand and salt are estimated from MnDOT records. The default values are indicated below.

Table 6.12: *Sand and salt application costs*

Salt	$67.00	*per ton*
Treated Salt	$85.00	*per ton*
Sand	$5.50	*per ton*

These values can be up dated on the agency parameters worksheet. This worksheet is locked and requires the administrator password to make changes.

6.2.2.4 Sand/Salt Truck Mobilization

In addition to the costs to treat the blow ice the sand/salt truck needs to reach the snow problem area. The distance can vary based on how far the truck travels from where it is stored and/or in the case of multiple blow ice treatments per trip, how much extra distance does the snow problem area add to the trip. The user must input this information on the input worksheet.

Table 6.13: *Distance to blow ice problem area*

Blow Ice Mobilization	10	miles

The cost to mobilize the sand/salt truck includes all costs and is a per mile cost.

Sand/Salt Mobilization Costs	*per mile*

These values can be up dated on the agency parameters worksheet. This worksheet is locked and requires the administrator password to make changes.

6.3 Transportation Benefits

Living snow fences provide transportation benefits by improving road conditions resulting in reduced snow and ice related accidents and increased travel time. The total of these benefits and the transportation agency benefits are on the $ Output worksheet under the social benefits section.

6.3.1 Crashes

Blowing snow can cause drifting snow, reduced visibility and icy road conditions. LSF can reduce these problems resulting in an 8% reduction of snow and ice related accidents. The reduction on roadways with super elevated curves is substantially higher (40%). This data was collected and summarized by the Safety Section of MnDOT's Office of Traffic, Safety and Technology, 2011 and results of the crash data is found in Appendix R and Appendix S.

Table 6.14: *Accident reductions*

Super Elevated Curve	**Fatal**	**A**	**B**	**C**	**N**
N	*8%*	*8%*	*8%*	*8%*	*8%*
Y	*40%*	*40%*	*40%*	*40%*	*40%*

The number of avoided accidents is calculated from the initial number of snow and ice related crashes in the snow problem area. If the transportation agency has a snow problem prioritization database that includes crashes this information is automatically retrieved based on the segment ID. This can be manually inputted or overridden on the “input” worksheet.

Table 6.15: *Input for crash data*

Fatal Crash (K)	0
Incapacitating Injury (A)	0
Non-Incapacitating (B)	0
Possible Injury (C)	0
Property Damage Crash (N)	0

The economic costs of these accidents are based on U.S. Department of Transportation values.

Table 6.16: *Economic costs for crash categories*

Fatal Crash (K)	$7,100,000
Incapacitating Injury (A)	$415,000
Non-Incapacitating (B)	$137,000
Possible Injury (C)	$91,000
Property Damage Crash (N)	$12,000

These costs can be found on the HIDDEN “parameters” WORKSHEET. This worksheet is locked and requires the administrator password to make changes.

6.3.2 Travel Time

Poor winter driving conditions can reduce speed therefore increasing travel time. This results in economic costs to drivers. This is calculated based on the number of blow ice events, the time it takes the transportation agency to return the road to bare pavement and the speed reduction. This information must be entered in the input worksheet.

Table 6.17: *Conditions affecting travel time*

Blow Ice Events	10	per year
Poor Driving Conditions	16	hours/event
Speed Reduction	5	mph

To calculate the increased travel time the roadway speed is also required. This is automatically retrieved based on roadway type and can be manually overridden.

Table 6.18: *Roadway speed*

Speed	55	mph

If the transportation agency has a snow problem database that includes roadway type this information is automatically retrieved based on the segment ID.

Table 6.19: *Roadway type*

Roadway Type	USTH

The economic costs of increased travel time are based on the value MnDOT uses for cost/benefit analyses. The values are per occupant. They can be updated on the parameter worksheet.

Table 6.20: *Economic cost of travel time*

	Cost	Unit	Occupants
Car Time	$13.80	*per hour*	1.4
Truck Time	$17.46	*per hour*	1.0

The number and type of vehicles that benefit from the increased travel time is based on the average annual daily traffic and the heavy commercial daily traffic. In addition the growth rate of both the AADT and HCADT are used to calculate the changes and resulting benefits over time.

Table 6.21: *Number and type of vehicle use*

Annual Average Daily Traffic (AADT)	2223	per day
AADT Growth rate	1.02%	per year
Heavy Commercial Average Daily (HCADT)	456	per day
HCAADT Growth Rate	3.54%	per year

If the transportation agency has a traffic database, these values are retrieved automatically. They can be manually overridden in the input worksheet.

6.4 Costs

6.4.1 LSF

6.4.1.1 Installation/Planting

Establishment of living snow fences requires an initial investment in site preparation, plantings, and geo-textile fabric and is typically completed by the transportation agency or contractor (not

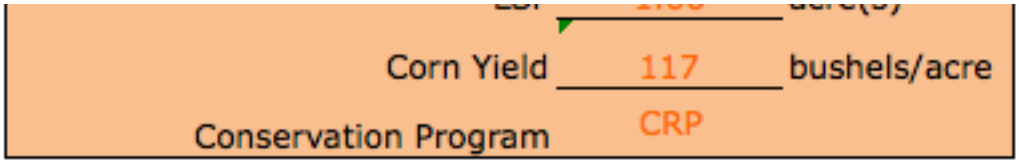
the landowner). The details of these costs can be found on the HIDDEN "establishment" WORKSHEET. This worksheet is locked and requires the administrator password to make changes. Below are the default values.

Table 6.22: *Establishment costs of LSF (trees/shrubs) (Paudel 2010)*

	$/acre
Geo-textile fabric	$1,725
Seedling planting	$464
Site Prep	$71
Total	**$2,260**

Conservation programs such as the conservation reserve program (CRP, agricultural land) and the environmental quality incentives program (EQIP, all land) will cost share establishment of living snow fences. If the transportation agency has a snow problem prioritization database that codes for agricultural land and vegetation type than this data is automatically retrieved (see 0 for details of the database). Conservation program cost share can be manually inputted or overridden on the "input" worksheet.

Table 6.23: *Conservation program input*



None: Not eligible for CRP or EQIP

CRP: Agricultural land that meets the requirements of conservation reserve program

EQIP: Non-agricultural land the meets the requirements of the environmental quality incentive program

The calculator uses the following values to calculate the establishment cost share. EQIP program includes a per foot payment and a per acre payment that varies with current vegetation type.

Table 6.24: *Conservation program cost share*

	Current Vegetation	Cost Share
CRP	Agricultural land	90%
EQIP		$1.32/foot (2 rows @ $0.66/foot)
	Grass or Tilled	$20/acre
	Scrub	$136/acre
	Combination	$607/acre
	Tree	$1078/acre

In addition to these values the CRP program also pays an annual soil rental rate (see 0).

6.4.1.2 Landowner Opportunity Cost

6.4.1.2.1 Land Rent

Living snow fences prevent use of the land for other productive purposes. The landowner must be compensated for the value of this loss, which varies widely over the counties. This value is based on land value estimates and annualized using landowner's discount rate. If the transportation agency is located in Minnesota the annual land rent is automatically retrieved based on the "county" input (see 0 for details of database). This value can also be inputted manually or overridden in the "input" worksheet.

Table 6.25: *Land rental rates*

Rental Rate	$195	per acre
Soil Rental Rate	$150	per acre

As mentioned above (see 0) eligible agricultural land that is enrolled in the conservation reserve program receives an annual soil rental rate. If the transportation agency is located in Minnesota the annual soil rental rate is automatically retrieved based on the "county" input (see 0 for details of database). This value can also be inputted manually or overridden in the "input" worksheet.

Landowner opportunity costs may also include the option of working with MnDOT officials to purchase a small area of land in which MnDOT would create a perennial LSF structure or planting that would protect the roadway from winter weather conditions.

In the calculator there is no difference between purchasing the land and renting it. The rental rate is based off of the land value. In theory this makes sense but because of imperfect capital markets, transaction costs, etc., it might not be the case.

6.4.1.3 Maintenance

Living snow fences must be continually maintained to encourage growth of planted species and discourage weeds. In the first three years maintenance costs are higher than years four and beyond. The details of these costs can be found on the HIDDEN "maintenance & production" WORKSHEET. This worksheet is locked and requires the administrator password to make changes. Below are the default real values.

Table 6.26: *Maintenance costs for LSF per acre (trees/shrubs) (Paudel 2010)*

Year	Mowing	Handpicking	Watering	Replanting	Spot Spraying	**Maintenance Subtotal**
1	$50	$10	$300		$24	**$384**
2	$37	$10	$300	$35	$24	**$406**
3	$37	$10		$35	$24	**$106**
4+	$10	$10			$24	**$44**

6.4.1.3.1 Inconvenience

A properly designed living snow fence is set back from the roadway's right of way. Farmers are able to farm in-between the LSF and the roadway. However, having a LSF in the field creates difficulties in mobilizing farm equipment. This includes planting, tilling, combining and pesticide application. The default total additional time required per acre of LSF is 45 minutes at a cost of $40 per hour (Paudel 2010). Changes to these values can be made in the "maintenance & production" worksheet. This worksheet is locked and requires the administrator password to make changes.

6.4.1.3.2 Yield Reductions

The living snow fence results in reduced crop productivity on land surrounding it due to agronomic difficulties such as plowing, fertilizing and moisture content. This area is roughly equal to the area of the snow fence. The default loss of productivity is 15% and changes can be made in the "maintenance & production" worksheet, which is locked and requires the administrator password. The initial yield can vary in different areas. If the transportation agency is located in Minnesota the corn yield data is automatically retrieved based on the "county" input (see 0 for details of the database). The initial yield can also be inputted manually or overridden in the "input" worksheet.

Table 6.27: *Corn yield*

	Corn Yield	173	bushels/acre

The value of this crop per bushel is the "corn price" from the "parameters" WORKSHEET. This worksheet is locked and requires the administrator password to make changes. The default value is $4.50 per bushel.

6.4.2 Corn Rows

Leaving standing corn rows over the winter reduces yields and creates an inconvenience for the farmer. Inconveniences include having to harvest around the corn rows and harvesting the corn in the spring.

Standing corn rows are planted with the rest of the corn crop but are not harvested until the spring resulting in a 30% reduction in yield. The spring harvest can also delay planting resulting in a 15% reduction in yield. This results in a 45% reduction in corn yield (Paudel 2010). This value can be changed in the "Corn Row Costs" worksheet, which is locked and requires the administrator password.

Yield Loss	45%

If the transportation agency is located in Minnesota the corn yield data is automatically retrieved based on the "county" input (see 0 for details of the database). The initial yield can also be inputted manually or overridden in the "input" worksheet.

Table 6.28: *Manual input for corn yield*

	Corn Yield	173	bushels/acre

The value of this crop per bushel is the "corn price" from the "parameters" WORKSHEET.

	Corn Price	$4.50	*per bushel*

This worksheet is locked and requires the administrator password to make changes. The default value is $4.50 per bushel.

Standing corn rows also creates an inconvenience for farmers. Farmers have to harvest around the corn rows in the fall. This results in approximately 45 mins of extra time and equipment use per acre at a rate of $40/hour (Paudel 2010). Harvesting in the spring also requires extra time including combining the corn in the spring, getting the equipment ready for use and cleaning the equipment. The total cost is $70 per acre. These values can be changed in the "Corn Row Costs" worksheet, which is locked and requires the administrator password.

Table 6.29: *Cost of standing corn rows*

Year	Income Loss	Inconvenience Cost	Total Cost
1	$350.33	$70.00	**$420.33**

6.5 Output

The output worksheet gives costs and benefits of living snow fences and standing corn rows for the snow problem area and on a per acre basis. This information can be used to identify the net benefits to the transportation agency and to society. It can also be used to aid in estimating the payment range and payment schedule.

6.5.1 Establishment

The first box in the output screen outlines the establishment costs, the conservation cost share on a total and per acre basis. In addition the installation of a structural snow fence is also calculated as a comparison.

6.5.2 Total Annual Costs and Benefits

The second box is the total costs and benefits of LSF and standing corn rows. The third box is this same information but on a per acre basis. All of the years are adjusted for inflation to aid in payment calculation.

The annual costs for living snow fences, standing corn rows, and structural snow fences is indicated. This also includes the annual costs share for CRP. These values are adjusted for inflation.

The transportation agency benefits includes cost saving directly to the transportation agency. The net benefits are the benefits minus the costs plus the CRP payment.

The social benefits include the transportation agency benefits plus the accident reduction, increased travel time, and carbon benefits. The net benefits are the benefits minus the costs.

6.5.3 Total Annual Physical Changes

This worksheet outlines the quantity changes that are used to calculate the costs and benefits. This information is useful in understanding where the savings come from and the physical changes (i.e. reduced salt usage). This includes avoided accidents, equipment hours, sand/salt, travel hours and carbon.

6.6 Carbon

There are two main ways in which living snow fences and standing corn rows can reduce greenhouse gasses: Carbon sequestration and avoided carbon emissions.

6.6.1 Carbon Sequestration

Living snow fences generally replace agricultural land. This results in a net carbon sequestration in biomass and soil carbon. The default value is below.

Carbon Sequestration	4.0	*tons per acre*

This value can be changed in the parameters worksheet and requires the administrator password.

6.6.2 Avoided Carbon

Living snow fences and standing corn rows reduce carbon emissions by reducing the use of fuel. Fuel is used in the mobilization of equipment and trucks and the snow drift removal.

Table 6.30: *Avoided carbon*

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	.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

This information in addition to the usage information is used to calculate the fuel usage. The CO2 emissions can then be calculated from this using an average CO2 per gallon ratio from the EPA

Table 6.31: *CO2 emissions calculation data*

CO2 emissions	22.20	*lbs./gal*	EPA	http://www.epa.gov/oms/climate/420f05001.htm
CO2 to C ratio	3.67	*lbs./gal*	EPA	http://www.epa.gov/oms/climate/420f05001.htm

6.7 Data

6.7.1 Snow Prioritization

The snow prioritization database is used to retrieve data that has been collected on the snow problem areas. Each bullet point below is a variable in the database

- Segment ID
- County
- Segment Length (feet)
- Roadway Type (USTH, ISTH, MNTH)
- Snow Equipment Usage
    - V-Plow (Y/N)
    - Bulldozer (Y/N)
    - Snow Blower (Y/N)
- Blow Ice (Y/N)
- Super-Elevated Curve
- Vegetation Type

1	2	3	4	5
Absent	Grass	Scrub	Trees	Combination

- Agricultural Land (1,0)
- Snow and Ice related Accidents (11 years)
    - Fatal
    - Incapacitating
    - Non-Incapacitating
    - Possible Injury
    - Property Damage

6.7.2 AADT

The average annual daily traffic (AADT) database is used to retrieve traffic data including heavy commercial trucks (HCAADT) and growth estimates based on segment ID.

- Segment ID
- AADT
- AADT growth (%)
- HCADDT
- HCADDT growth (%)

6.7.3 Rental Rate

The rental rate database is used to retrieve the annual rental rate based on the county input. This value is calculated using land values that are annualized by multiplying by the discount rate.

- County
- Rental Rate ($ per acre per year)

6.7.4 Soil Rental Rate

The soil rental rate database is used to retrieve the soil rental rate for CRP annual payments based on the county input. This data was aggregated from farm service agency soil specific data.

- County
- Soil Rental Rate ($ per acre per year)

6.7.5 Corn Yields

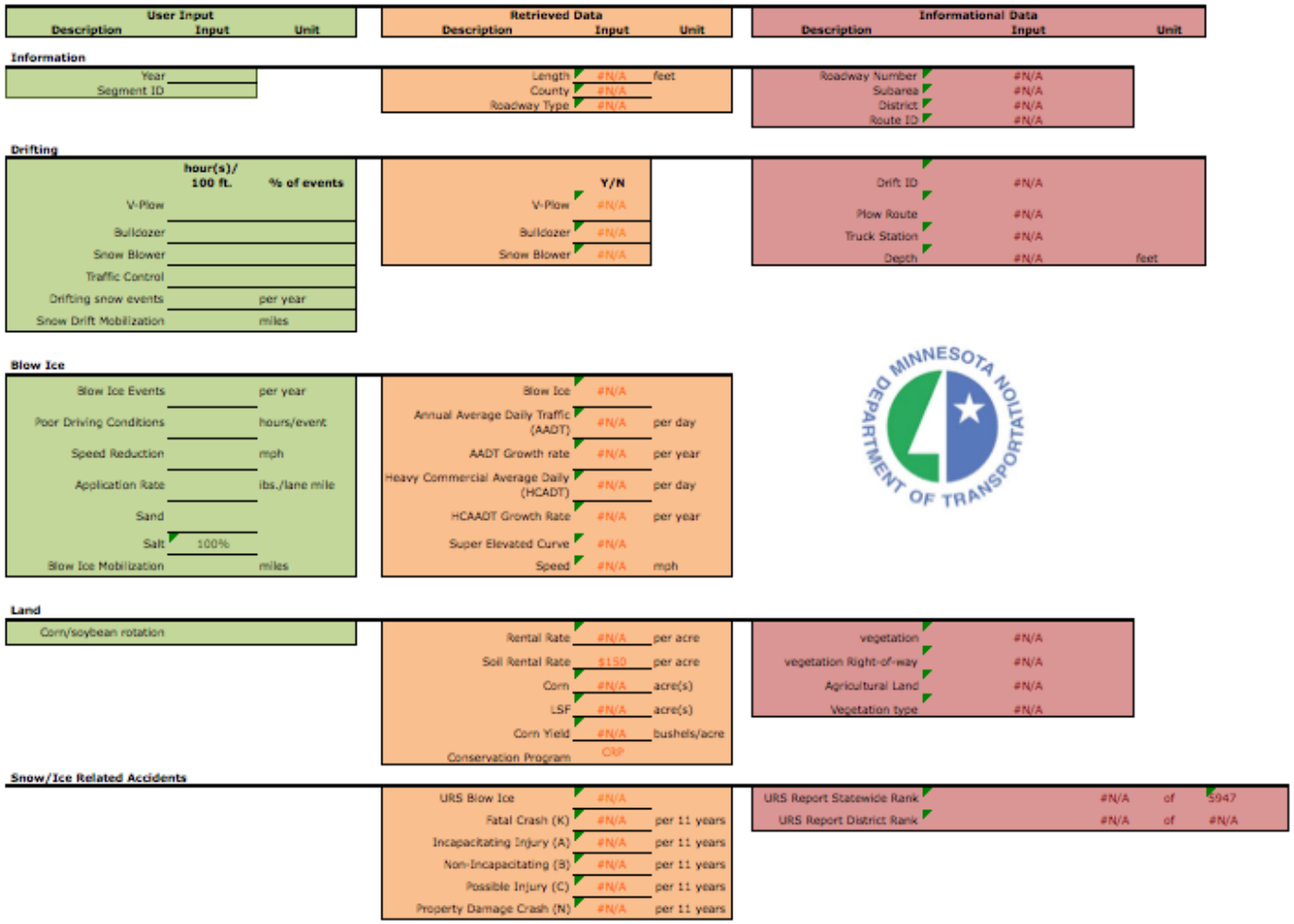
The corn yields database is used to retrieve the corn yield based on the county input. This data is average county yields for corn from USDA data.

- County

Corn Yield (Bushels per acre)

6.8 Worksheets

Table 6.32: *Input worksheet*



User Input			Retrieved Data			Informational Data		
Description	Input	Unit	Description	Input	Unit	Description	Input	Unit
Information								
Year			Length	#N/A	feet	Roadway Number	#N/A	
Segment ID			County	#N/A		Subarea	#N/A	
			Roadway Type	#N/A		District	#N/A	
						Route ID	#N/A	
Drifting								
	hour(s)/ 100 ft.	% of events		Y/N		Drift ID	#N/A	
V-Plow			V-Plow	#N/A				
Bulldozer			Bulldozer	#N/A		Plow Route	#N/A	
Snow Blower			Snow Blower	#N/A		Truck Station	#N/A	
Traffic Control						Depth	#N/A	feet
Drifting snow events		per year						
Snow Drift Mobilization		miles						
Blow Ice								
Blow Ice Events		per year	Blow Ice	#N/A				
Poor Driving Conditions		hours/event	Annual Average Daily Traffic (AADT)	#N/A	per day			
Speed Reduction		mph	AADT Growth rate	#N/A	per year			
Application Rate		lbs./lane mile	Heavy Commercial Average Daily (HCADT)	#N/A	per day			
Sand			HCAADT Growth Rate	#N/A	per year			
Salt	100%		Super Elevated Curve	#N/A				
Blow Ice Mobilization		miles	Speed	#N/A	mph			
Land								
Corn/soybean rotation			Rental Rate	#N/A	per acre	vegetation	#N/A	
			Soil Rental Rate	$150	per acre	vegetation Right-of-way	#N/A	
			Corn	#N/A	acre(s)	Agricultural Land	#N/A	
			LSP	#N/A	acre(s)	Vegetation type	#N/A	
			Corn Yield	#N/A	bushels/acre			
			Conservation Program	CRP				
Snow/Ice Related Accidents								
			URS Blow Ice	#N/A		URS Report Statewide Rank	#N/A	of 5947
			Fatal Crash (K)	#N/A	per 11 years	URS Report District Rank	#N/A	of #N/A
			Incapacitating Injury (A)	#N/A	per 11 years			
			Non-Incapacitating (B)	#N/A	per 11 years			
			Possible Injury (C)	#N/A	per 11 years			
			Property Damage Crash (N)	#N/A	per 11 years			

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Table 6.33: *$ Output worksheet*

Establishment	Fence	per acre
MNDOT	#N/A	#N/A
CRP	#N/A	#N/A
EQIP	#N/A	#N/A
TOTAL	#N/A	$2,260
Structural	#N/A	

		Opportunity Cost					Transportation Agency Benefits				Total Social Benefits			
			LSF						Net				Net	
Year	Program Year	Corn	Total	Agency	CRP	Structural	Corn	LSF	Corn	Net LSF	Corn	LSF	Corn	LSF
0	1	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
1	2	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
2	3	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
3	4	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
4	5	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
5	6	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
6	7	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
7	8	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
8	9	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
9	10	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
10	11	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
11	12	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
12	13	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
13	14	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
14	15	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
Includes Est	Total	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
	Average	#N/A	#N/A	#N/A	#N/A		#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A

		Minimum Payment (Acre)					Transportation Agency Benefits (Acre)				Total Social Benefits (Acre)			
			LSF						Net				Net	
Year	Program Year	Corn	Total	Agency	CRP	Structural	Corn	LSF	Corn	LSF	Corn	LSF	Corn	LSF
0	1	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
1	2	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A		#N/A		#N/A		#N/A
2	3	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
3	4	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A		#N/A		#N/A		#N/A
4	5	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
5	6	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A		#N/A		#N/A		#N/A
6	7	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
7	8	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A		#N/A		#N/A		#N/A
8	9	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
9	10	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A		#N/A		#N/A		#N/A
10	11	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
11	12	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A		#N/A		#N/A		#N/A
12	13	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
13	14	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A		#N/A		#N/A		#N/A
14	15	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
	Total	#N/A	#N/A	#N/A	#N/A		#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
	average	#N/A	#N/A	#N/A	#N/A		#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A

Table 6.34: *# Output worksheet*

Year	Program Year	Fatal Crash (K)	Incapacitating Injury (A)	Non-Incapacotating (B)	Possible Injury (C)	Property Damage Crash (N)	Total	Car Drivers Hours	Heavy Commerical Hours	Avoided Fuel	Avoided Sand	Avoided Salt	V-Plow Hours	BullDozer Hours	SnowBlower Hours	Carbon Avoided (ton CO2)	Carbon Sequestered	Total Carbon
0	1	#N/A	#N/A	#N/A	#N/A	#N/A	**#N/A**	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	**#N/A**
1	2	#N/A	#N/A	#N/A	#N/A	#N/A	**#N/A**	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	**#N/A**
2	3	#N/A	#N/A	#N/A	#N/A	#N/A	**#N/A**	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	**#N/A**
3	4	#N/A	#N/A	#N/A	#N/A	#N/A	**#N/A**	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	**#N/A**
4	5	#N/A	#N/A	#N/A	#N/A	#N/A	**#N/A**	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	**#N/A**
5	6	#N/A	#N/A	#N/A	#N/A	#N/A	**#N/A**	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	**#N/A**
6	7	#N/A	#N/A	#N/A	#N/A	#N/A	**#N/A**	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	**#N/A**
7	8	#N/A	#N/A	#N/A	#N/A	#N/A	**#N/A**	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	**#N/A**
8	9	#N/A	#N/A	#N/A	#N/A	#N/A	**#N/A**	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	**#N/A**
9	10	#N/A	#N/A	#N/A	#N/A	#N/A	**#N/A**	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	**#N/A**
10	11	#N/A	#N/A	#N/A	#N/A	#N/A	**#N/A**	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	**#N/A**
11	12	#N/A	#N/A	#N/A	#N/A	#N/A	**#N/A**	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	**#N/A**
12	13	#N/A	#N/A	#N/A	#N/A	#N/A	**#N/A**	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	**#N/A**
13	14	#N/A	#N/A	#N/A	#N/A	#N/A	**#N/A**	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	**#N/A**
14	15	#N/A	#N/A	#N/A	#N/A	#N/A	**#N/A**	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	**#N/A**
	Total	**#N/A**	**#N/A**	**#N/A**	**#N/A**	**#N/A**	**#N/A**	**#N/A**	**#N/A**	**#N/A**	**#N/A**	**#N/A**	**#N/A**	**#N/A**	**#N/A**	**#N/A**	**#N/A**	**#N/A**

Chapter 7
Living Snow Fence Recommendations

The research on the costs and benefits of living snow fences has generated a number of recommendations to make the program more robust and lead to greater adoption of the practice by landowners. The recommendations are a result of the input from focus groups, individual landowners, agency representatives that assist with the implementation of LSF programs and the input of MnDOT field and central office staff. This section includes a presentation and discussion of recommendations related to: 1) the constraints to and opportunities for adoption of LSF by landowners; 2) how to work with agencies and approach farmers; 3) technical aspects of the program including species selection; 4) how the calculator might be used to select options for improving the program; and 5) follow up research and dissemination of the results of the study.

7.1 Adoption Issues – Constraints and Opportunities

7.1.1 Contract Length/Rental Payment and Changes Over Time

Issue: When landowners sign up for a LSF contract they usually sign up for a fixed rental rate for the length of the contract (up to 15 years). Rental rates that were a fair reflection of the market at the time of signing a contract have not increased as rental rates and land prices have increased over time. Landowners are left with a payment that is lower than the going market rate that does not adequately compensate them for implementing a LSF. The issue is primarily the fixed rental payment combined with a long contract length.

Recommendations:

- Contract could be written with a built in periodic (1-5 years) adjustment of the rental payment to prevailing conditions. New payment could be based on published land or rental prices.
- Contract length could be shortened which could have a similar impact as the contract would be renegotiated on renewal but that creates the risk that the landowner might not renew.

7.1.2 Maintenance Costs/Uncertainty/Tree Removal at End of Contract

Issue: In current contracts landowners are responsible for maintaining the LSF and making sure vegetation survives. In focus groups and particularly with landowners who had not implemented LSF, landowners were concerned about having to pay to reestablish the LSF if plantings failed. In addition, there was some concern that all maintenance activities were not covered in the current program and particular costs incurred beyond the first year. Many landowners mentioned the cost of removing trees as the end of the contract which is not covered under the current arrangements.

Recommendations:

One approach that was discussed among the team and with landowners would be to hire a contractor to provide maintenance to the LSF plantings. This would likely be more expensive but would also address the risk/uncertainty expressed by the landowners.

- MnDOT could consider adding a provision to the contract that would cover the cost of tree removal at the end of the contract.

- MnDOT should ensure that all potential maintenance activities required over the life of a contract are covered. This could be handled on a "per event" basis since maintenance needs will vary from one LSF to another and, in some cases, will not be required. You might want to have the implementing agency approve the maintenance before going ahead.

7.1.3 Covering Fetch Area with CRP or Other Payment

Issue: When LSF are implemented, there is often a strip of field between the LSF and the road ditch approximately 100 ft. wide that is difficult for a farmer to prepare and cultivate for crops. One of the landowners interviewed suggested that if that strip received a rental payment as well, some landowners would be more willing to adopt LSF. Those strips are not always eligible for CRP payments.

Recommendations:

- Create a mechanism through existing or future funding that would pay rent on the strip of land between the LSF and the road ditch/right of way. This may provide an opportunity for a landowner to "square off" their fields adding an additional incentive to adopt LSF.
- The strips could potentially be used for bioenergy or wildlife plantings. A bioenergy planting could contribute income to the landowner. Conservation groups may also help fund large areas for wildlife.

7.1.4 Incentive/Payments for Landowners

Issue: There was some discussion of how incentives might be provided to landowners. Some stretches of roadways would have priority and a greater value for MnDOT because of their location and the potential impact of a living snow fence. Two types of payments were discussed: 1) a standard per acre payment that would apply to all LSF; or 2) a per acre payment based on the value of the LSF from the calculator. Landowners seemed to be agreeable to either type of payment. Most landowners agreed that the payment for an LSF should provide a fair compensation for lost income opportunities/opportunity costs but that the payment should do more than just compensate the lost income.

Recommendations:

- A 10-20% increase over the opportunity cost payment may be required to motivate farmers to implement LSF. The only way to determine what is required will be test different payments with landowners.
- MnDOT will have to determine what kind of a per acre payment to utilize. Responses from landowners were mixed.
- MnDOT and partners may want to explore different types of payments and amounts to arrive at a satisfactory mechanism.

7.1.5 Benefits to Communities

Issue: Owners of LSF and community members often mentioned the benefits of the LSF to the community in keeping roadways clear of drifting snow in the winter. Focus group

participants commented on the effectiveness of LSF and owners mentioned their neighbors would often comment on how the fences worked to keep the roadways clear of snow.

Recommendation:

- MnDOT and other agencies promoting LSF should be sure to include mention of community benefits from LSF as this may motivate some landowners to participate.

7.1.6 Wildlife Benefits (may be opportunity or constraint)

Issue: LSF can provide wildlife benefits as another benefit. Landowners commented on the increased abundance of wildlife around their LSF's. Others were concerned that the LSF would attract deer to the roadside which might lead to deer related accidents.

Recommendation:

- Increased wildlife may be an incentive for some people to implement LSF and wildlife benefits could be used to help convince landowners to adopt. More information is probably necessary to understand to what extent LSF may attract deer to roadsides and lead to accidents.

7.1.7 Additional Benefits

Issue: There are additional benefits from LSF's that may help motivate landowners to install them. Aesthetics, carbon sequestration, screening, reduced wind erosion, and increased moisture that can be a benefit.

Recommendation:

- Potential benefits of LSF should be included in promotional materials. Although it is likely that the deciding factor may be an incentive payment, associated benefits may help motivate landowners to adopt LSF.

7.2 Approaching Farmers and Working with Agencies

7.2.1 Presentation to Individual, Targeted Landowners

Issue: In focus group discussions and individual interviews the effectiveness of current efforts to advertise the LSF program were discussed. Many focus group participants were not aware of the program and others said they had heard about it on the radio. In one case, plow drivers contacted their neighbors in areas with blowing and drifting snow problems. Overall there seems to be a need for targeting of individual landowners in problem areas.

Recommendations:

- A more coordinated effort is needed to target landowners and groups of landowners in areas that have already been identified by MnDOT as having blowing and drifting snow problems.
- In areas where blowing and drifting snow problems include several properties along the same roadway, it might be necessary to work with groups of farmers. Spotty coverage can often lead to dangerous conditions as vehicles move between protected and unprotected areas.

7.2.2 Who Should Promote Program to Landowners?

Issue: There may be opportunities to use landowners who have already adopted LSF and plow drivers to help promote living snowfences. Some LSF owners expressed interest in working with their neighbors to help convince them to install LSF. Plow drivers and maintenance personnel have been effective in working with landowners in the past and oftentimes talking to a neighbor with experience with a LSF can help convince landowners to adopt.

Recommendations:

- MnDOT should consider working with LSF owners, MnDOT plow drivers and maintenance personnel familiar with the landowners and the blowing and drifting snow problems to work directly with landowners to promote LSF. Not all individuals may be able to successfully take on that role so a careful selection should be undertaken to identify individuals for that task.
- If utilizing landowners with LSF, MnDOT should consider some kind of an incentive payment and other support to those individuals. A similar trial program for conservation plantings was successful in Nebraska. A training program would probably be required for such a program.

7.2.3 Clear Complete Presentation of Program to Landowner

Issue: We heard comments from landowners regarding the presentation of the LSF program. One of the landowners indicated that he wasn't sure what he would be paid until he signed the LSF contract. Other landowners suggested that people needed a clear description and explanation of the financial aspects of the LSF program. They suggested approaching landowners with a clear explanation of the program and what they might receive if they enrolled in the program.

Recommendation:

- A worksheet should be prepared explaining the area required, and expected payments for adopting a LSF and the obligations of the landowner before visiting a landowner. This could be prepared during the first visit with the landowner.

7.2.4 Working with Agencies and Service Providers – Approaching Farmers

Issue: Agencies must be prepared to work with landowners to promote and then implement living snow fences. This requires an inter-agency coordination effort and training of selected agency representatives.

Recommendations:

- All agency staff must understand the value, importance and benefits of the LSF program.
- Each MnDOT district should have a LSF coordinator that meets on a regular basis with SWCD, FSA and NRCS staff and helps promote the program.
- Each SWCD, FSA and NRCS office should also have a dedicated staff member to be the "LSF contact" or go to person.

- All LSF contacts should be trained and others in these offices should know the program and who in their office to contact.

7.3 Technical Aspects

7.3.1 Making Use of AVL Data

Issue: The use of AVL data has just been initiated by MnDOT in Minnesota to register the movements of plow trucks, their speed, application of sand and salt and other chemicals. This information has the potential to provide fairly accurate data on the impact of LSF and the cost savings associated with them. As the application is new and there are limited trucks AVL equipped, the technology is going through a testing and calibrating stage so there is limited data and incomplete data due to equipment malfunction that is part of any new installation. The project has developed a program that will be able to take the AVL data and evaluate the impact of LSF on roadway maintenance costs and operations related to snow and ice events.

Recommendation:

- As MnDOT is able to test and install additional AVL units in their trucks, it would be worth developing a research plan that would allow MnDOT to use the data generated to estimate impacts of living snow fences. The plan could include strategically locating AVL units and the subsequent analysis of that data.

7.3.2 Species and Planting Arrangements

Issue: The effectiveness of LSF depends on having a fence tall enough to be able to capture the snow and deposit it in the fetch area so it does not reach the roadway. Some of the current species being used are very effective but relatively slow growing requiring a number of years to reach an effective height. There may be alternate species that would reach an effective height in a year or two that could be considered. Some of those species may also provide biomass for energy alone or combined with grasses planted in the fetch area. There may be other species that could provide food for wildlife or potentially nuts and/or berries for consumption.

Recommendations:

- There are many shrubs that can be used for LSF. Landowners should identify what goals they might have in creating the planting. Vegetative plants can be planted to produce food for people or wildlife and even bio-energy.
- Planting arrangements can vary with the goals. A single shrub row or twin row could be planted. Three or more rows can be planted but the most common is 1 or 2 rows.
- Edible shrub plantings may include: Hazelnut, Serviceberry, Elderberry, Black Chokeberry, American Plum
- MnDOT should consider using fast growing willows as a way to establish an effective LSF in a years' time. Research has been carried out in New York that could provide guidelines for MN.

7.4 Using the Calculator

7.4.1 Errors, Updates and New Data

Issue: Even though the LSF Calculator has been developed and beta tested, error corrections and updates will be needed overtime to correct these problems and/or improve functionality and usability. The calculator also uses a number of databases and parameters that while current as of the publication of this report will become outdated over time.

Recommendations:

- Designate an internal LSF calculator administrator. This person would be in charge of distribution, annual database and parameter updates, training, and support. The individual would be the only user with access to the password protected cells and worksheets. Using a centralized approach such as this will provided consistency across the calculator users and prevent the users from making unnecessary edits.
- Update the databases and parameters on an annual basis as applicable so that the information the calculator uses remains current.

7.4.2 Training

Issue: As the calculator has evolved the user interface and outputs have become increasingly complicated. This additional input and output information is useful but requires a trained user to understand the required inputs, results, and general underlying functionality. As with all new tools there is a learning curve and users on the flat part of the curve will have trouble getting results, are more likely to get incorrect results, and are less likely to use the tool.

Recommendations:

- Train potential calculator users to get beyond the flat part of the learning curve. This training should include examples from the trainer but the majority of the time should be spent allowing the user to interact with the calculator.

7.4.3 Use of Results

Issue: Results that show a potential net positive benefits to Mn/DOT from snow & ice maintenance costs savings due to LSF does not guarantee for a specific location that Mn/DOT will save money. The LSF calculator was developed to allow a set of user inputs to calculate the benefits and costs of LSFs. Therefore, it cannot take into account specifics of every location and scenario.

Recommendations:

- Use the calculator as a guide to prioritize locations for possible LSFs. Before deciding to install the LSF a more detailed analyses should be conducted independently from the calculator.
- If cost data on the snow problem area is not available, data collection including but not limited to equipment usage should begin the following snow and ice season and continue after installation of the LSFs.

- If there is uncertainty about the cause of the snow problem area a temporary snow fence can be installed to test the effectiveness and reduction is snow and ice maintenance costs from a snow fence.

7.5 Follow-up Research and Data Gathering and Use Recommendations (What can be done from here on out to strengthen and disseminate this work and make it more useful?)

7.5.1 AVL Data Use

- MnDOT needs to get more AVL equipment working in their fleet of trucks and functioning correctly before further research analysis can be done looking at paired routes evaluating the effectiveness of LSF.

7.5.2 Outreach to Counties

- Implementation studies could be done to evaluated training and door to door experiences with local staff working with landowners to encourage adoption of LSF contracts, either LSF with trees and shrubs or standing corn rows.

7.5.3 Outreach to Other States

- Iowa State University may be willing to test the LSF payment calculator.
- Michigan has also expressed interest in the Minnesota work.
- Work with NRCS forester Bruce Wight.

7.5.4 Research

- Tons of salt are applied in Minnesota roadways during winter affecting the environment. EPA recently had raised a concern that continuous application of salt to clear roads during winter could not only affect water quality but also affect the productivity of the soil. Currently, only a few shrub and tree species are used as vegetation for LSF, and those species have not been evaluated of their phytoremediation potentials. Assessment of the potential of commonly used species for LSF must be evaluated.
- Research must also be done to broaden the types and varieties of species suitable for LSF. This would include native shrubs (willows, dogwoods, etc.) to measure rate of growth, biomass potential and water quality/environmental benefits.

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Appendix A
Template Recruitment Letter

Date

Recipient Name
Recipient Address

Dear Recipient Name,

This letter is sent to you on behalf of the University of Minnesota (UMN) and the Minnesota Department of Transportation (MnDOT). UMN and MnDOT are working on a project to better understand what landowners know about living snow fences and how landowners feel about the living snow fence program. The project will explore the benefits and values of living snow fences, and also the costs of the living snow fences and constraints landowners face to participating in the program. The goal is to better understand the environmental and economic costs and benefits associated with living snow fence plantings.

UMN and MnDOT would like to get a small group of landowners together for discussion to share perspectives on living snow fences and to provide input to help improve the program. Your input in the discussion would be very valuable! In fact, you are invited to participate because you are a landowner in a snow problem areas identified by MnDOT's Geographic Information System study. UMN and MnDOT would like to get a group of about 8 landowners together for the discussion. It will be:

Date:

Time:

Place:

Refreshments will be provided as well as $25 gas card as a thank-you for contributing your time and ideas. Your views and experiences will be extremely helpful to assist MnDOT to improve the living snow fence program. We hope that you will be able to join us for this important discussion.

Warm Regards,

Sierra Schroeder
Graduate Research Assistant, UMN
Email: schro646@umn.edu
Telephone: 612-501-5635

Appendix B

Focus Group Questioning Route (Landowners with LSF)

Introduction:

"Good morning and welcome to our session! I really appreciate everyone's attendance and I am looking forward to hearing more about your thoughts and experiences with the living snow fence program. My name is Sierra Schroeder and I am a Graduate Student in the Conservation Biology program at the University of Minnesota. The University of Minnesota is working with the Minnesota Department of Transportation to better understand how land owners feel about the living snow fence program. We'd like to hear about the benefits and values of living snow fences, and we are also interested in hearing about the costs of the living snow fences and constraints to participating in the program.

[*Groups WITH LSF*]: You were invited to participate today because you are all currently participating in the Living Snow Fence program and have valuable firsthand stories to share about your experiences establishing and maintaining the snow fence and your experience with the MnDOT program.

Please don't hesitate to discuss any of your different viewpoints, experiences, or perspectives. There are no right or wrong answers here! We are interested in the costs and constraints associated with the living snow program as well as hearing about the value and benefits of the program. Today you all are the experts and I hope to hear a variety of perspectives and different points of view.

We'll take about an hour and half today to go through all the questions. And I'd like this to be an open conversation, with people bouncing off each other's comments and thoughts. My role today is just to make sure that everybody talks and I get everybody's opinion as much as I can. So if I call on you, I am not trying to pressure you, I just want to make sure I capture everyone's perspective.

Again, thank you for meeting me today and for your willingness to participate in this conversation. We are working with a small number of Minnesota residents and the responses of each individual are very important to us. You may have noticed the digital recorder. This session will be recorded to help out with our note taking and so that we don't miss anything you say. All the information you provide is completely voluntary and will be kept fully confidential; no names will be used on any of our reports.

Please take a moment to silence your cell phones and pagers. If you do need to take a call, please step outside the room. As a reminder the restrooms are located _____, and please feel free to help your selves to snacks & drinks during the conversation.

Well, let's go ahead and get started. To begin let's find out more about each other by going around the table with introductions. I'd like to hear three things from each person – first please tell us your name, second where you are from, and third please tell us one thing you like to do in your free time."

Questions: (time)

Opening: 1) Tell us your name, where you are from, and one thing you like to do in your free time. (5)

Introductory: 2) How did you first learn about the Minnesota Department of Transportation's living snow fence program? (10)

Probe: How did you feel about this person or agency introducing you to the program? Is there another person or agency you would have liked to hear from?

Transition: 3) Think back to when you first heard about the living snow fence program. What were your initial thoughts about the program? (5)

4) Were there incentives or conditions that convinced you to join the living snow fence program?

Probe: Tell me about the incentives and conditions (10)

Key Questions: 5) What's the value of the living snow fence program? (15)

Probe: Are living snow fences valuable to the community? How? To families? How? To landowners? In what ways? MnDOT, plow drivers, county, city, state? **Wildlife**, environment?

Probe: Do any of your neighbors have a living snow fence? What do they say about it? Have any of your neighbors asked you about your living snow fence? What do they think of it?

6) As a landowner, what are the benefits of participating in the living snow fence program? (10)

Probe: How satisfied are you with these benefits? Are there other benefits you would like to see in the program? How do you want to be compensated for LSF? For use of the land? For establishing & maintaining planting?

Probe: Who would you want to plant the LSF? AND: Who would you want to maintain the LSF?

7) We've talked a bit about the values and benefits of living snow fences. Thanks for sharing your stories and perspectives. Let's shift gears now, and I'd like you to think back to when you first established the living snow fence on your land. What were the costs of establishing the fence?

Probe: Were those one time only costs? What are the costs of maintaining the living snow fence? Are there hassles involved? (time, bureaucracy, working with agency staff) (15)

8) What is the cost to farmers for leaving Living Snow fence structures (standing corn rows, trees, shrubs, grasses)?

Probe: Is the payment offered for living snow fences appropriate? (10)

End Questions: 9) We've had some great discussion today, thank you! My notes from our conversation today include these key points _____. How well does that capture what was said here? (5)

10) We want you to help us evaluate the living snow fence program and your input is very valuable in determining appropriate compensation for landowners who participate in the program. Is there anything that we missed in our discussion today? Is there anything you came wanting to say that you didn't get a chance to say? (5)

Total Time (90)

Appendix C

Focus Group Questioning Route (Landowners without LSF)

Introduction:

"Good morning and welcome to our session! I really appreciate everyone's attendance and I am looking forward to hearing more about your thoughts and experiences with the living snow fence program. My name is Sierra Schroeder and I am a Graduate Student in the Conservation Biology program at the University of Minnesota. The University of Minnesota is working with the Minnesota Department of Transportation to better understand how land owners feel about the living snow fence program. We'd like to hear about the benefits and values of living snow fences, and we are also interested in hearing about the costs of the living snow fences and constraints to participating in the program.

[*Groups WITHOUT LSF*]: You were invited to participate today because you are all landowners in snow problem areas identified by MnDOT's Geographic Information System study. Currently no one in this group is participating in the living snow fence program and I'd like to hear from you today about what you know about the program, what's holding you back from participating, and finally I'd like to hear you describe what conditions would have to be like in order for you to participate.

Please don't hesitate to discuss any of your different viewpoints, experiences, or perspectives. There are no right or wrong answers here! We are interested in the costs and constraints associated with the living snow program as well as hearing about the value and benefits of the program. Today you all are the experts and I hope to hear a variety of perspectives and different points of view.

We'll take about an hour and half today to go through all the questions. And I'd like this to be an open conversation, with people bouncing off each other's comments and thoughts. My role today is just to make sure that everybody talks and I get everybody's opinion as much as I can. So if I call on you, I am not trying to pressure you, I just want to make sure I capture everyone's perspective.

Again, thank you for meeting me today and for your willingness to participate in this conversation. We are working with a small number of Minnesota residents and the responses of each individual are very important to us. You may have noticed the digital recorder. This session will be recorded to help out with our note taking and so that we don't miss anything you say. All the information you provide is completely voluntary and will be kept fully confidential; no names will be used on any of our reports.

Please take a moment to silence your cell phones and pagers. If you do need to take a call, please step outside the room. As a reminder the restrooms are located _____, and please feel free to help your selves to snacks & drinks during the conversation.

Well, let's go ahead and get started. To begin let's find out more about each other by going around the table with introductions. I'd like to hear three things from each person – first please tell us your name, second where you are from, and third please tell us one thing you like to do in your free time."

Questions: (time)

Opening: 1) Tell us your name, where you are from, and one thing you like to do in your free time. (5)

Introductory: 2) What do you know about MnDOT's Living Snow Fence program? (5)

(Provide explanation and details to groups without LSF)

3) Think back to when you first heard about the living snow fence program. What were your initial thoughts about the program? (5)

Transition: 4) Who would you like to be your initial contact that would provide additional information and work with you on a project like this? (10)

Probe: MnDOT? Or highway engineer, a snow plow operator, a right of way agent, NRCS, FSA, or SWCD representatives?

Probe: Who would you want to plant the LSF? AND: Who would you want to maintain the LSF?

Key Questions: 5) What's the value of the living snow fence program? (15)

Probe: To communities, families, landowners, the county, city, state.

Do any of your neighbors have a living snow fence? What do they say about it? What do you think about it?

6) What would hold you back from joining a program like this? (15)

Probe: what are your constraints?

What do you perceive as the costs associated with establishing and maintaining a living snow fence?

Other thoughts on what would make you hesitate to participate in this program?

7) As a landowner, what would it take to get you to participate in the living snow fence program?

Probe: How would you describe the ideal conditions that would convince you to join the program? (15)

8) What would be an appropriate payment to landowners who participate in the living snow fence project? Let's hear both your ideal payment and a realistic payment you would accept.

Probe: What is the cost to farmers for leaving Living Snow fence structures (standing corn rows, trees, shrubs, grasses)? (10)

End Questions: 9) We've had some great discussion today, thank you! My notes from our conversation today include these key points _____. How well does that capture what was said here? (5)

10) We want you to help us evaluate the living snow fence program and your input is very valuable in determining appropriate compensation for landowners who participate in the program. Is there anything that we missed in our discussion today? Is there anything you came wanting to say that you didn't get a chance to say? (5)

Total Time (90)

Appendix D

Consent Form: Living Snow Fence Payment Calculator Study

You are invited to be in a research study of farmers and land owners regarding Minnesota Department of Transportation's (MnDOT) living snow fence program. You were selected as a possible participant because you are land owner in a snow problem area identified by MnDOT's Geographic Information System study. We ask that you read this form and ask any questions you may have before agreeing to be in the study.

This study is being conducted by: Dean Current, a Professor in the Dept of Forest Resources, University of Minnesota.

Background Information

The purpose of this study is to develop a standing corn row and living snow fence payment calculator to assist in the delivery of MnDOT's standing corn and living snow fence program.

Procedures:

If you agree to be in this study, we would ask you to do the following things: 1) respond to questions about the living snow fence program, 2) confirm our interpretation of your comments

Risks and Benefits of being in the Study

The study has at least one risk. First, you will be sharing and recalling experiences and some of them may be unpleasant.

The benefits to participation include providing information to MnDOT to improve your experiences with the living snow fence program to assist MnDOT in calculating appropriate compensation for landowners who participate in the program.

Compensation:

You will receive payment: $25 gas card at the end of the focus group discussion.

Confidentiality:

The records of this study will be kept private. In any sort of report we might publish, we will not include any information that will make it possible to identify a subject. Research records will be stored securely and only researchers will have access to the records and recordings.

Voluntary Nature of the Study:

Participation in this study is voluntary. Your decision whether or not to participate will not affect your current or future relations with the University of Minnesota or the MnDOT. If you decide to participate, you are free to not answer any question or withdraw at any time without affecting those relationships.

Contacts and Questions:

The researchers conducting this study are: Dean Current and Sierra Schroeder. You may ask any questions you have now. If you have questions later, **you are encouraged** to contact them at 115 Green Hall, St Paul; 612 624 3400, curre002@umn.edu & schro646@umn.edu

If you have any questions or concerns regarding this study and would like to talk to someone other than the researcher(s), **you are encouraged** to contact the Research Subjects' Advocate Line, D528 Mayo, 420 Delaware St. Southeast, Minneapolis, Minnesota 55455; (612) 625-1650.

You will be given a copy of this information to keep for your records.

Appendix E

MnDOT Maintenance Supervisors Conference 2010
Living Snow Fence Payment Calculator – presentation
Wednesday, October 20, 2010
Mankato, MN

1. **What factors should MnDOT consider in making a payment to landowners to protect a highway from snow and blowing snow?**

   - Long term contracts
   - Possibly adjusting payments when value in land or crops change
   - State Patrol and MnDOT frequency in area class or farmland
   - Current market price on the commodity. Average cost per acre/rent.
   - ADT of roadway and how many times the roadway has been blocked and/or accidents
   - $1.00 more per BU per acre of the cost on Nov. 15th and keep this as the standard for all farmers to keep it equal across the playing field of all farmers
   - Need long term snow fence in the bad areas; work with FSA on payments
   - Should also consider the cost savings for accidents and injuries. We don't have the "blow-on" problem with ice in these areas. We don't have to re-salt these areas.
   - Should buy RW-be done with it. Whatever maintenance costs are saved by having fence should be considered. Is there room on our RW to have fence? Should be cap. Should average to all – pay by how many feet of fence.
   - Highway direction (E/W or N/S)
   - Width of right of way
   - Severity of snow blockages (once in X number of years vs. yearly, etc.)
   - Go for grass and brush areas
   - Corn is difficult to get signed up

   Other Comments:

   - Should be able to have snow fence in cow fields, not only agricultural (this may refer to pastures)
   - If the LSF is in the middle of a route and we still need to cover the route, some of those "cost savings" really is a non-factor
   - Plant snow fences at the edge of the right of way when possible
   - Even letting farmers not to plow under corn stubble till spring helped a lot in drifting
   - Possible LSF to monitor not funded by MnDOT - TH 210 Fergus Falls to Breckenridge tree, brush, grass; Wilken & Ottertail SWCD would be the contacts.

   (Presented by Gary Wyatt)

Appendix F

What are Living Snow Fences?
A description of living snow fences and payments for landowners
(Prepared by Dan Gullickson MnDOT)

What are Living Snow Fences?

Living snow fences are designed plantings of trees and/or shrubs and native grasses located along roads. Properly designed and placed, these living barriers catch blowing and drifting snow before it reaches a road to improve access to markets, work, schools and emergency services during severe winter weather.

Participating in the Program

To participate in the living snow fence program, you can enroll in either the USDA Conservation Reserve Program or Environmental Quality Incentives Program (EQIP) and enter into a living snow fence agreement with the Minnesota Department of Transportation.

You will receive annual compensation, up to a 15-year time period, for the:

- Acreage enrolled in the Continuous Conservation Reserve Program from the U.S. Department of Agriculture Farm Service Agency.
- Inconvenience of farming around the living snow fence from MnDOT.
- Growing and maintaining the living snow fence from MnDOT.

Compensation is based on the soils rental rates as established by USDA through the Conservation Reserve Program.

Participating landowners plant two or three rows of grasses, shrubs and/or trees about 150 feet from the road ditch edge. This allows the living snow fence to break the wind's force, causing the snow to tumble in the air and collect around the plants to be stored in the snow catch area before it reaches the roadway.

Compensation Example for a ¼ mile long Living Snow Fence with Snow Catch Enrolled in the Conservation Reserve Program

¼ mile long living snow fence that is 1,320 feet long
Width of the living snow fence is 150 feet
Acreage required for the living snow fence is 4.5 acres

Soil Rental Rate of $100 per acre for this example
(Note: some county FSA land rental rates are much higher than $100 per acre)

Annual rental payments over a 15 year period on 4.5 acres totaling $14,085.00

- From USDA Farm Service Agency = $450.00 annually or $6,750 over 15 years.
- From MnDOT for storing snow in your snow catch area and for the hassle of farming around the living snow fence = $225.00 annually or $3,375 over 15 years.
- From MnDOT for compensation for watering, weeding and growing the living snow fence = $264.00 annually or $3,960.00 over 15 years.

One time USDA Signing Incentive of $100 per acre on 4.5 acres is $450 dollars.

Compensation Example for a ¼ long Living Snow Fence without Snow Catch Enrolled in the Conservation Reserve Program

¼ mile long living snow fence that is 1,320 feet long
Width of the living snow fence is 50 feet
Acreage required for the living snow fence is 1.5 acres

Soil Rental Rate of $100 per acre for this example
(Note: some county FSA land rental rates are much higher than $100 per acre)

Annual rental payments over a 15 year period on 1.5 acres totaling $9,585.00

- From USDA Farm Service Agency = $150.00 annually or $2,250 over 15 years.
- From MnDOT for storing snow in your snow catch area and for the hassle of farming around the living snow fence = $225.00 annually or $3,375 over 15 years.
- From MnDOT for compensation for watering, weeding and growing the living snow fence = $264.00 annually or $3,960.00 over 15 years.

One time USDA Signing Incentive of $100 per acre on 1.5 acres is $150 dollars.

Side by Side Comparison of Two Types of Living Snow Fence Treatments

Landowner	**Program**	**Incentive payment**	**Annual payment**	**Total payment**	**Payment $/acre/yr**
Farmer A *(4.5 acres)*	snow fence & catch basin	$450.00	$939.00	$14,085	$208.67
Farmer B *(1.5 acres)*	Snow fence only	$150.00	$639.00	$9,585.00	$426.00

Appendix G
Resources (Custom farming rates and machinery costs)

Iowa State University - Custom Rates Survey:
www.extension.iastate.edu/publications/fm1698.pdf

University of Minnesota – Machinery Cost Estimates
www.agrisk.umn.edu/cache/ARL04449.pdf

University of Minnesota - Minnesota Crop Cost & Return Guide for 2011 (Lazarus 2010)
http://faculty.apec.umn.edu/wlazarus/documents/cropbud.pdf

Appendix H

Interviews of LSF Owners Related to Moisture Issues

Phone interview comments from farmers with MnDOT living snow fence contracts
District 7 – MnDOT
5/11/11

Question:
Have you had problems working the field related to the snow storage/catch area around the living snow fences or standing corn – being wetter than other parts of the field?

Living Snow Fences (trees or shrubs)

G.P. – No
No problem being wetter yet, it is a new planting the trees are only 3 foot tall, trees are looking good, LSF is a good idea, happy with the project.

D.H. – No
No problem at all…snow is a good thing every year...alfalfa hay is planted on the south side and the snow provides moisture and also protects the alfalfa from winter kill, one row of eastern red cedar, it is very much worth the effort, visible benefits from snow protection, worth every penny.

D.K. – No
Tiled around the LSF area, when they built the highway they used some of the clay soil from this field, it is not as productive as other fields in the County, somewhat of a nuisance to farm around and watch spraying but they knew that going into the project. They may expand the highway to 4 lanes in the future, when they do that we will need to remove and replant.

M.G. – No
No complaints at all from the renter or neighbors, it works very well, neighbors/community like it because it is making the highway passable and safer, catches a lot of snow.

M.H. – No
The field is patterned tiled around the LSF so water is not usually a problem, tiled every 75 feet, corn was planted in a timely manner already this spring (2011).

S.J. – Yes
This field has always been wet, they added more tile and have improved the drainage in the field, not a problem to farm around.

Standing Corn

M.T. – No
No, not really, some inconvenience, neighbors like it very much, it has worked very well in protecting the highway.

J.C. – Yes
Yes, a little more wet, slightly less yield, alternate every year (corn & soybean rotation), there is no snow fence in soybean years, would need more money if planted into soybean field.

D.T. – Yes
Yes, but not a problem with planting, no delay in planting, deer eat most of the corn in the winter.

B.S. – No
The soil dries well around the standing corn, the field is well tiled, sometimes plants corn on corn and sees corn yield loss due to trash and volunteer corn, community and neighbors comment about how the corn protects the highway, people want to pick corn in the fall, farmers ask what corn variety is standing so well in the field.

B.F. – No
No not really, no snow on the road, estimated 6 million tons of snow in drifts, draw back…this was the first year he thought that the price of corn outside the standing corn returned more dollars than the payment from MnDOT, the snow cover of greater than 3 feet deep actually insulated the soil and helped allow the soil to thaw quicker in the spring thus drying the soil before the rest of the field, he predicts a 20% increase in soybean yields due to the extra soil moisture, wonderful program, great for wildlife/snow plows/community, he also plants standing corn row in soybean fields, a plus for the environment, in the spring he burns the corn stalks then rakes up the ears to feed to cattle.
(This participant could be a LSF spokes person, he is very positive about this program)

Compiled by Gary Wyatt, 5/11/11

Appendix I

Agroforestry Practices and Stored Carbon

Agroforestry potential to store carbon on Nebraska farmland. Storage values are calculated at 20 and 40 years following planting. However, depending on species and purpose, planted trees can live for many decades or more than a century.

Agroforestry Practice	Stored CO2 / Land Unit* *At Age 20* *metric tons (mt)*	CO2 Storage Potential for Nebraska *million metric tons (mmt)* *20 years*	*40 years*
Field Windbreak[2] (planted on 5% of cropland)	36 - 72 mt /mile *(20 ft width, 0.4 mi. = 1 ac.)*	11.7 - 23.4	23.4 - 46.8[1]
Living Snow Fence[3] (high priority roadways)	162 - 324 mt /mile *(50 ft width)*	5.4 - 10.8	10.8 - 21.6[1]
Riparian Forest Buffer[3]	426 - 852 mt /mile *(100 ft width, each side stream)*	9.2 - 18.4**	18.4 - 36.8
Pivot Irrigation Corners[4]	352 - 704 mt /pivot *(4 corners, each 6 acres)*	6.6 - 13.2***	13.2 - 26.4
-pivots below 23 inch annual precipitation	" "	15.1 - 30.2	30.2 - 60.4
-all corner pivots			
TOTAL		**41.4 - 82.8**	**82.8 - 165.6**

*Tree biomass and subsequent CO2 storage estimates are based on volume tables derived from trees grown under shaded forest stand conditions. Recent research at the University of Nebraska (Zhou et al., *submitted)* has shown that tree biomass for green ash grown under windbreak conditions can be as much as 100% greater. This is attributed to the greater branch biomass and changes in the stem diameter to height relationship that occur in open grown, sunlit trees. Research is underway to determine if similar biomass patterns occur for other windbreak tree species. The upper bounds of the ranges reflect this possibility

**Riparian estimates are derived from the rate of trees growing in field windbreaks. Due to the more favorable moisture and nutrient conditions typical of riparian landscape positions, these estimates are likely to be conservative.

***1997 data show 42,940 pivots in Nebraska, and most of these are located on 160 acre ¼ sections. Only irrigation pivots on lands averaging 23 inches or less of precipitation would likely be available for tree planting (44 percent of pivots), as farmers could still plant the non-irrigated corners to corn or soybeans above this moisture level.

[1]Brandle et al 1992. [2]USDA, SCS. 1990. [3]Garrett, H.E., et.al., 1994. [4]Boellstorff et al.1997.

References

Boellstorff, D., J. Conklin, P. Dappen, S. Hatten, P. Lamb, J. Taylor, M. Tooze, M. Warner, and J. Wolf. 1997. Center-Pivot Irrigation Systems in Nebraska. Conservation and Survey Division, Univ. of Nebraska, Lincoln, NE.

Brandle, J.R., T.D. Wardle, and G.F. Bratton, 1992. Opportunities to increase tree planting in shelterbelts and the potential impacts on carbon storage and conservation. *In:* Sampson, R.N. and D. Hair (eds), 1992. Forests and Global Change. Volume 1: Opportunities for Increasing Forest Cover. American Forests, Washington D.C., pages 157-176.

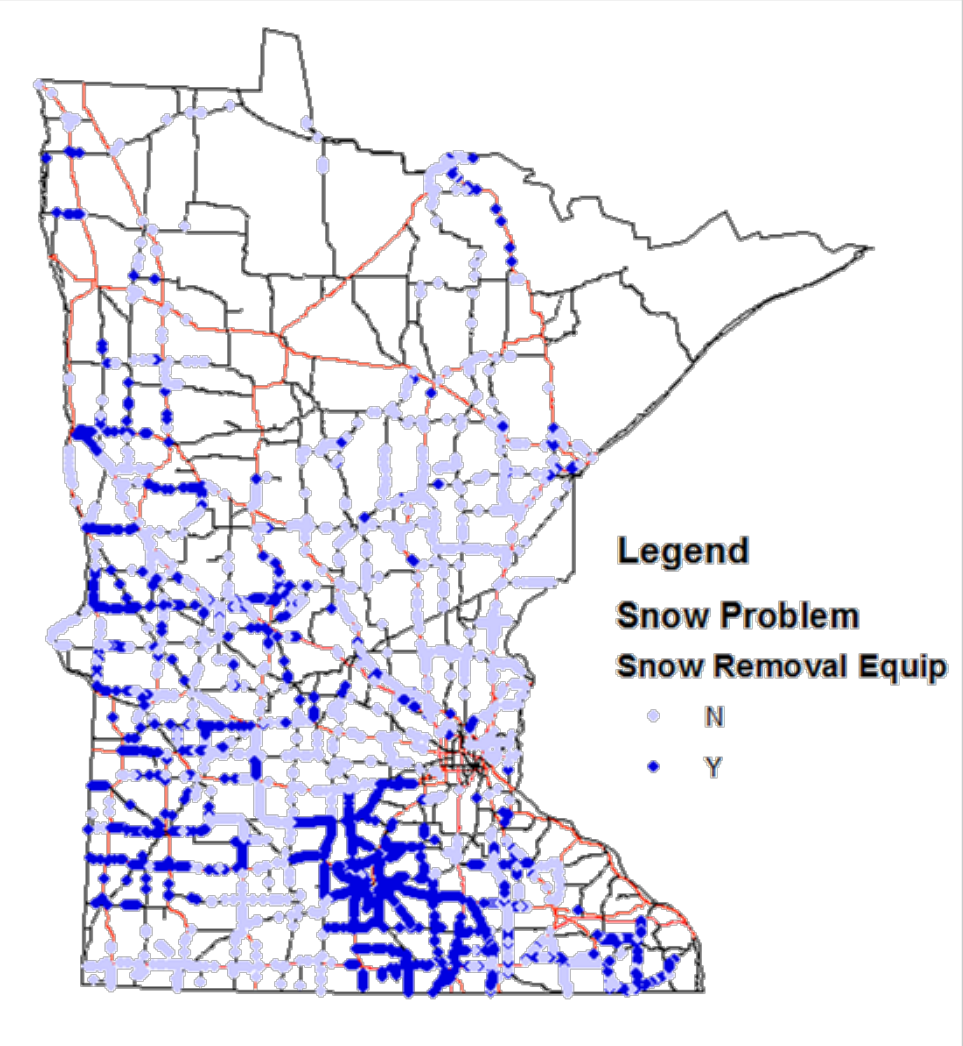
Garrett, H.E., et.al., 1994. Agroforestry: An Integrated Land-Use Management System for Production and Farmland Conservation. USDA SCS.

U.S.D.A., Soil Conservation Service. 1990. Estimated Number, Area, and Length of 1987-1990 Farmstead and Field Windbreaks, by State.

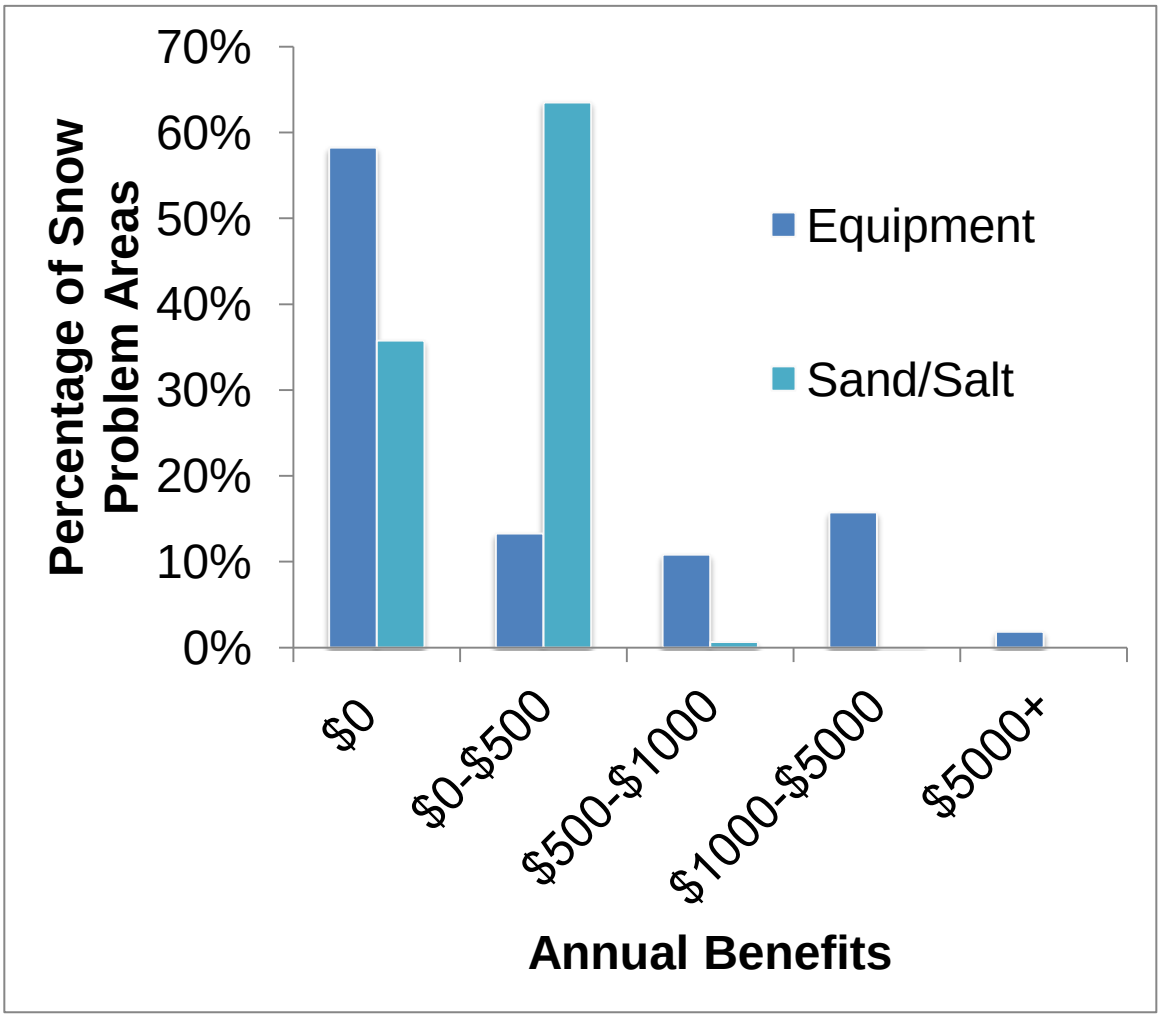
Appendix J

Snow Removal Equipment Usage

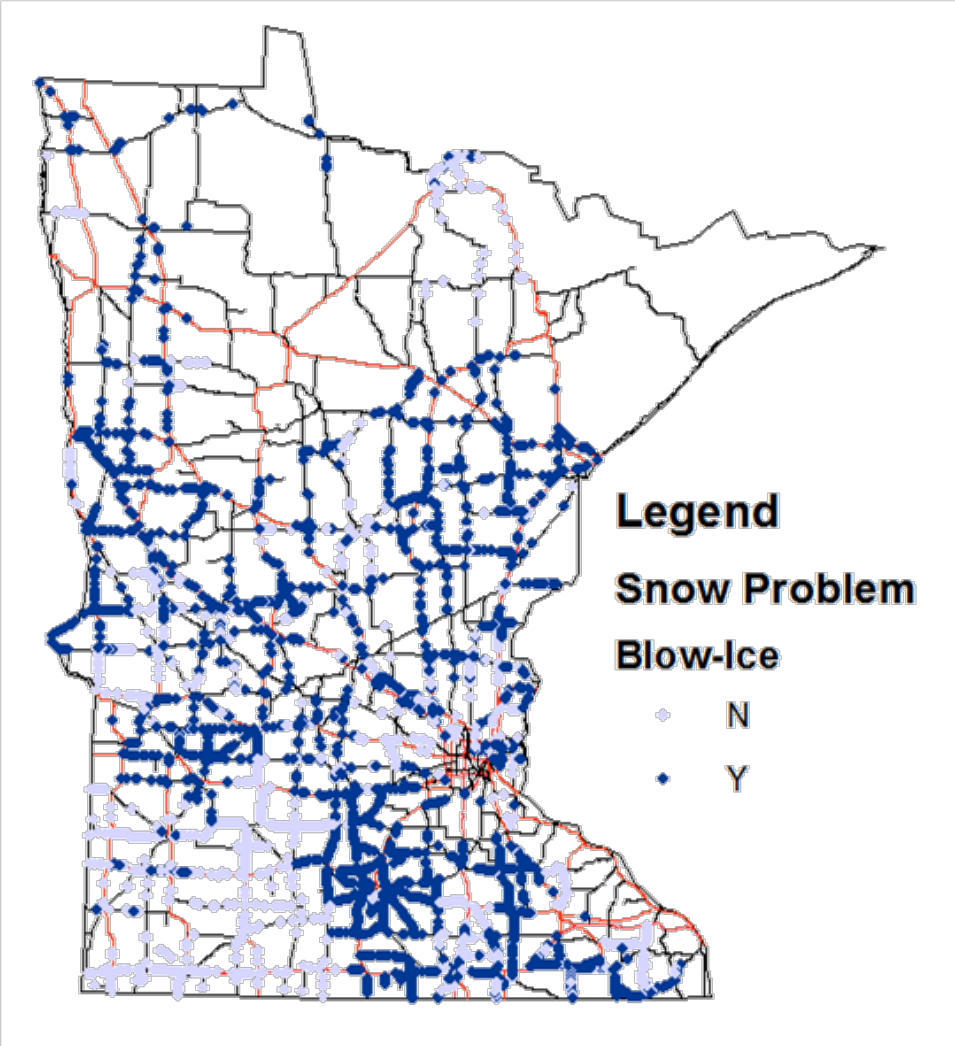
Snow Removal Equipment Usage



Transportation Agency Benefits



Blow Ice



Appendix K

Plow Routes by District

with Living Snow Fences

Plow Routes by District

with Living Snow Fences

District	Station	Description	Job Number	Hwy	Class
D1					
	Grand Rapids	TH 169 302.866-304.220 305.961-306.862	TP1ER413	US169	UC
	Moose Lake	I-35 210.063 - 231.736	TP1AR107	I35	UC
	Pike Lake	From TH 53 to TH 2 Including Scale	TP1CR214	MN33	RC
	Sandstone	I-35 188.927 - 210.063	TP1AR102	I35	UC
D2					
	Baudette	Baudette Truck Station to Jct. TH 71 a	TP2HR131	MN11	P
	Bemidji (#207509)	E Jct TH 2 to W Jct. TH 2	TP2J1971	MN197	UC
	Bemidji (#208556)	N. Jct. TH 2 to Jct. TH 72 at Blackduc	TP2J0713	US71	RC
	Grygla	Jct. TH 89 to Jct. TH 1	TP2HR501	MN219	S
	Grygla	Jct. TH 89 to Jct. TH 1	TP2HR501	MN219	S
	Warren (#204562) (Unit # Ameritrak)	Jct. TH 75 at Warren to ND Line at Osl	TP2F0011	MN1	P
D3B					
	Albany	I94: 238 to 237 Left Lane	TP3TR123	I94	UC
	Albany	I94: 238 to 237 Right Lane	TP3TR121	I94	UC
	Albany	I94: 238 to St. Johns Lt Lane	TP3TR123	I94	SC
	Albany	I94: 238 to St. Johns Rt Lane	TP3TR122	I94	SC
	Sauk Centre	I94: TH 237 to Osakis Left Lane	TP3TR114	I94	UC
	Sauk Centre	I94: TH 71 to Osakis Right Lane	TP3TR114	I94	UC
	Sauk Centre	I94: TH 71 to TH 237 Right Lane	TP3TR112	I94	UC

District	Station	Description	Job Number	Hwy	Class
D4					
	Brec	TH 9, Jct TH 210 - Barnesville	TP4C5325	MN9	S
	Henn	TH 29, Jct TH 210 - Jct TH 235	TP4Y5331	MN29	RC
	Morr	TH 27, Jct TH 9 (Herman) - Hoffman	TP4P6109	MN27	S
	Morr	TH 28, Graceville - Jct TH 7 (Beardsle	TP4P6105	MN28	P
	Morr	TH 28, Morris - Jct US 75 (Graceville)	TP4P6105	MN28	P
	Morr	US 12, Jct US 59 - Jct TH 119	TP4P6107	US12	P
	Wheaton	TH 27, Wheaton - Jct TH 9	TP4P6202	MN27	P
D6E					
	St Charles	Jct 52 to Jct 74 St Charles	TP6C0901	I90	UC
	Stewartville	Jct 16 Dexter to Jct 63 Stew.	TP6B0901	I90	UC
D6W					
	Albert Lea	JCT I35 - JCT CR 46	TP6R0902	I90	UC
	Albert Lea	JCT I90 - JCT TH30	TP6R0352	I35	UC
	Albert Lea	JCT TH109 - JCT I35	TP6R0901	I90	UC
	Austin	JCT CR46 - JCT TH105	TP6T0901	I90	UC
	Austin	JCT TH105 - JCT TH56	TP6T0902	I90	UC
	Austin	JCT TH56 - JCT TH16	TP6T0903	I90	UC
	Owatonna	JCT TH30 - JCT TH14	TP6X0351	I35	UC
D7E					
	GAYLORD	MN 19: Fairfax to Gaylord	TP7AR121	MN19	RC
	MANKATO	US 14: Jct MN 22 to Janesville	TP7BR223	US14	UC
	MONTGOMERY	MN 13: Jct. MN 60 to Montgomery	TP7AR142	MN13	RC

District	Station	Description	Job Number	Hwy	Class
D7W					
	Jackson	I-90: CSAH 9 to Jct. US 71	TP7RR215	I90	UC
	Luverne	I-90: South Dakota Line to Jct. US 75	TP7PR102	I90	UC
	Storden	MN 30: Westbrook to Darfur	TP7RR212	MN30	P
	Windom	MN 86: Iowa Line to Jct. MN 60	TP7RR213	MN86	RC
	Worthington	I-90: US 59 to Jct. CSAH 9	TP7PR114	I90	UC
	Worthington	MN 60: Iowa Line to S.Wgtn Cty Limits	TP7PR111	MN60	RC
D8					
	Granite	TH 67 from Jct 23 to Jct 19	TP8R1331	MN67	P
	Hutch	TH 4 Hector to Jct 7 Cosmos	TP8R2230	MN4	P
	Ivanhoe	TH 68 West of Canby	TP8R3110	MN68	P
	Lake Benton	TH 14 SD Border to Jct 23	TP8R3310	US14	P
	Madison	SD Border to Jct 75 - Madison	TP8R1111	MN40	S
	Marshall	TH 19 Marshall to Ivanhoe	TP8R3270	MN19	P
	Marshall	TH 23 Jct 14 to Jct 19 Marshall -- 2-l	TP8R3260	MN23	RC
	Marshall	TH 23 Jct 14 to Jct 19 Marshall -- 4-l	TP8R3260	MN23	RC
	Marshall	TH 91 Jct 23 to 14	TP8R3261	MN91	S
	Olivia	TH 212 Olivia to Hector	TP8R2420	US212	RC
	Redwood	TH 19 Redwood to Fairfax	TP8R2530	MN19	RC
	Tracy	TH 14 Tracy to Jct 71	TP8R3620	US14	P
	Tracy	TH 14 W of Tracy	TP8R3610	US14	P

District	Station	Description	Job Number	Hwy	Class
METRO					
	ANOKA	Median X-over .26 miles east of MN101/	TP5A1179	US10	SC
	LAKEVILLE (#?)	Jct Dakot Cty Rd 70 to S Jct I 35E/I35	TP9P0347	I35	SC
	LAKEVILLE	Jct Mn 50 to Dakota Cty Rd 42 in Rosem	TP9P0348	MN3	UC
	LAKEVILLE	S Jct I35/I35W to Cliff Road	TP9P0346	I35E	SC
	MAPLE GROVE	Bass Lake Road to Jct 94/Fish Lake int	TP5B1251	I494	SC
	NORTH BRANCH	Wash/Chis Cty ln to Chisago/Pine line	TP9A0176	I35	SC

Appendix L

Measuring Positive Impacts Poster

Measuring Positive Impacts of Living Snow Fences on Mn/DOT Snow Removal Efforts

Don Kilberg - University of Minnesota - Masters GIS Program - kilbe008@umn.edu

Research Objectives

The Minnesota Department of Transportation (Mn/DOT) has been encouraging farmers to create and maintain Living Snow Fences for several years. Reports from the field indicate highways sheltered by these fences are easier to clear and result in fewer accidents but the snow fences are not free. Farmers are paid to install and maintain them. Prior to expanding this program, Mn/DOT has commissioned a study with the University of Minnesota to pursue this question in more detail, both the cost to maintain the fences as well the benefits. This project focused on evaluating the benefits. The goal is to identify paired segments of roadway that have all key attributes identical with the exception of one member of the pair having a living snow fence and the other not. Information captured during the actual plowing operation can then reflect the cost in time and materials to clear both segments and determine if there is a significant, measurable value in having the fence.

A

Methodology: Determine Route Segment Pairs

The research team was provided with several GIS shape files depicting key information. The first provided all highways in the state managed by Mn/DOT plows, the type of highway, length of route and other data. A second shape file provided the location of all living snow fences in the state. To be considered matched highway segments the following characteristics had to be met:

1) the azimuth in degrees of the two segments had to be the same within a specifiable number of degrees
2) the two segments had to be on the same plow route. (this ensured the highway priority was the same as well as minimized time differences)
3) the predominant land cover classification within a specified distance from each segment is the same
4) the type of snow fence had to be identifiable in the results

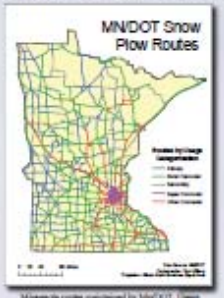
An ArcGIS geoprocessing model was developed that processed the plow route segments appropriately so we could find segments that met the above requirements.

B

Methodology: Evaluate Route Segment Pairs

Once pairs have been identified using GIS tools they can be evaluated. Mn/DOT snow plows contain significant technology. Central Maintenance Decision Support systems capture conditions from airports, remote weather information platforms, radar and driver input and create recommendations for plow drivers. Plow route recommendations are sent real time to the drivers. Environmentally hardened computers on the plow capture key information such as the route, road conditions, material being deposited and deposition rate by the spreader, speed, road pavement temperature from infrared thermometers, air temperature, as well as GPS position. This information is captured every 2 seconds and sent to a central location for processing. Because we know the GPS location of each data point we can quite easily match this data to our road segments to objectively determine the time and materials required to plow snow fence segments vs. their non-fenced paired segments

Major Geoprocessing Steps:



Example of a living snow fence

Geoprocessing Model to Determine Segment Pairs

Research Results:

The geoprocessing model to segment the plow routes into like portions successfully created matched plow route segments. When data is available next year from the plows the final data assessment of living snow fences can be initiated.

Acknowledgements:

Jakin Koll from Mn/DOT St. Cloud was most helpful in explaining the snow plow operation and data capability. Dan Gullickson from Mn/DOT St. Paul provided GIS shape files and guidance throughout the segment processing operation. In addition I thank Dr. Joe Knight and Tim Loesch for their advice during the project.

Appendix M

Snow and Ice Costs by Fiscal Year

FISCAL YEAR	METRO	GREATER MN DISTRICTS	TOTAL
2001	17,805,973	33,591,732	51,397,705
2002	15,104,586	27,754,344	42,858,930
2003	9,876,188	25,869,908	35,746,096
2004	10,964,790	37,126,309	48,091,099
2005	11,389,163	32,365,459	43,754,622
2006	12,765,481	37,430,398	50,195,879
2007	12,558,440	31,763,586	44,322,026
2008	17,537,201	39,965,075	57,502,276
2009	22,674,964	45,771,100	68,446,064
2010	18,210,987	41,317,336	59,528,322
2011	28,295,308	52,790,193	81,085,501

Includes Activities

2401	Stationary Anti-icing
2402	Winter Stockpiling
2403	Mobile Anti-icing
2405	Snow Fence Inst/Repr/Maint/Rem
2406	Plowing & Sanding
2408	Night/Dawn Patrol
2410	Post Storm Clean up
2411	Snow & Ice Traffic Control
2412	RWIS
2415	Snow & Ice Control Direct Support
2416	Winter Equipment Inspection
3435	Brine Systems (Snow & Ice Control)

Reporting begins 7-1 of each fiscal year through Pay Period ending closest to May 10th of each year

6/3/11

Source: MnDOT's Office of Maintenance

Appendix N

Abstracts of 2011 Conferences

Living Snow Fence Payment Calculator: Research and Assess the Farmer and MnDOT Economic and Environmental Costs and Benefits of Living Snow Fences including carbon impacts

Authors:

Gary Wyatt, Diomy Zamora, University of Minnesota Extension Educators
Dean Current, Steve Taff, University of Minnesota

Key words: Living Snow Fence, Carbon Sequestration, Carbon Footprints, Carbon Impact

Blowing and drifting snow on Minnesota's roadways is a transportation efficiency and safety concern. Establishing standing corn rows and living snow fences improves driver visibility, road surface conditions, and has the potential to lower costs of road maintenance as well as accidents attributed to blowing and drifting snow; and sequester carbon and avoid the carbon emissions of snow removal operations.

In recent years MnDOT has paid farmers to leave standing corn rows to protect identified snow problem roadways. They have paid farmers $1.50 per bushel above market rate. With increasing demand for corn to fuel the ethanol industry, paying $1.50 per bushel above market rate may not be sufficient incentive for leaving standing corn rows. Also, with MnDOT's memorandum of understanding with USDA to plant living snow fences through the Conservation Reserve Program (CRP), now is an opportune time to review MnDOT's annual payment structure to farmers and prepare a new one.

This project will: 1) develop a calculator to estimate payments for farmers that will include consideration of safety and snow removal cost savings; 2) estimate potential income from carbon payments; 3) working closely with MnDOT engineers and plow operators, estimate the safety and snow removal costs and carbon emissions avoided by MnDOT through establishing living snow fences; and 4) evaluate farmers' willingness to establish living snow fences and identify farmers/landowners constraints to adoption. This data will be provided to MnDOT to assist them in their decision making related to their Living Snow Fence Program.

Transportation Agency Tool to Analyze Benefits of Living Snow Fences

David J. Smith[1], Dean Current[2], Daniel Gullickson[3], Gary Wyatt[4], Diomedes Zamora[5]

Abstract

A benefit and cost analysis tool was developed for the Minnesota Department of Transportation's (MnDOT) living snow fence (LSF) program. This transportation agency tool calculates global and site-specific economic, transportation and environmental benefits and the opportunity costs to landowners. This aids in prioritizing snow problem areas and developing landowner payment programs. Results from the application of the tool on U.S. interstate and U.S. and Minnesota (MN) highway snow problem areas in MN suggests an expansion of the program in the study agency and to other states with snow precipitation is justified. LSF are plantings of trees and/or shrubs set back from the right of way along the upwind roadside to minimize drifting and blowing snow problems on the roadway.

Blowing and drifting snow are costly realities for transportation agencies in regions with significant snow precipitation. Drifts that are large and heavy enough to be unmovable by standard plows require specialized equipment to keep roadways passable. Blowing snow can require extra trips by standard plows, increased plow time, and increased usage of sand and salt. Analysis of automatic vehicle location (AVL) system data and field surveys are used to estimate these cost savings from LSFs.

Snow fences can decrease travel time and reduce the severity and number of snow related accidents. The number and type of vehicles affected during these events is estimated from average daily traffic flows. A study in Wyoming shows that snow fences along interstate 80 have reduced accidents during blowing snow conditions by seventy percent (Tabler 1982). An analysis of accidents in Minnesota from 1995 to 2005 found over nine thousand snow related accidents in snow problem areas including sixty four fatal and one hundred and thirty one incapacitating accidents (URS Corporation 2008).

In addition LSF also provide environmental services such as wildlife conservation, hunting opportunities, and carbon storage and sequestration. The MnDOT LSF program includes collaboration with Soil and Water and Conservation Districts (SWDC), the USDA Farm Service Agency and the Natural Resources Conservation Service (NRCS). Coordinating the LSF program with the Conversation Reserve Program (CRP) and the Environmental Quality Incentives Problem (EQIP) provides additional resources that can reduce the transportation agency's share of the landowner payments by sharing in the cost of establishment and annual landowner payments. This lowers financial barriers to development and expansion of a program with substantial economic net benefits.

Key words: benefit cost tool; blowing; environment; fence; drifting; snow

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Appendix O

Professional Conference Posters

Living Snow Fence Payment Calculator

Wyatt, G.[1]; Zamora, D.[1]; Current, D.[2]; Taff, S.[3]; Gullickson, D.[4]; Paudel, D.[5]; Schroeder, S.[5]; Knight, J.[6]; Kilberg, D.[6]
1 Extension Educator; 2 CINRAM Program Director; 3 Extension Economist; 4 Mn/DOT Forester; 5 Research Assistant; 6 Forest Resources

Abstract

Blowing and drifting snow on Minnesota's roadways is a transportation efficiency and safety concern. Establishing standing corn rows and living snow fences improves driver visibility, road surface conditions, and has the potential to lower costs of road maintenance as well as accidents attributed to blowing and drifting snow; and sequester carbon and avoid the carbon emissions of snow removal operations.

In recent years the Minnesota Department of Transportation (Mn/DOT) has paid farmers to leave standing corn rows to protect identified snow problem roadways. They have paid farmers $1.50 per bushel above market rate. With increasing demand for corn to fuel the ethanol industry, paying $1.50 per bushel above market rate may not be sufficient incentive for leaving standing corn rows. Also, with Mn/DOT's memorandum of understanding with USDA to plant living snow fences through the Conservation Reserve Program (CRP) with the new farm bill, now is an opportune time to review Mn/DOT's annual payment structure to farmers and prepare a new one.

This project will: 1) develop a calculator to estimate payments for farmers that will include consideration of safety and snow removal cost savings; 2) estimate potential income from carbon payments; 3) working closely with Mn/DOT engineers and plow operators, estimate the safety and snow removal costs and carbon emissions avoided by Mn/DOT through establishing living snow fences; and 4) evaluate farmers' willingness to establish living snow fences and identify farmers/landowners constraints to adoption. This data will be provided to Mn/DOT to assist them in their decision making related to their Living Snow Fence Program.

Objectives

This project centers around rural landowner adoption and implementation of Living Snow Fence (LSF) plantings with the Minnesota Department of Transportation LSF program.

1. **Costs of Living Snow Fence Adoption:**
   To identify LSF costs interviews will be conducted with farmers who have adopted living snow fences to better understand their costs in establishing and maintaining living snow fences.
2. **Constraints to the Adoption of Living Snow Fences:**
   Focus groups and individual farmer interviews will be used to identify reasons why a farmer/landowner might not be willing to adopt a living snow fence. County, State and Federal agency staff will also be surveyed to record LSF adoption.
3. **Avoided Maintenance and Safety Costs:**
   The University will work closely with Mn/DOT engineers to estimate two types of avoided costs. The avoided costs associated with removing blowing and drifting snow and costs avoided from crashes caused by blowing and drifting snow based on Mn/DOT data on those costs.
4. **Calculating Carbon Emissions from Maintenance and Sequestration by Living Snow fences.**
   Estimate the carbon footprint of snow removal and maintenance equipment plus the sequestration of living snow fence vegetative plantings. Carbon emissions would be avoided by reducing the need for plowing and maintenance associated with snow removal.
5. **Develop a Payment Calculator:**
   To develop a payment calculator which will include a) data on costs of establishment and maintenance of LSF; b) avoided road maintenance and safety costs; and c) carbon emissions avoided and carbon sequestered, estimating a value for each landowner costs plus public and Mn/DOT benefits.

Minnesota State Highway 212 near Bird Island, MN

Before LSF

After LSF

(Photos are taken the same day showing the visibility and blowing snow improvement provided by LSF planting)

Assessing Carbon Emissions and Storage

Carbon Emissions from Snow Removal Equipment will be Documented

Living snow fences planted to perennial vegetation provides carbon storage. The amount of carbon storage and return from carbon credits will also be calculated.

www.extension.umn.edu/agroforestry

Results

Landowner Focus Groups:

Costs:
- Life cycle costs (implementation, establishment, maintenance, rejuvenation, and removal)
- Opportunity costs (taking good land out of production for an extended period)
- Costs related to changing land values (land value increases while contract payment is static)
- Compensation is insufficient to offset the costs (payment is just not worth it)

Constraints:
- Risk (plant mortality and landowner liability)
- Hassle (farming around snow fence and removing corn rows in spring)
- Time constraint (no time available to dedicate to a living snow fence planting)
- Contract (length and rigidity, lack of adjustment for changing values)

Factors Positively Influencing Adoption:
- Awareness of the program (personal & local agency contacts, targeted recruitment)
- Relative advantage (taking poor land out of production)
- Perception the program promotes the landowner's objectives (pro-conservation landowners)
- Incentives and compensation (premium incentive)

Conclusion

Living snow fences and standing corn rows are effective practices to reduce blowing and drifting snow on highways. In order for landowners to establish these practices compensation should be comparable to or greater than other land use practices or revenues. The majority of landowners would prefer someone else maintain these plantings. The computerized LSF payment calculator should be available on-line in fall of 2010.

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Living Snow Fences

Economic, Transportation and Environmental Benefits

David J. Smith[1], Dean Current[2,3], Steve Taff[1,3]

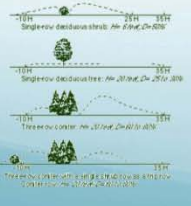
[1] Department of Applied Economics, [2] Center of Integrated Natural Resources & Agricultural Management, [3] Department of Forest Resources

Introduction: The Minnesota Department of Transportation's (MnDOT) living snow fence (LSF) program was implemented to mitigate the drifting and blowing snow problems associated with nearly four thousand snow problem areas identified by field surveys in Minnesota (Figure 1). The Center for Integrated Natural Resources and Agricultural Management conducted a benefit and costs analysis of the program.

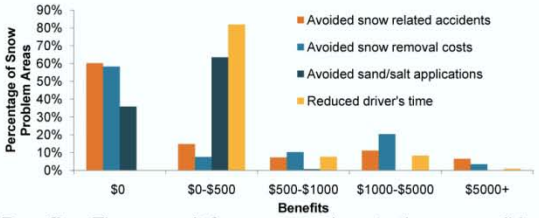
Figure 1: Snow Problem Areas

Solution: LSFs are plantings of trees and/or shrubs set back from the right of way along the upwind roadside to minimize drifting and blowing snow.

Figure 2: LSF

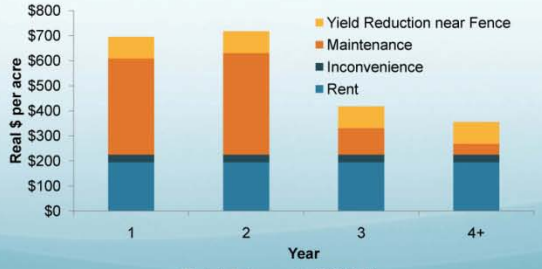


Before **After**



Benefits: These result from cost savings to the responsible transportation agency (e.g. reduced equipment, sand, and salt use) and transportation benefits for the public (e.g. decreased travel time and number and severity of accidents). In addition LSFs also provide environmental services such as wildlife conservation, hunting opportunities, and carbon storage and sequestration.

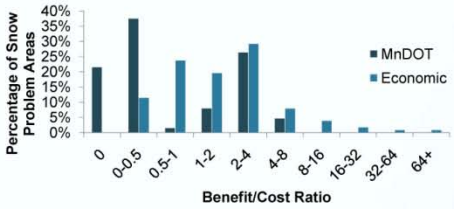
Costs



Establishment: $2261/acre

The benefit and cost analysis suggests an expansion of the program in the study agency and to other states with high snow precipitation.

Net Benefits $14 Million



Coordination with Conservation Agencies: Coordinating the LSF program with the Conversation Reserve Program (CRP) and the Environmental Quality Incentives Problem (EQIP) provides additional resources that can reduce the transportation agency's share of the landowner payments. This lowers financial and technical barriers to development and expansion of a program with substantial economic net benefits.

Center for Integrated Natural Resources & Agricultural Management

Future Research

- Quantify Environmental Services of LSF
- Statistical Analysis of Accident Data
- Ecosystem Service Value of Scrubland & Forestland

Appendix P

MnDOT Payments for Standing Corn Rows (SCR)

MnDOT Payments for Standing Corn Rows (SCR)

Years	# Contracts	# Acres	Payments		Total $ Paid
			$ Price/bu.	$ Price/A	
2001-2002	17	NA	$2.75	N	$8,874
2002-2003	15	NA	$4.00	N	$13,735
2003-2004	7	NA	$3.50	N	$5,413
2004-2005	40	71.68	3.15 to 4.30	N	$36,401
2005-2006	29	50.18	3.00 to 3.50	N	$30,768
2006-2007	37	65.8	3.45 to 5.00	N	$51,709
2007-2008	24	46.07	3.45 to 5.00	$700	$31,824
2008-2009	19	34.47	5.12 to 6.88	$700	$32,688
2009-2010	24	75.54	4.63 to 5,50	$700	$31,427
2010-2011	18	37.08	6.22 to 7.00	$700	$42,786

Appendix Q

MnDOT Living Snow Fence (Trees/Shrubs) Contracts

MnDOT Payments to Landowners for LSF (Trees and Shrubs)

MnDOT District	Year Installed	County	Type	Total Length (ft)	Acres	Installation Cost	Rental Cost/Year	Total Rental Cost
D1	2010	Koochiching	LSF	975	0.7	868.53	216.00	3,240.00
D1	2010	Koochiching	LSF	813	0.58	1,026.02	180.00	2,700.00
D1	2010	Koochiching	LSF	525	0.5	467.31	120.00	1,800.00
D1	2010	Koochiching	LSF	1,300	0.9	1,160.46	287.00	4,305.00
D3	2008	Isanti	LSF	4,125	14.2	4,089.49	1,251.00	18,765.00
D4	2004	Wilkin	LSF	2540	8.7	5,648.03	831.03	12,465.45
D4	2004	Wilkin	LSF	3550	12.22	8,027.37	1,148.45	17,226.75
D4	2005	Otter Tail	LSF	850	5.7	2,506.62	341.00	5,115.00
D4	2005	Wilkin	LSF	1,700	5.9	3,391.50	555.35	8,330.25
D4	2006	Wilkin	LSF	585	2.01	1,017.39	198.71	2,980.65
D4	2006	Wilkin	LSF	4,550	15.67	9,161.83	1,622.36	24,335.40
D4	2006	Wilkin	LSF	4,000	13.77	3,252.95	1,445.40	21,681.00
D4	2006	Wilkin	LSF	2,000	6.9	3,404.28	683.59	10,253.85
D4	2006	Wilkin	LSF	2,500	8.6	4,240.43	883.39	13,250.85
D4	2009	Stevens	LSF	3,450	11.9	5,467.16	1,356.40	20,346.00
D4	2009	Wilkin	LSF	825	2.84	1,413.63	308.28	4,624.20
D4	2009	Wilkin	LSF	3,075	10.59	4,861.35	1,114.85	16,722.75
D4	2009	Wilkin	LSF	3,625	12.48	5,695.89	1,272.75	19,091.25
D4	2011	Stevens	LSF	1,600	4.9	N/A	633.50	9,502.50
D4	2011	Otter Tail	LSF	2,600	4.4	2,364.45	910.49	13,657.35
D4	2011	Otter Tail	LSF	4,460	5.3	3,730.84	1,585.96	23,789.40
D4	2011	Otter Tail	LSF	1,305	1.5	953.00	429.06	6,435.90
D4	2011	Otter Tail	LSF	1,575	4.1	1,996.48	575.43	8,631.45
D4	2011	Otter Tail	LSF	1,180	1.3	1,041.40	443.71	6,655.65
D4	2011	Otter Tail	LSF	1,170	1.4	1,000.54	417.37	6,260.55
D4	2011	Otter Tail	LSF	810	1.3	976.21	297.65	4,464.75
D4	2011	Otter Tail	LSF	2,545	2.9	2,261.72	781.35	11,720.30
D4	2011	Otter Tail	LSF	1,370	2.3	1,582.42	453.12	6,796.80
D6	2010	Filmore	LSF	3,052	1.7	2,857.60	1,604.59	24,068.85
D7	1992	Brown	STR	544	0.26	N/A	299.20	N/A
D7	1995	Cottonwood	FWB	1,600	1.2	0.00	880.00	4,400.00
D7	1996	Cottonwood	FWB	650	0.36	0.00	357.50	1,787.50
D7	1998	Cottonwood	LSF	950	0.57	N/A	522.50	2,612.50
D7	1998	Watonwan	LSF	1,600	2.1	N/A	880.00	4,400.00
D7	1998	Watonwan	LSF	1,600	2.1	N/A	880.00	4,400.00
D7	1999	Cottonwood	LSF	1,000	0.76	N/A	83.33	1,249.95
D7	2002	Jackson	FWB	1,010	1.9	N/A	324.61	N/A
D7	2002	LeSueur	LSF	900	3.09	N/A	366.95	5,504.25
D7	2002	Scott	LSF	2,370	2.72	N/A	474.00	948.00
D7	2003	Jackson	LSF	1,260	4.34	1,299.34	503.07	7,042.95

MnDOT District	Year Installed	County	Type	Total Length (ft)	Acres	Installation Cost	Rental Cost/Year	Total Rental Cost
D7	2003	Cottonwood	LSF/STR	1,124	3.87	N/A	418.84	5,026.08
D7	2003	LeSueur	LSF	500	1.72	909.72	192.02	2,880.30
D7	2003	LeSueur	LSF	800	2.75	1,616.66	293.38	4,400.70
D7	2004	Rock	LSF	760	2.62	1,619.55	296.10	4,145.40
D7	2004	Jackson	LSF	1,140	3.93	2,500.00	440.74	6,170.36
D7	2004	Jackson	LSF	888	3.06	2,500.00	330.60	4,628.40
D7	2004	Sibley	LSF	600	2.1	649.28	242.33	3,634.95
D7	2007	Nobles	LSF	2,250	7.75	6,156.62	898.88	12,584.32
D7		Jackson	LSF	3,000	3.4	0.00	300.00	1,500.00
D7		Brown	FWB	1,245	1.2	0.00	684.75	3,423.75
D7		Watonwan	N/A	300		0.00	165.00	875.00
D7		Watonwan		2,500		0.00	1,375.00	6,875.00
D8	2003	Renville	LSF	2,716	2.5	2,822.79	1,110.56	16,103.12
D8	2003	Renville	LSF	2,380	2.5	3,238.79	901.50	13,071.75
D8	2003	Yellow Medicine	LSF	1,350	1.33	1,055.95	501.24	7,518.60
D8	2004	Renville	LSF	770	0.7	1,244.32	306.00	4,590.00
D8	2004	Pipestone	LSF	2,075	1.8	2,948.61	711.31	10,669.70
D8	2004	Lincoln	LSF	2,020	2.4	3,992.64	685.88	10,288.20
D8	2004	Lyon	LSF	1,100	0.25	1,489.48	220.00	3,080.00
D8	2007	Redwood	LSF	1,500	2.58	6,058.68	603.61	9,054.15
D8	2008	Renville	LSF	1,292	0.6	2,255.93	613.88	9,208.20
D8	2009	Renville	LSF	350	0.26	1,457.38	146.23	2,193.45
D8	2009	Lincoln	LSF	945	3.9	6,494.86	407.11	6,106.65
D8	2009	Lincoln	LSF	2,033	7	4,738.69	894.51	9,839.61
D8	2010	Redwood	LSF	525	2.8	1,209.39	214.09	3,211.35
M	2003	Chisago	LSF	3,150	1.8	0.00	955.50	9,555.00
M	2003	Chisago	LSF	700	1.48	0.00	212.00	3,180.00
M	2003	Chisago	LSF	620	2.13	0.00	187.90	2,818.50
M	2009	Scott	LSF	860	2.03	0.00	382.69	5,740.35
M	2010	Scott	LSF	2,330	7.4	11,956.25	1,012.00	15,180.00
Totals				114,910	260.52	152,679.83	41,403.92	531,834.74

Appendix R

Safety Assessment of the Installation of Snow Fences

Safety Assessment of the Installation of Snow Fences

Structural Snow Fence Protecting TH 14 Near Cobden, MN
http://www.dot.state.mn.us/environment/livingsnowfence/2007storm.html

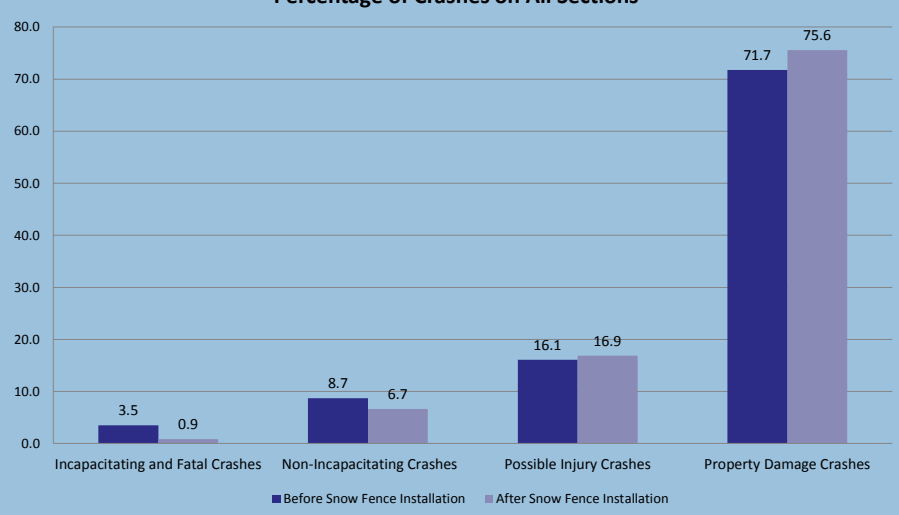
Data Sources

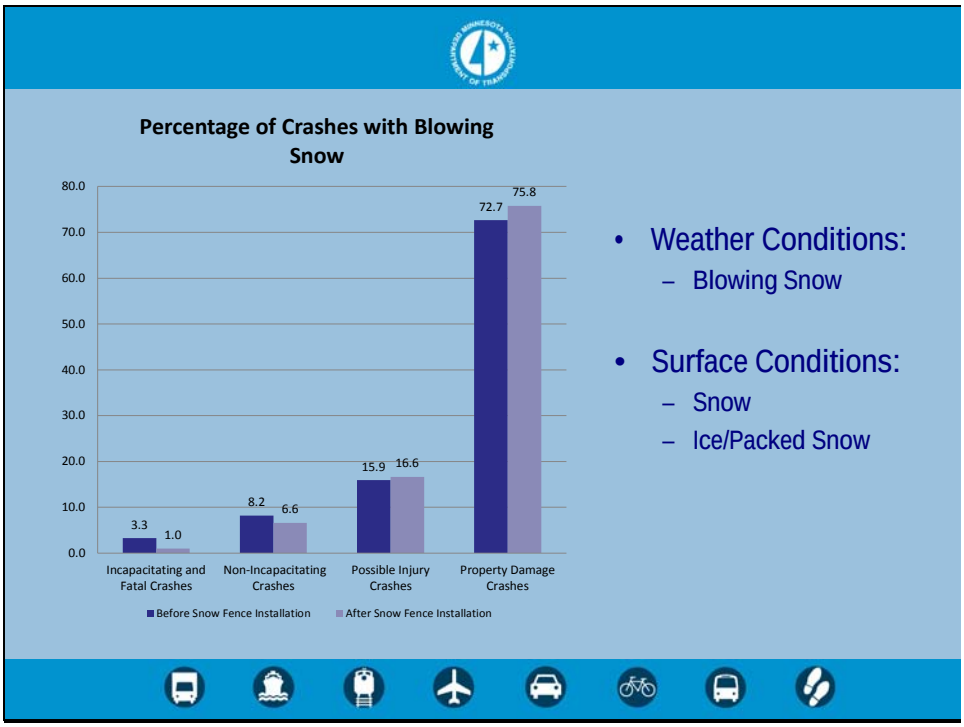
- Crash data collected from TIS Crash Data 1984-2009
- Snow Fence location data collected from Mn/DOT's Office of Environmental Services

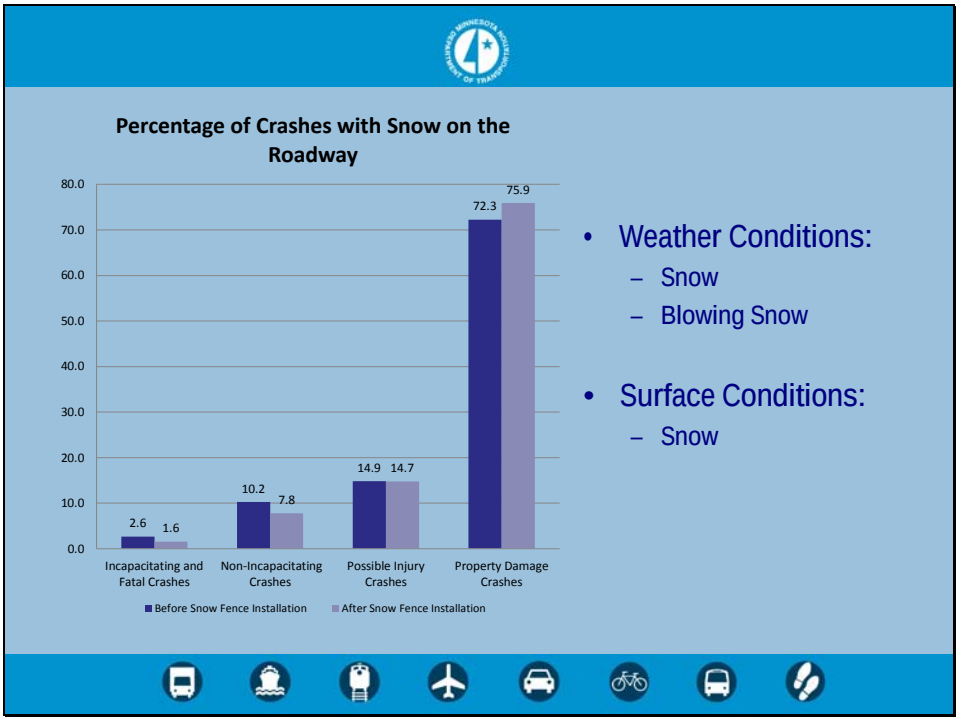
- Data only includes crashes within ~1000 ft of a snow fence
- Percentages shown are from Statewide Crash locations

Safety Analysis for Severe Injury and Fatal Crashes on All Sections

- Considered crashes before and after the installation of a snow fence
- Data only includes crashes that occurred between October and May
- Weather conditions considered:
  - -Snow
  - -Blowing Sand/Dust/Snow*
- Surface conditions considered:
  - -Snow
  - -Ice/Packed Snow




Percentage of Crashes with Blowing Snow
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
3.3
1.0
8.2
6.6
15.9
16.6
72.7
75.8
Incapacitating and Fatal Crashes
Non-Incapacitating Crashes
Possible Injury Crashes
Property Damage Crashes
Before Snow Fence Installation
After Snow Fence Installation
• Weather Conditions:
– Blowing Snow
• Surface Conditions:
– Snow
– Ice/Packed Snow


Percentage of Crashes with Snow on the Roadway
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
2.6
1.6
10.2
7.8
14.9
14.7
72.3
75.9
Incapacitating and Fatal Crashes
Non-Incapacitating Crashes
Possible Injury Crashes
Property Damage Crashes
Before Snow Fence Installation
After Snow Fence Installation
• Weather Conditions:
– Snow
– Blowing Snow
• Surface Conditions:
– Snow

Preliminary Results

- The installation of Snow Fences reduces severe injury and fatal crashes associated with blowing snow and snow on the roadway by about 2.5%

- The installation of Snow Fences play a larger roll in preventing crashes during blowing snow than when snow is present on the roadway surface

Note: Difference between snow fence types were not statistically significant

Example: 12 ft Snow Fence on I-80 in Wyoming

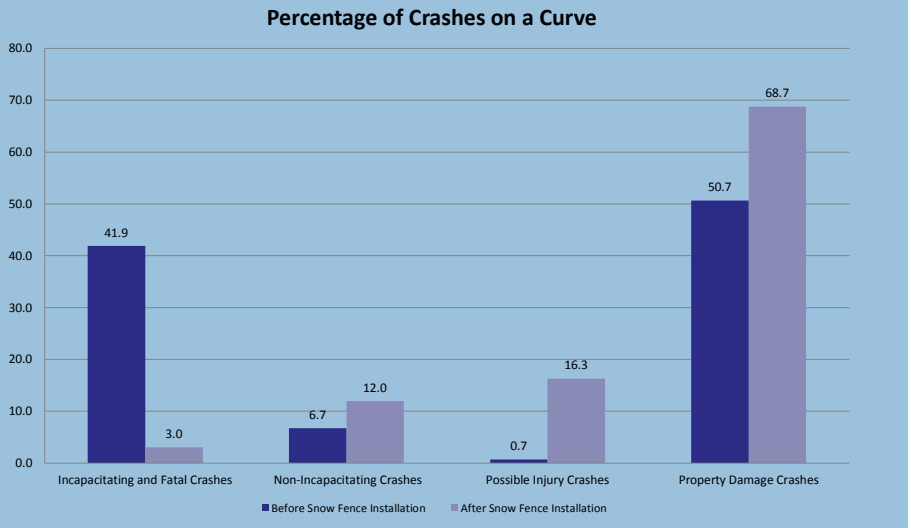
Before Snow Fence Section

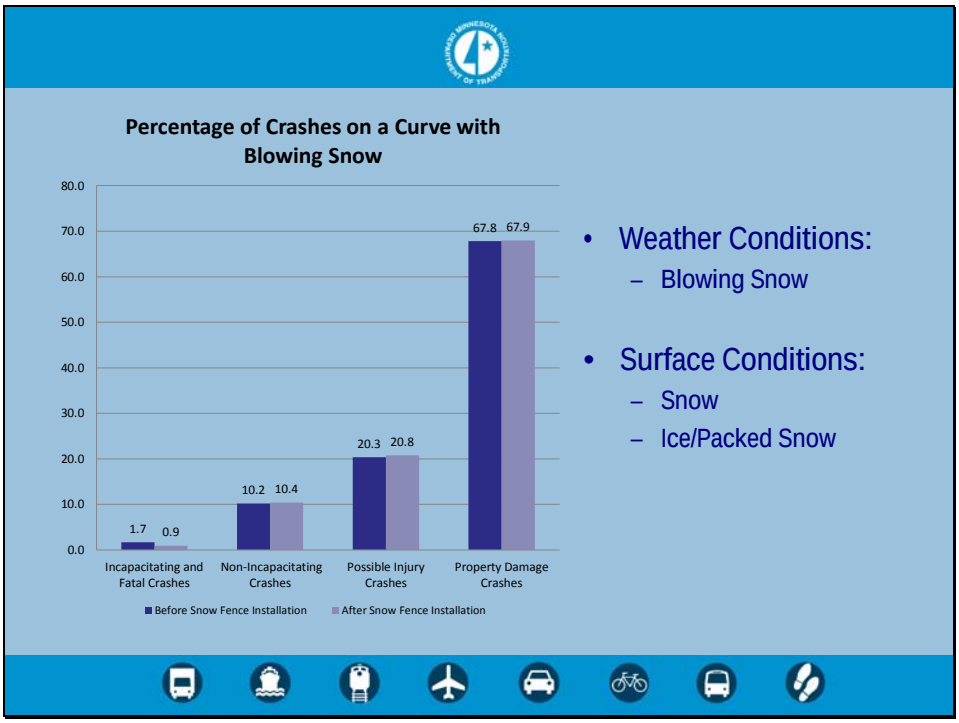
Snow Fence Section

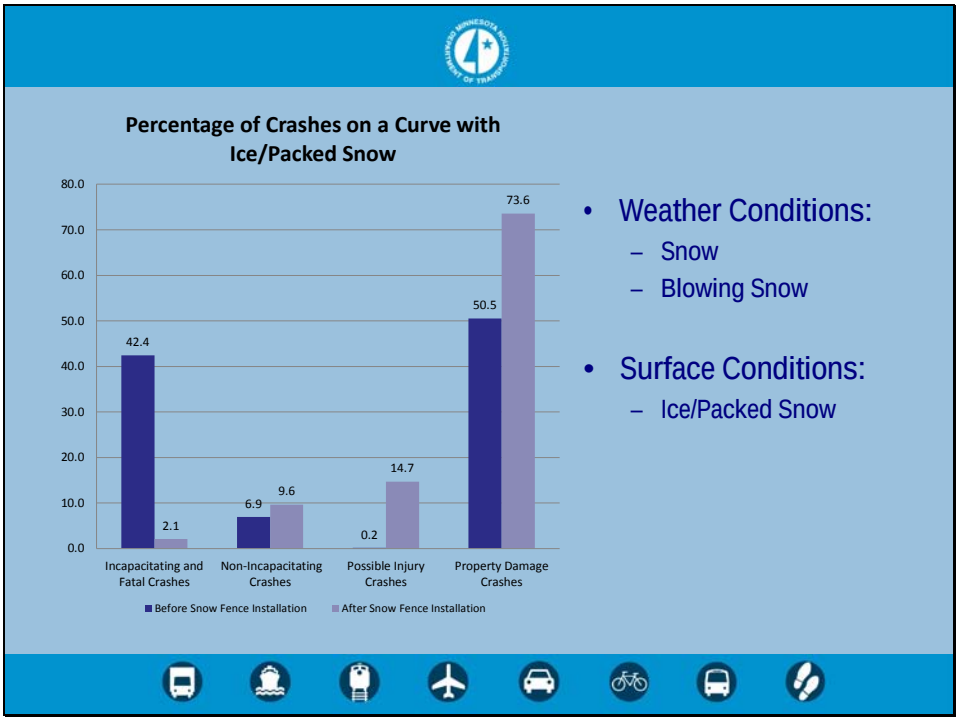
http://www.tablerassociates.com/assets/Docs/US287rep.pdf

Safety Analysis for Severe Injury and Fatal Crashes on Curves

- Considered crashes before and after the installation of a snow fence
- Only considered crashes that occurred on a Curve and a weather condition described as Ice/Packed Snow and Blowing Snow
- Curves include:
  - -Curve and Level
  - -Curve and Grade
  - -Curve at Hillcrest
  - -Curve at Sag




Percentage of Crashes on a Curve with Blowing Snow
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
1.7
0.9
10.2
10.4
20.3
20.8
67.8
67.9
Incapacitating and Fatal Crashes
Non-Incapacitating Crashes
Possible Injury Crashes
Property Damage Crashes
Before Snow Fence Installation
After Snow Fence Installation
• Weather Conditions:
– Blowing Snow
• Surface Conditions:
– Snow
– Ice/Packed Snow

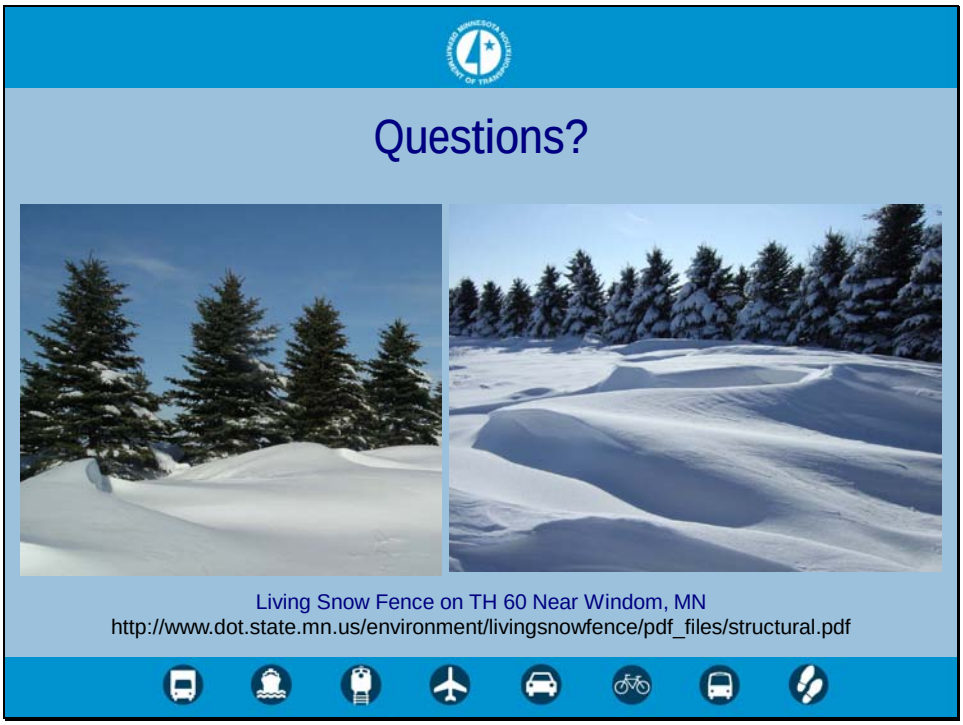

Percentage of Crashes on a Curve with Ice/Packed Snow
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
42.4
2.1
6.9
9.6
0.2
14.7
50.5
73.6
Incapacitating and Fatal Crashes
Non-Incapacitating Crashes
Possible Injury Crashes
Property Damage Crashes
Before Snow Fence Installation
After Snow Fence Installation
• Weather Conditions:
– Snow
– Blowing Snow
• Surface Conditions:
– Ice/Packed Snow

Preliminary Results

- The installation of Snow Fences substantially reduces severe injury and fatal crashes on curves associated with packed snow by about 40%
- The installation of Snow Fences play a larger roll in preventing crashes when there is Ice/Packed Snow present on the roadway surface than during Blowing Snow
- The increase of Non-Incapacitating Crashes on curves may be related to the drastic reduction in severe injury and fatal crashes

Example: 12.5 ft (3.8m) Snow Fence on I-80 in Wyoming

http://www.tablerassociates.com/assets/Docs/US287rep.pdf



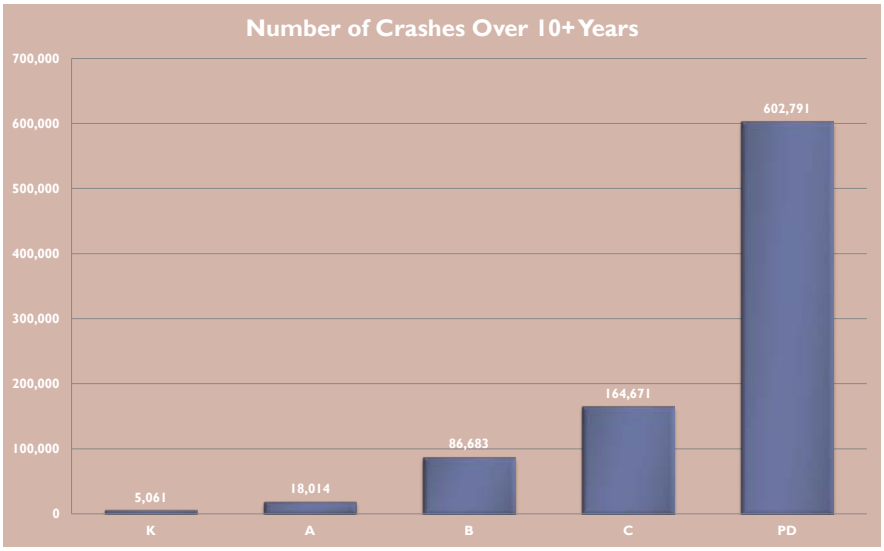
Data collected and summarized by the
Safety Section of MnDOT's Office of Traffic, Safety and Technology, 2011

Appendix S

Winter-Related Crashes

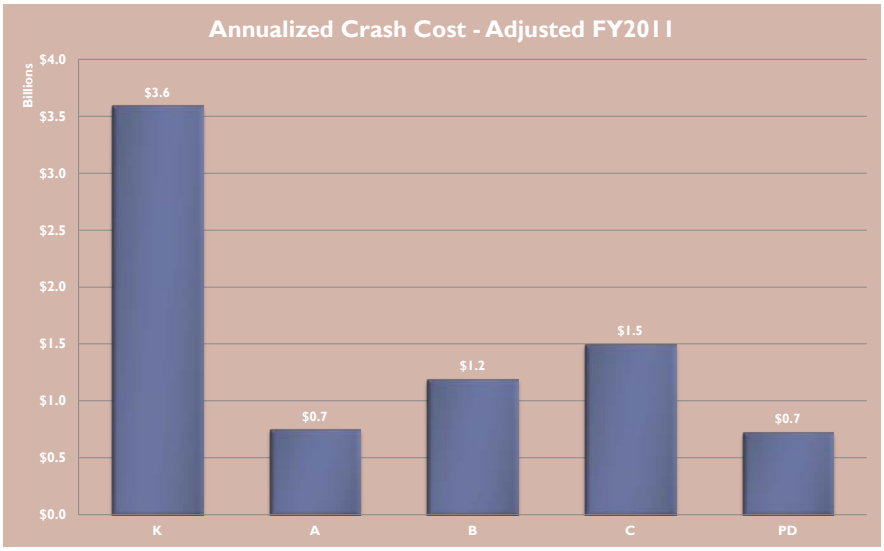
Winter-Related Crashes

At a Glance…



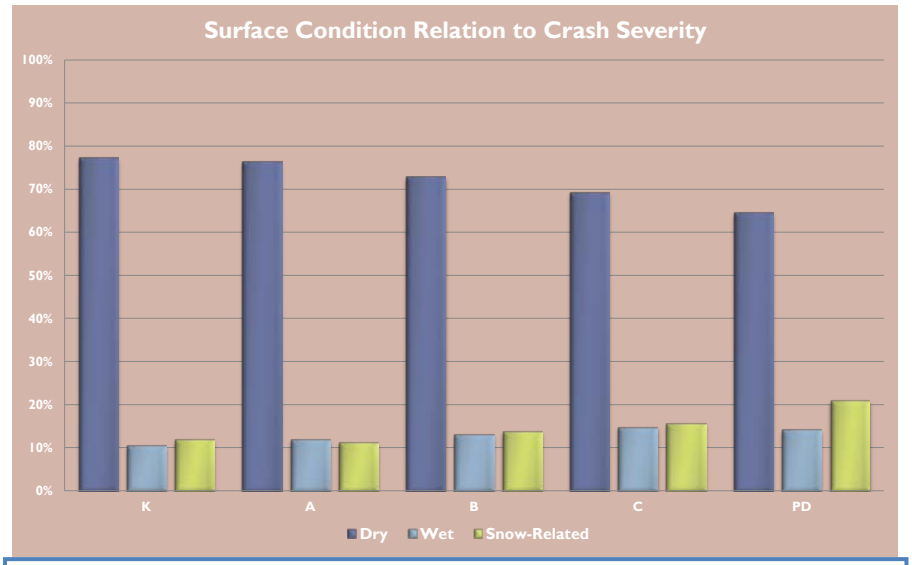
K=Fatal **A**=Incapacitating **B**=Non-incapacitating **C**=Possible Injury **PD**=Property Damage

At a Glance…



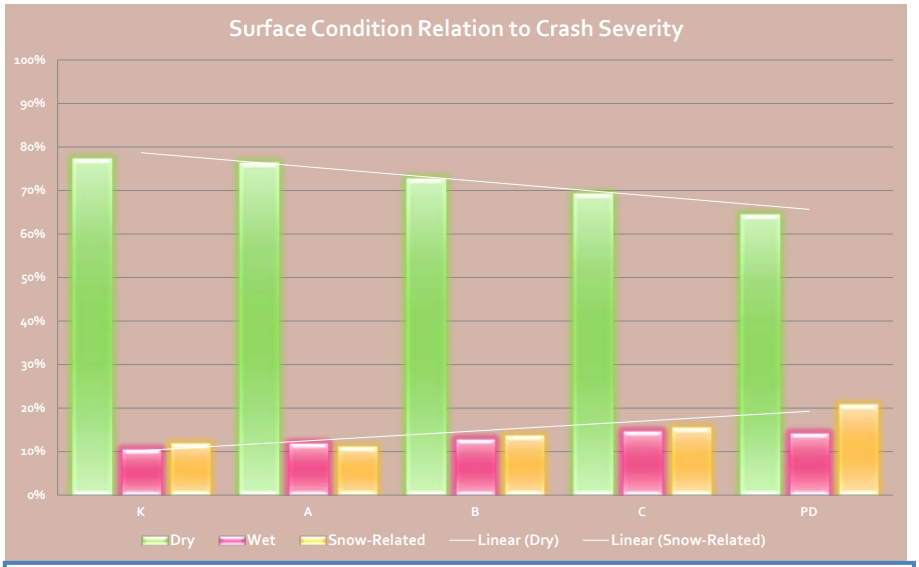
K=Fatal **A**=Incapacitating **B**=Non-incapacitating **C**=Possible Injury **PD**=Property Damage

Surface Condition



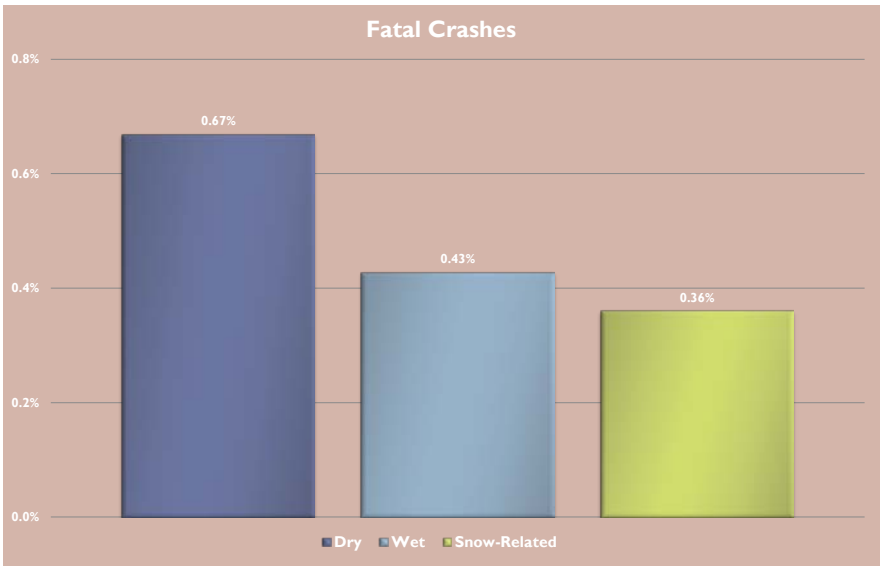
K=Fatal **A**=Incapacitating **B**=Non-incapacitating **C**=Possible Injury **PD**=Property Damage

Surface Condition



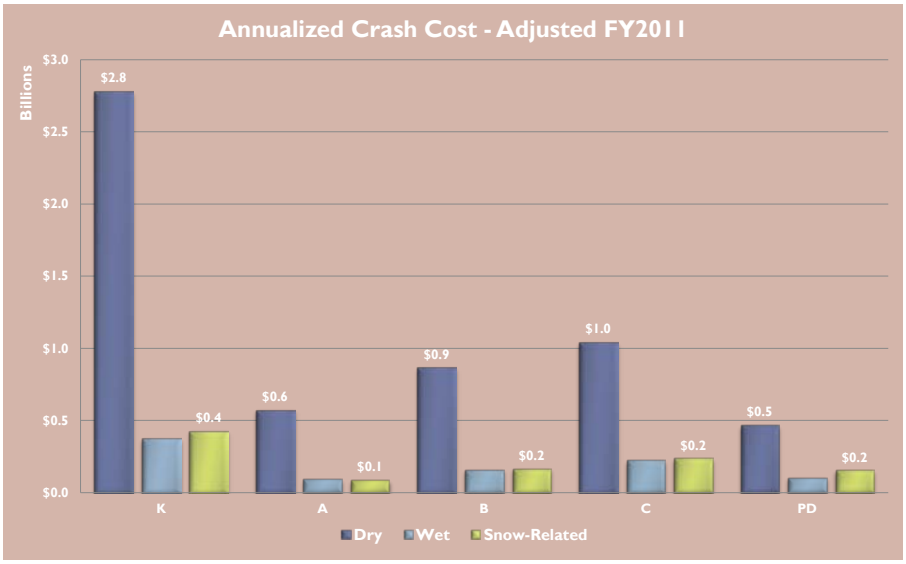
K=Fatal **A**=Incapacitating **B**=Non-incapacitating **C**=Possible Injury **PD**=Property Damage

Surface Condition



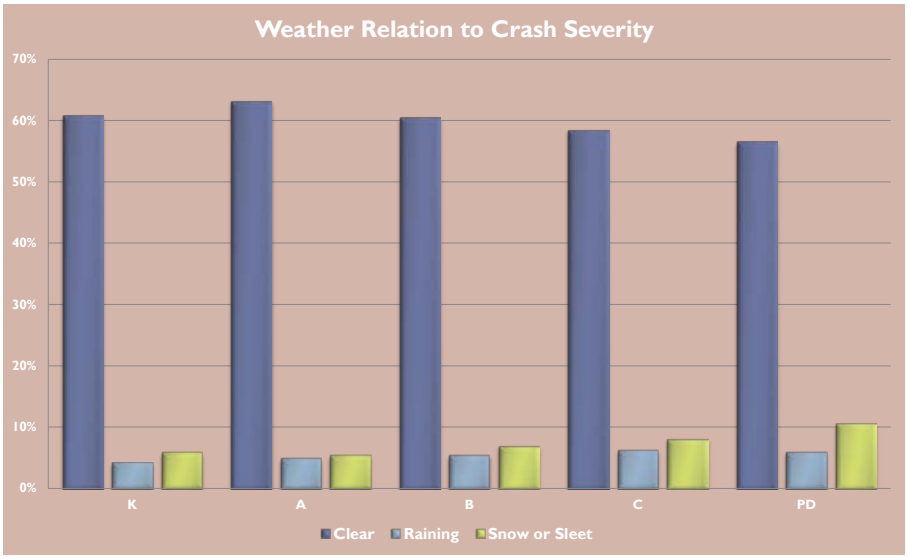
Surface Condition

Surface Condition



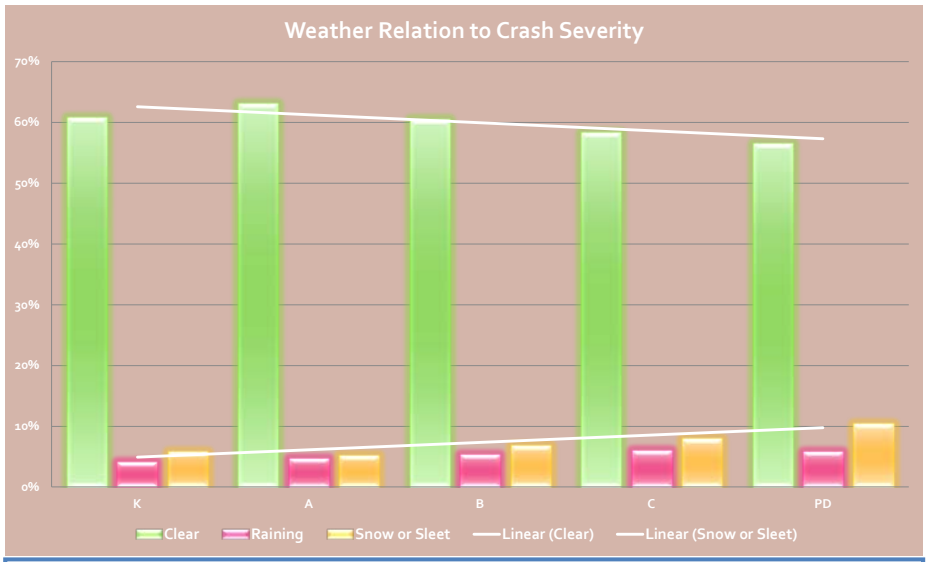
K=Fatal **A**=Incapacitating **B**=Non-incapacitating **C**=Possible Injury **PD**=Property Damage

Weather Condition



K=Fatal **A**=Incapacitating **B**=Non-incapacitating **C**=Possible Injury **PD**=Property Damage

Weather Condition

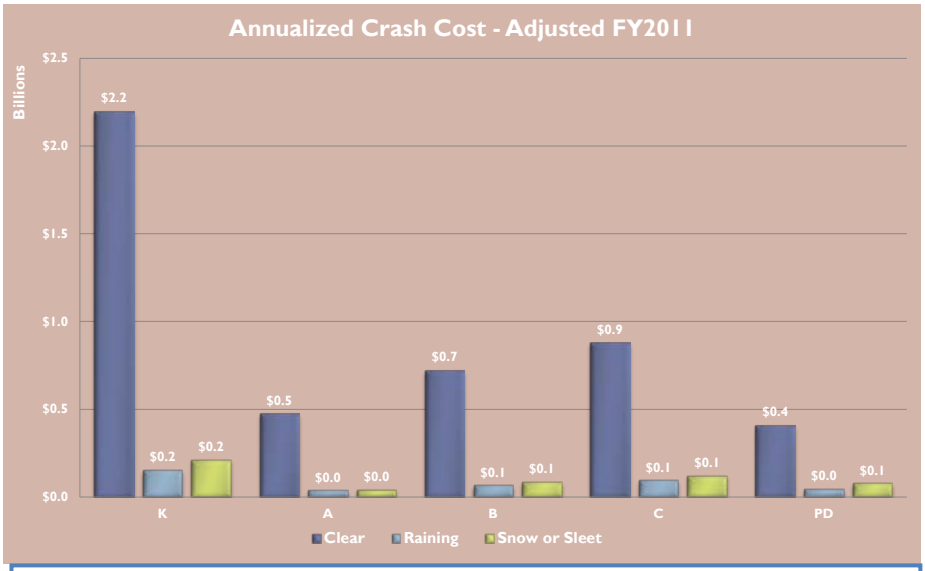


K=Fatal **A**=Incapacitating **B**=Non-incapacitating **C**=Possible Injury **PD**=Property Damage

Weather Condition

Weather Condition

Weather Condition



K=Fatal A=Incapacitating B=Non-incapacitating C=Possible Injury PD=Property Damage

- Correlation between poor conditions and decreased fatal crashes and increased property damage crashes
- Reduction due to cautious drivers? Fewer drivers on roadways?
- What ever the reason, snow-related crashes cost less overall due to decreased severity

Data collected and summarized by the
Safety Section of MnDOT's Office of Traffic, Safety and Technology, 2011