LIVING SNOW FENCES

IOWA HIGHWAY RESEARCH BOARD PROJECT TR 460

Final Report

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ABSTRACT

Blowing snow can cause significant problems for mobility and safety during winter weather in three distinct ways. It may drift onto the road, thus requiring almost continuous plowing while the wind is blowing (which may occur when a given winter storm is over). Snow may drift onto wet pavement (perhaps caused by ice control chemicals) and dilute out the chemicals on the road, creating ice on the road. And sufficient blowing snow can cause a major deterioration in visibility on the road, a factor which has been shown to be significant in winter crashes.

The problem of blowing snow can be very effectively addressed by creating a snow storage device upwind of the road that requires protection from snow drifting. Typically, these storage devices are fences. Extensive design guidance exists for the required height and placement of such fences for a given annual snowfall and given local topography. However, the design information on the placement of living snow fences is less complete. The purpose of this report is to present the results of three seasons of study on using standing corn as snow fences. In addition, the experience of using switch grass as a snow storage medium is also presented. On the basis of these experimental data, a design guide has been developed that makes use of the somewhat unique snow storage characteristics of standing corn snow fences.

The results of the field tests on using standing corn showed that multiple rows of standing corn store snow rather differently than a traditional wooden snow fence. Specifically, while a traditional fence stores most of the snow downwind from the fence (and thus must be placed a significant distance upwind of the road to be protected, specifically at least 35 times the snow fence height) rows of standing corn store the majority of the snow within the rows. Results from the three winters of testing show that the standing corn snow fences can store as much snow within the rows of standing corn as a traditional fence of typical height for operation in Iowa (4 to 6 feet) can store. This finding is significant because it means that the snow fences can be placed at the edge of the farmer’s field closest to the road, and still be effective. This is typically much more convenient for the farmer and thus may mean that more farmers would be willing to participate in a program that uses standing corn than in traditional programs.

On the basis of the experimental data, design guidance for the use of standing corn as a snow storage device in Iowa is given in the report. Specifically, it is recommended that if the fetch in a location to be protected is less than 5,000 feet, then 16 rows of standing corn should be used, at the edge of the field adjacent to the right of way. If the fetch is greater than 5,000 feet, then 24 rows of standing corn should be used. This is based on a row spacing of 22 inches. Further, it should be noted that these design recommendations are ONLY for the State of Iowa. Other states of course have different winter weather and without extensive further study, it cannot be said that these guidelines would be effective in other locations with other winter conditions.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1. INTRODUCTION

Once wind speed exceeds about 15 mph snow will begin to drift. There are a number of consequences to this drifting. The snow itself will typically move along at a height approximately equal to that of a passenger vehicle windscreen, thus having a significantly detrimental effect on the visibility of the road as perceived by vehicle operators. A low visibility condition caused by blowing snow is shown in Figure 1.1. A second impact is that the blowing or drifting snow will often accumulate in drifts across the road. In some circumstances, these drifts may be many feet deep, and may effectively close the road. Even when the drifting is not that severe, the snow will make driving on the segment of road with drifting more hazardous than it needs to be. The third drawback of drifting snow is that if the road across which it is drifting is either wet, or warm (above freezing temperature) the snow will tend to stick to the pavement surface, rather than blowing across it. Under this circumstance, there is a high probability that the drifted snow will turn to ice on the pavement surface, thus creating a hazardous situation.

Figure 1.1: Reduced Visibility Due to Blowing Snow

Even if snow drifts across a road are cleared, considerable effort will be expended that could be more usefully expended on other tasks. Further, the snow will drift back across the road, leading to an unending task (see Figure 1.2), and any snow stored by the road side is subject to melting and refreezing. This refreezing can create hazardous conditions, in essence giving rise to ice patches on the road (see Figure 1.3). Further, as shown in Figure 1.2, the snow drifts themselves may restrict vision around curves in the road.

Figure 1.2: A Road with Significant and Recurrent Drifting

Figure 1.3: Melting and Refreezing from Drifted Snow

This situation can be avoided if the snow can be accumulated in some place other than the pavement surface, and constrained to stay in that location. If this is not done, significant effort will be required by maintenance forces to achieve and maintain bare pavement in those locations impacted by drifting. One way of achieving this snow storage has been through the use of a snow fence. The snow fence is typically an artificial structure placed some distance upwind of the roadway. As the snow blows through this structure, it decelerates, and deposits the snow particles that were previously being blown by the wind. The result of this is the creation of a snow drift located for the most part downwind of the snow fence (see Figure 1.4).

Figure 1.4: A Typical Snowdrift Formed by a Snow Fence

The use of snow fences dates back to at least 1852 (Tabler, 2003), and extensive use of snow fences on highways began (in Wyoming) in the 1930’s. Not all of these early fences were made of wood. Tabler (1986) reports on a snow fence constructed in 1868, made of rock, and used to protect a railroad cut. A variety of different plants and vegetation have been considered for use in snow fences for many years (Bates and Stoeckler, 1941; Tabler, 2003) and it is clear that the use of such natural snow fences can be particularly effective with regard to cost, under the correct circumstances (Walvatne, 1991; Shaw, 1989; Powell et al., 1992)

The purpose of this study was to examine the use of living snow fences (specifically making use of standing corn) and by use of this examination, develop design guidelines that will be relevant and useful in Iowa. To achieve these goals, a literature survey was conducted, and a number of field studies were performed. Using the results of these two stages, some straightforward design guidelines have been developed. In developing the design guidelines, considerable weight was given to the need to develop designs that were not only technically feasible, but also “humanly” feasible. Specifically, the designs guidelines have attempted to address some of the stated concerns of farmers and other landowners with regard to snow fence placement.

2. LITERATURE REVIEW

Previous work on snow fences can be considered in two parts for the purpose of this study. The first part is the literature on snow fences in general, which tends to concentrate on artificial or constructed snow fences. The second part, which is to some degree, but not totally, contained within the first is the literature that pertains to living snow fences in their various forms. This literature review will first present a brief overview of the first part, followed by a more detailed review of the literature of living snow fences.

2.1 Snow Storage Devices in General

Initial placement of many artificial snow fences was incorrect, as noted by Tabler (2003) due to an incomplete understanding of how snow fences store snow. This was coupled with an incomplete knowledge of how to design such fences not only in terms of placement but also in terms of height, and porosity.

The benefits of appropriately designed and located snow fences in areas of drifting snow are significant both in terms of money saved and in terms of improvements to both mobility and safety. Tabler and Furnish (1982) and Tabler (2003) discuss these savings in detail, using data from a study on Interstate 80 in Wyoming. In terms of reductions in accidents, the cost of the fences installed on the section in the study was repaid in approximately one winter season. The benefits in terms of reduced snow removal clearly is a function of how much snow the fences keep off the road (which thus does not have to be plowed off the road). Tabler (2003) reports that a permanent snow fence will have a benefit to cost ratio of between 50 and 100 to 1 in terms of snow removal costs alone.

Tabler (1991, 2003) shows that the amount of snow that a fence needs to store can be related, for design purposes, to two factors: the average annual snowfall at the location in question, and the fetch over which wind can blow unimpeded upwind of the snow fence and the location to be protected. This understanding has been developed from a number of fundamental studies on the behavior of snow under the effect of wind. Mellor (1965) identified three types of snow movement: creep, saltation, and turbulent diffusion.

Large snow particles will roll or creep along the surface of the snow until wind speeds reach about 35 mph. This action creates dunes of snow that will migrate downwind. Approximately one quarter of the total snow transported at low wind speeds is transported by this mechanism (Tabler, 2003).

Smaller particles move by the process of saltation. This can be described as a bouncing along the surface in steps of about 4 inches in length and about half an inch high (Kobayashi, 1972). The smallest particles move by turbulent diffusion. In this mode of motion, the particles of snow are suspended in the air and do not come into contact with the ground. For this to happen, the lift forces on the snow particle due to the wind must be greater than the gravitational force on the particle due to its mass. Pomeroy (1988, 1989) indicates that most snow carried by turbulent diffusion is within about three feet of the surface, and further, that most transported snow moves by turbulent diffusion. The aim, therefore, of a snow storage device is to interrupt this process, and ensure that once particles have settled to the ground they do not get given the impetus to become airborne again.

Studies indicate that most snow transport by the three processes described above will cease when wind speeds drop below about 15 mph (Schmidt, 1981; Tabler et al., 1990). This certainly is consistent with rules of thumb for the use of salt or other chemicals in drifting conditions. For salt in particular, such rules talk in terms of 15/15 or 20/20. That is, salt should not be used when wind speeds exceed 15 mph, or when surface temperatures drop below 15º F. Tabler (1991), using work by Mellor and Fellers (1986) showed that the quantity of snow carried by the wind (termed Q, and measured in kg/s) can be expressed in terms of U_{10} the wind speed (measured in m/s) at a height of 10 meters (this height is one at which many meteorological measurements of wind speed are taken) in the form:

$$Q = \frac{U_{10}^{3.8}}{233{,}847} \tag{1}$$

While calculating such mass transport values is clearly not a particularly useful function in the realm of winter maintenance, the nature of the equation indicates clearly that as wind speed drops, so too will snow transport. Thus, one role of a snow fence is to cause a local decrease in wind speed, such that snow will be deposited at the location of the snow fence. In addition to this, fences create a turbulent zone at a height greater than that of the fence, from which snow particles will be deposited.

Tabler (2003) uses this theory of snow particle movement to develop general relationships between the geometry of a fence, and the maximum amount of snow the fence stores. Of particular importance in this regard is the impact of fence height (H, in meters) and the quantity of snow stored per unit length of fence (Q, in metric tons per meter):

$$Q \propto H^{2.2} \tag{2}$$

Thus the amount of snow stored increases at a rate slightly greater than the square of the fence height. Tabler (2003) also gives specific relationships for particular types of snow fence. Thus for fences comprising vertical slats of wood (see Figure 1.4 for an example of this type of fence) the relationship (for fences less than 2 meters in height – a little more than 6 feet) is:

$$Q = 7.9H^{2.2} \tag{3}$$

Where Q and H are as defined above. Other fence designs (such as the Wyoming fence, which is 8 feet high, and approximately triangular in cross section) exhibit similar relationships, but Tabler (2003) gives no such relationships (in the form of equations 1, 2, or 3) for living snow fences. This relationship will be of value when estimating how much snow typical snow fences in Iowa need to store. The vertical slat type of fence is very common in Iowa.

Another approach to snow drift control on highways is to attempt to accelerate the snow across the highway. This approach has been used in Japan (see for example Yamazaki, 2006). This study used a vaned fence directly adjacent to the highway (in the right of way). The purpose of this fence is to accelerate the wind as it approaches the road, thus carrying the snow particles across the road, avoiding drift problems at that location. The primary concern with this approach is that it places a significant barrier in the clear zone. In Japan these accelerating fences are typically more than 6 feet high, made of metal, and placed within six feet of the edge of the highway. Such an approach is not suitable for highways in the U.S.

In additional recent work, Tabler (2004) reported on the impact of blowing snow on pavement temperatures and ice formation. He found that temperatures on sections of highway protected by snow fences may be as much as 10º F (6º C) warmer than similar, unprotected, pavement surfaces. This result adds to the other benefits of snow fences as a method for protecting the pavement during winter weather, and thus improving both safety and mobility for the traveling public.

2.2 Living Snow Fences

There are a number of reports that discuss the use of living snow fences. In considering the information from these reports, distinction must be made between permanent living snow fences (e.g. stands of trees) and temporary or single season living snow fences (rows of standing corn left unharvested in the fall). Popular selections for living snow fences are trees and shrubs, wildflowers, and rows of corn. Similar to the popular structural barrier, the living snow fence causes blowing snow to accumulate in a well-planned designated area. Installation and maintenance can be up to 90 percent cheaper and the alternate snow fence can capture up to 12 times more snow per foot of height than a traditional snow fence (USDA, 1994).

Three principle references consider the use of living snow fences. Tabler (2003) considers both permanent and temporary living snow fences. For both sorts of fences he indicates that the set-back from the road should be at least 35 times the height required for a structural fence at the given location. In particular, he notes that standard practice in Minnesota requires a setback of at least 46 m (150 feet) from the right of way, and that a setback of 30 m (100 feet) proved too close. Tabler (2003) recommends two stands of six to eight rows of corn in each stand, with the stand closest to the road set back 65 m (220 feet) and with a further 45 m (150 feet) between the first stand and the second stand.

Minnesota DOT (1999) has developed an extensive guide to the design of living snow fences and living snow retention devices (basically, shrubs and smaller vegetation located closer to the road to catch drifting snow in small amounts at very localized trouble spots). This guide is also available on the web at: www.plantselector.dot.state.mn. Many other States have developed their own guides to living snow fences, and information can be found from the following web sites:

Table 2.1 Web Sites with Relevant Information on Living Snow Fences

Web Site Source	Web Site URL
Minnesota Department of Transportation Office of Environmental Services	http://www.livingsnowfence.dot.state.mn.us/design.html and http://www.livingsnowfence.dot.state.mn.us/mou_info.html
USDA Conservation Reserve Program (CRP)	http://www.fsa.usda.gov/pas/publications/facts/html/crpcont03.htm
USDA National Agroforestry Center	http://www.unl.edu/nac/aug94/snowfences/snowfence.html
Iowa Department of Natural Resources	http://www.iowadnr.com/forestry/pdf/CRPLivingsnowfen.pdf
South Dakota Department of Agriculture	http://www.state.sd.us/doa/forestry/publications/LSF%20Brochure.pdf
Kansas Forest Service	http://www.oznet.ksu.edu/library/FORST2/L744.PDF

In addition, the Snowbreak Forest Book Highway Snowstorm Countermeasures Manual (Hokkaido Development Bureau, translated by FHWA in 1996) provides a detailed process for designing a living snow fence based mainly on the use of trees rather than any other plants. In this design manual, they recommend a distance of only 7.5 m (about 25 feet) between the edge of the forest and the road (page 32), which is significantly less than that recommended by Tabler (2003) for example. They also note that the minimum width of the forest zone should be about 50 m (about 175 feet). It is of significant interest that this design guide indicates most snow is deposited within or upwind of the forest zone rather than downwind. This tendency reduces as the canopy cover becomes sparser and as the zone width becomes narrower, but it is clear that this guide envisages most snow being deposited upwind or within the snowbreak itself (see Diagram 3-3-2 on p. 32 of the Manual). This issue of deposition is considered further in the results segment of the study.

3. EXPERIMENTAL PROGRAM

3.1 Purpose

The purpose of this study is the development of design guidelines for living snow fences. While there is some information on this subject, it has not hitherto been collected and presented systematically. Further, there appear to be substantial gaps in the data, as indicated above. The snow fence guide (Tabler, 1991) produced during the SHRP program provides detailed design information on artificial snow fences, including size and placement as a function of average annual snowfall and dominant wind direction. Similar design information needs to be developed for living snow fences, and especially for standing corn. The goal of the project is thus to take all existing data, combined with the results of field tests, and develop a design guide for living snow fences.

The project has a number of objectives. First is to determine the optimal configuration of corn rows to "catch" drifting snow. Other living snow fences may also be studied during this part of the study, and direct comparison with artificial (i.e. wooden or plastic) snow fences will be made. This part of the project will require determining how much snow a given living snow fence configuration can store.

The second objective, once the snow storing capacity of living snow fences is determined and optimized, is to create guidelines for the use of rows of corn as snow fences. These guidelines will indicate how many rows of corn are required for given conditions, and where, relative to the road being protected, these rows should be placed.

3.2 Test Sites

Three seasons of field tests were conducted at a location on Highway 38, north of Tipton. This location had a reasonable fetch distance (approximately 1500 feet) and was at a site that had caused problems with drifting snow previously.

3.3 Testing Procedures

In all three seasons of testing, a variety of snow fence configurations were placed at the test site and their ability to trap snow during the winter season was assessed. Testing took place during the 2001-02, the 2002-03 and the 2003-04 winter seasons.

Figure 3.1 shows the average annual snowfall for Iowa over a period that includes these years

As figure 3.1 shows, the snowfall in the 2002-03 season was lower than any other year from 1988 on.

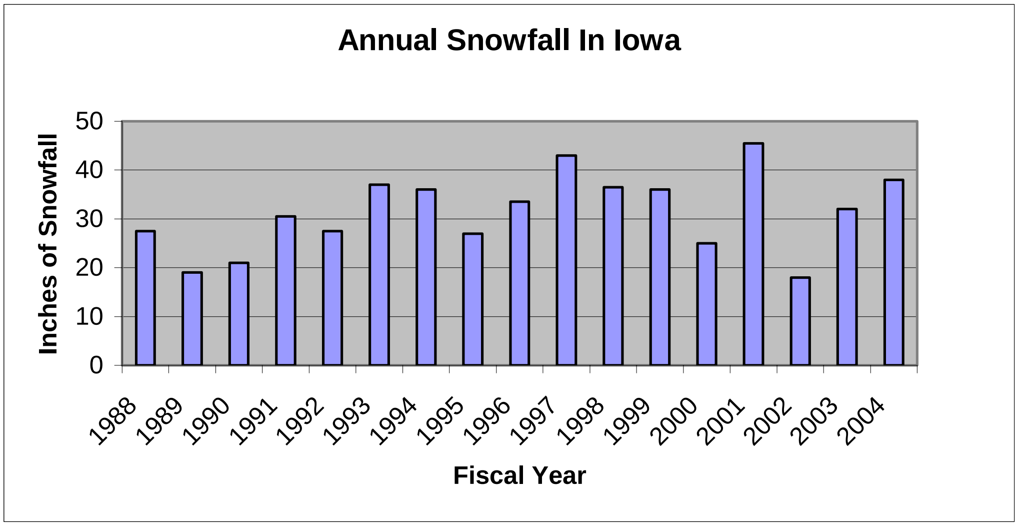

Figure 3.1 Average Annual Snowfall for Iowa (historical data)

In the first season, six lengths of snow fence protection were placed parallel to the highway. Each fence segment was 150 feet in length, and all were placed 140 feet back from the right of way. The segments alternated between rows of corn and traditional snow fence made from vertical wooden slats. The corn segments were 8 rows of corn, 16 rows of corn, and then two sets of 8 rows of corn, separated by a gap of 8 rows of corn that had been cut. The wooden snow fence segments were one segment of four-foot high wooden fence, one segment of six-foot high wooden fence, and one segment of four-foot high wooden fence with a six inch gap at the bottom of the fence. Figures 3.2 through 3.6 show various views of this configuration. Figure 3.7 shows a schematic plan of the snow fence segments.

It was immediately apparent from the observed snow storage that the rows of corn stored snow in a manner significantly different from the artificial snow fences. Rather than storing the snow downwind of the corn, the snow was stored within the rows of corn themselves. A second observation was that the rows of corn were capable of storing as much snow as the traditional snow fences, at least for the snow fall during the 2001-02 winter season. In other words, the corn snow fences, in their various configurations, were the equivalent of the artificial snow fences.

Figure 3.2: Year 1 Tests, 8 rows of corn

Figure 3.3: Year 1 Tests, 8 rows of corn adjacent to a 4 foot fence

Figure 3.4: Year 1 Tests, four foot fence adjacent to 16 rows of corn

Figure 3.5: Year 1 Tests, 16 rows of corn adjacent to six foot fence

It must be stressed that this result cannot be immediately extended to all winter seasons likely to be experienced in Iowa. The snow fall that year was above average, and the snow was completely stored within the corn rows but it remains unclear how well the corn row snow fences will perform in an extreme winter season. This will be discussed further below. However, notwithstanding the high snow fall accumulation, the corn fences worked as well as the traditional fences.

Figure 3.6: Year 1 Tests, two sets of eight rows of corn with an 8 row gap between

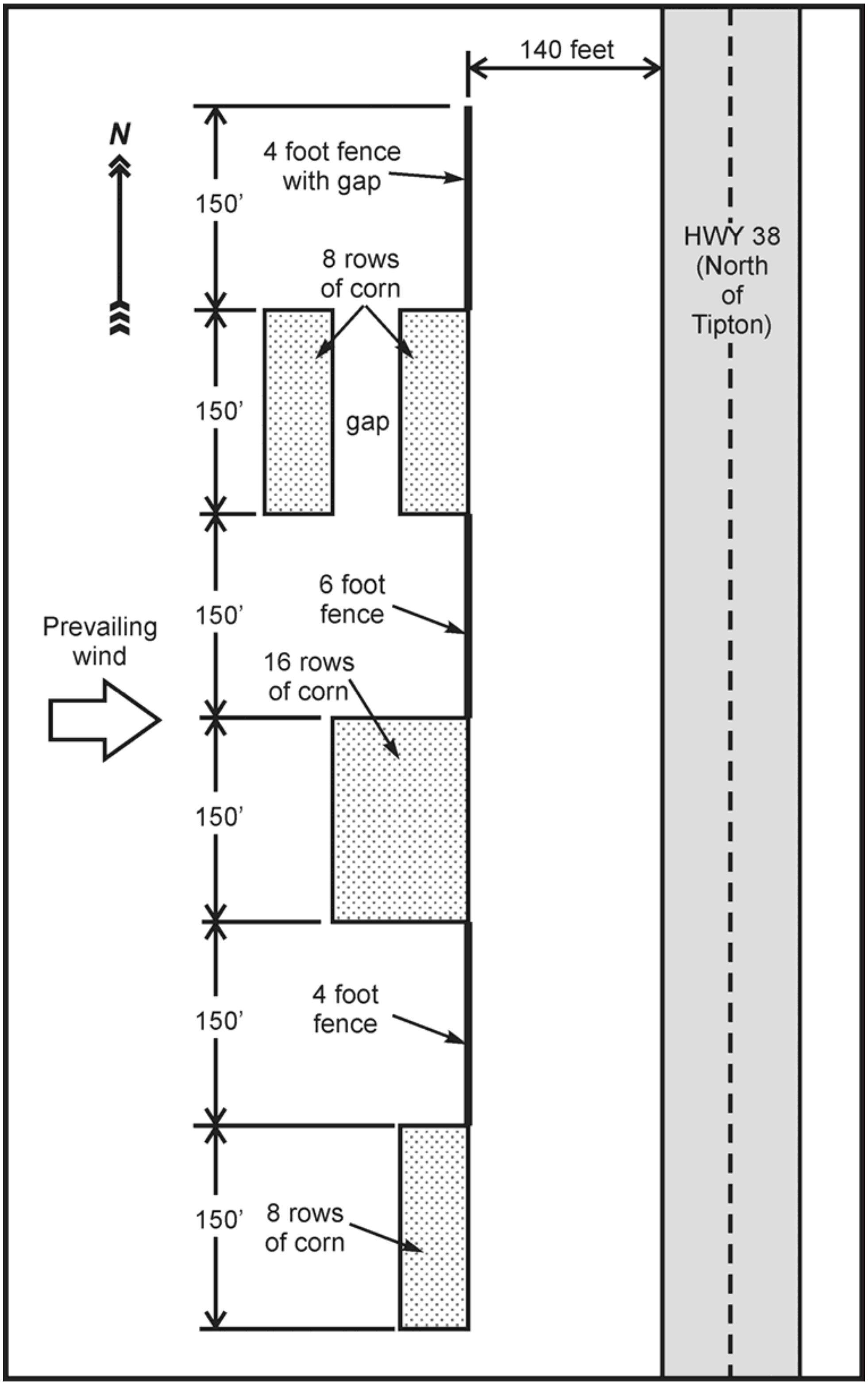

Figure 3.7: Schematic of Fence Layout for Year 1 Testing (note: the fences were placed 140 feet upwind of the edge of the pavement)

Specific depth information from the six types of fences show how effective the corn fences were when compared with traditional fences. In the following six figures (3.8 through 3.13), the x axis represents the distance (in inches) from either the traditional fence or the most upwind (i.e. farthest from the road being protected) row of corn. The data were collected on the same day that the photos in figures 3.2 through 3.5 were taken.

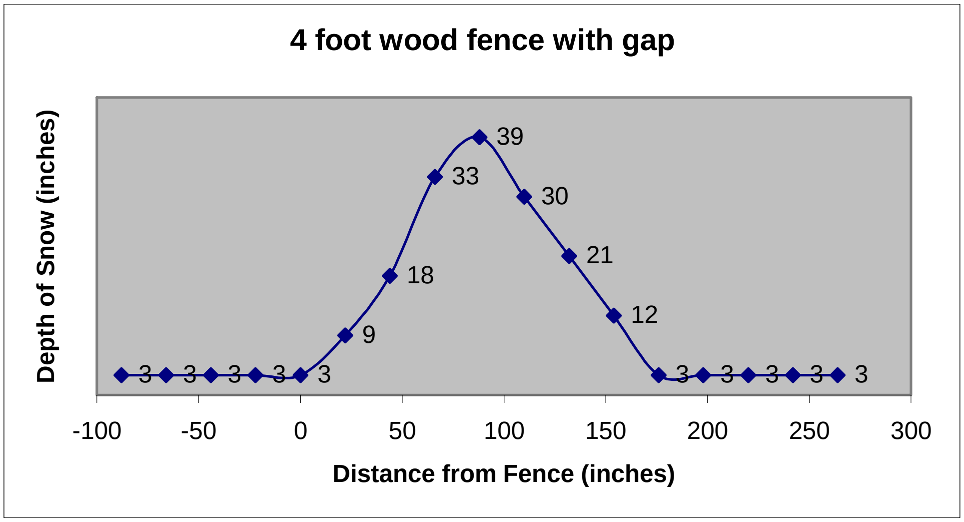

Figure 3.8: Snow Depth for a Traditional 4 ft Wood Fence with a Gap at the Bottom

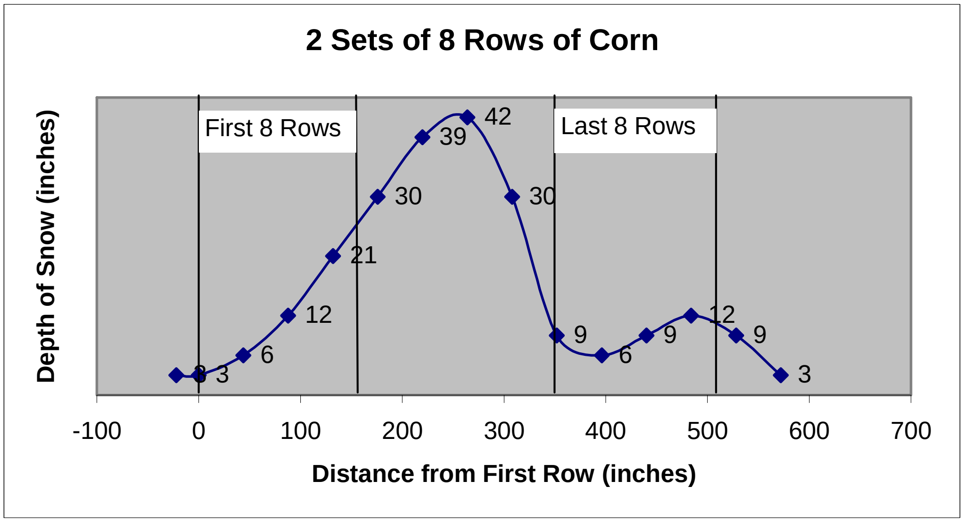

Figure 3.9: Snow Depth for Two Sets of Eight Rows of Corn, Separated by Eight Rows

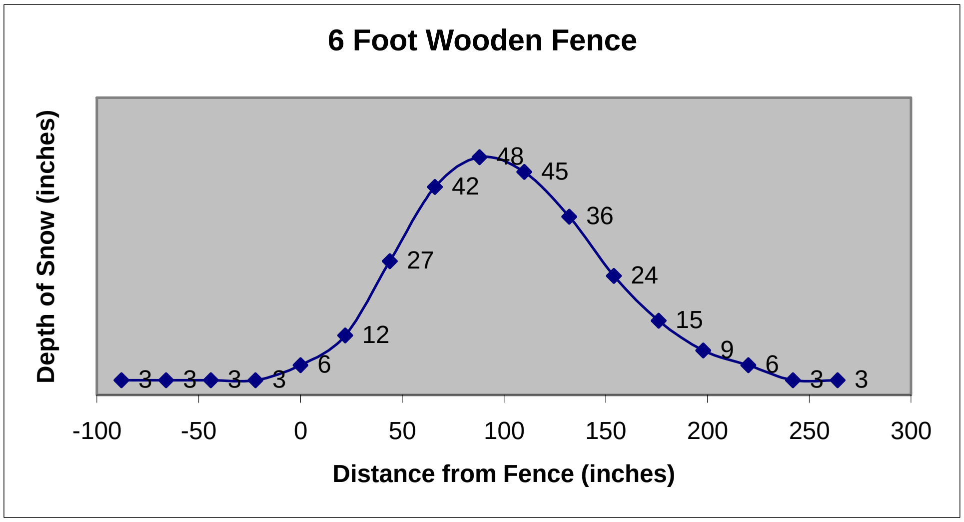

Figure 3.10: Snow Depth for Traditional Six Foot Wood Fence

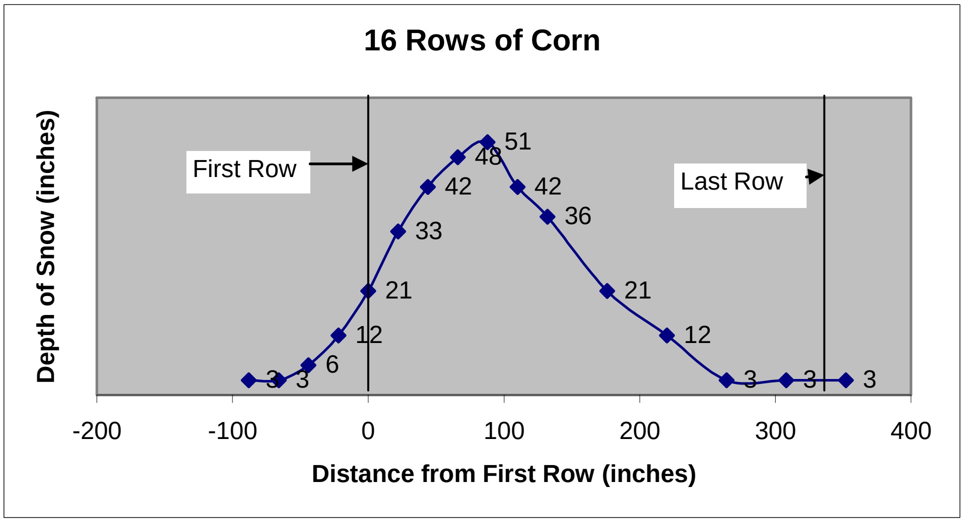

Figure 3.11: Snow Depth for Sixteen Rows of Corn

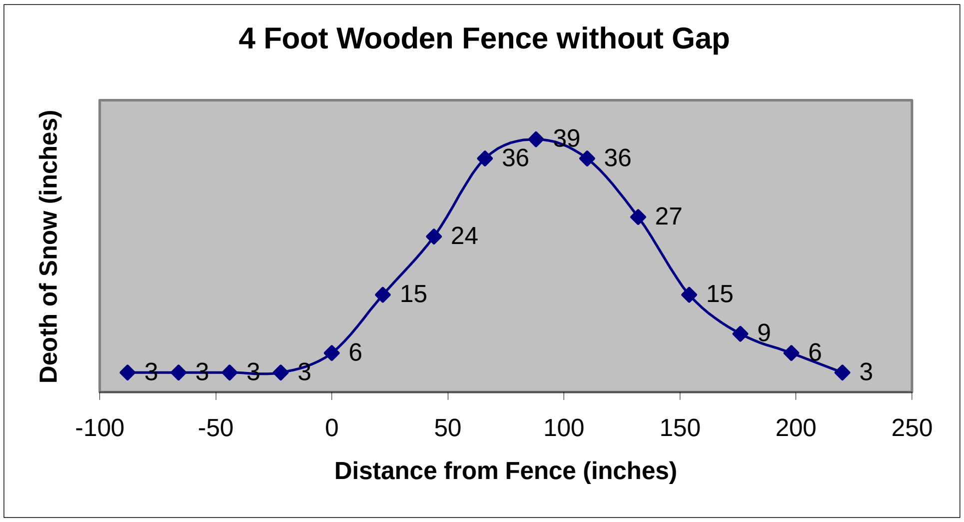

Figure 3.12: Snow Depth for Traditional Four Foot Wooden Fence without a Gap

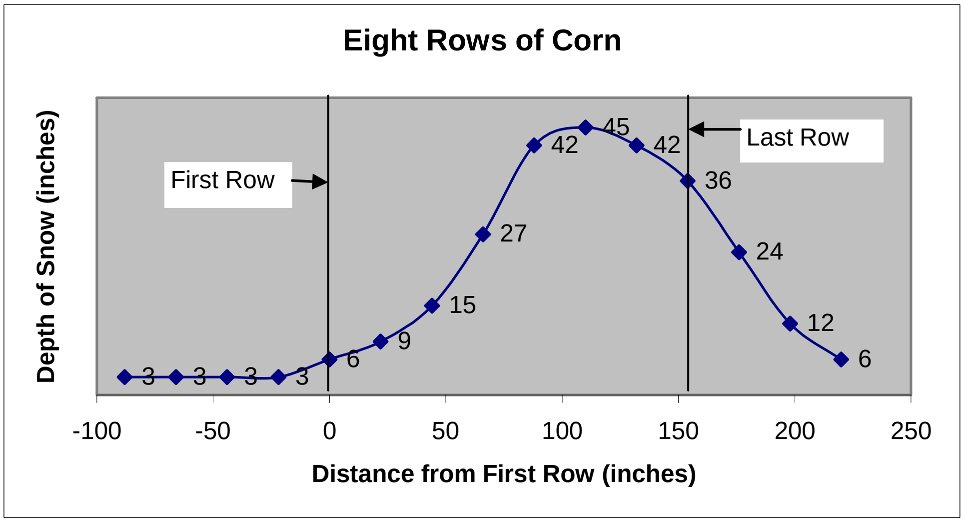

Figure 3.13: Snow Depth for Eight Rows of Corn

Snow depths shown in figures 3.8 through 3.13 were measured with a metal pole, marked at three inch intervals. Accordingly, the snow depths shown are accurate to about 1.5 to 2 inches. In each of the figures, the snow depth at a particular location is shown alongside the data point.

Given the results from the first season of testing, in the second season, it was decided to investigate further how and where snow was stored in the corn snow fences in comparison with more traditional artificial fences. To this end, a layout was developed with two arrays of corn, and one array of a traditional snow fence, as shown in Figure 3.14. Each “fence” was 150 feet long, and was placed 140 feet back from the road. Figures 3.15 and 3.16 show the fences. The traditional snow fence was four feet high.

During the season, snow depth measurements were taken after significant snow events. At that time, snow depths were measured in three-foot increments away from the base of the snow fence or the last row of corn. Thus site 3 in table 3.1 would be 9 feet from the base of the snow fence or the last (most down-wind) row of corn. February 5th and 17th were two days that had significant amount of snow to take measurements. The measurements recorded on these days are given in table 3.1.

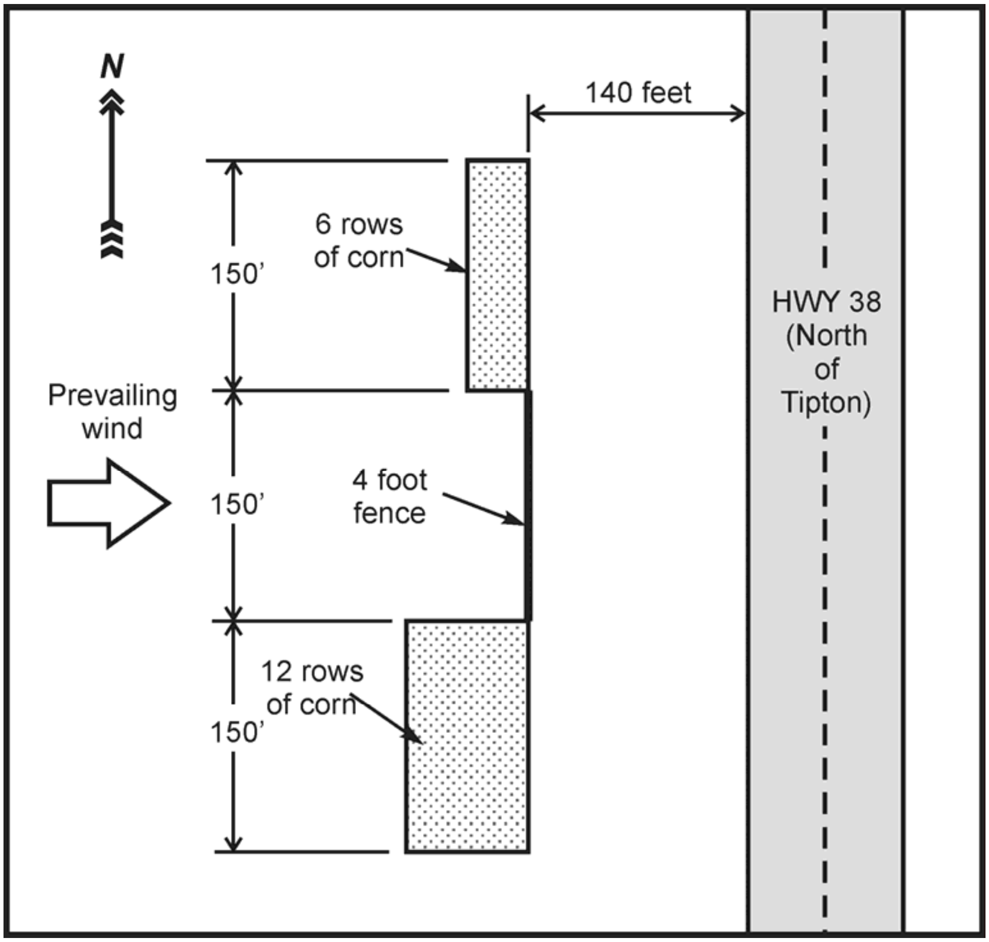

Figure 3.14: Schematic of Fence Layout for Year 2 Testing (note: the fences were placed 140 feet upwind of the edge of the pavement)

Figure 3.15: Traditional snow fence

Figure 3.16: 12 rows of corn

Table 3.1 Recorded Snow Depths (in inches) at four longitudinal positions (A, B, C, & D) and at six sites (respectively 3, 6, 9, 12, 15, and 18 feet from the fence).

Date: 2/5/2003

	6 Rows				**12 Rows**				**Snow fence**			
Site	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**J**	**K**	**L**	**M**
1	1.5	2.0	1.5	2.3	3.8	6.0	3.0	2.0	0.0	1.5	0.5	0.5
2	-	1.5	2.0	2.0	4.8	3.0	2.0	1.8	2.5	2.0	3.0	1.5
3	-	2.0	2.8	1.8	3.0	2.5	2.0	1.5	7.3	4.5	3.0	5.0
4	-	2.0	2.8	2.0	1.5	1.5	1.8	-	3.3	5.5	5.0	5.0
5	-	1.5	1.5	2.0	1.5	-	-	-	1.5	2.0	2.0	2.0
6	-	-	-	1.8	-	-	-	-	-	-	-	-

Date: 2/17/2003

	6 Rows				**12 Rows**				**Snow fence**			
Site	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**J**	**K**	**L**	**M**
1	1.0	2.5	2.5	2.3	4.5	6.5	4.0	2.5	0.5	1.0	0.5	0.5
2	-	2.0	2.5	2.0	4.0	4.5	4.0	1.5	3.0	3.0	3.3	2.0
3	-	1.5	2.0	2.0	4.3	2.0	2.5	1.5	7.0	5.5	4.0	4.5
4	-	2.0	1.0	1.5	1.5	1.0	0.5	1.0	4.5	4.5	4.5	5.0
5	-	1.0	1.0	0.5	1.0	1.0	-	-	1.3	1.5	1.5	2.0
6	-	-	-	-	-	-	-	-	-	-	-	0.5

During the research period the dew point, temperature, forecast, wind speed and directions were recorded using an automatic weather recording program and compiled into a database. The primary finding was consistent with the above annual snow fall data – the 2002-03 winter had a relatively small annual snow fall.

Figure 3.17 shows the comparison between the traditional snow fence, 6 rows of corn and 12 rows of corn.

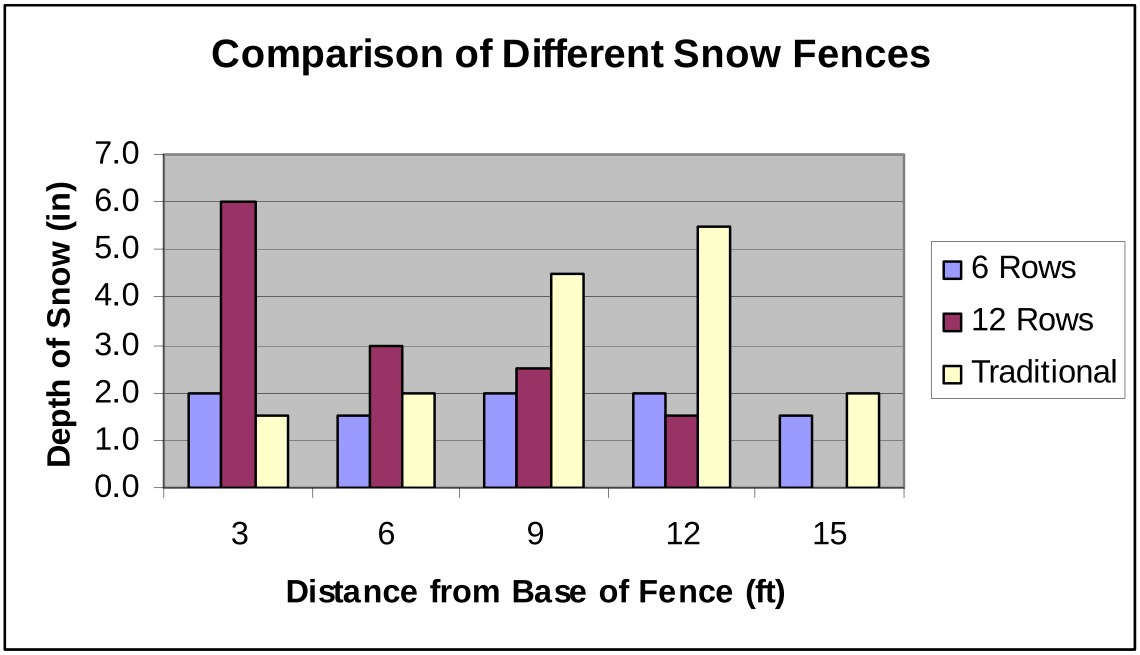

Figure 3.17: Snow Depths on February 5, 2003

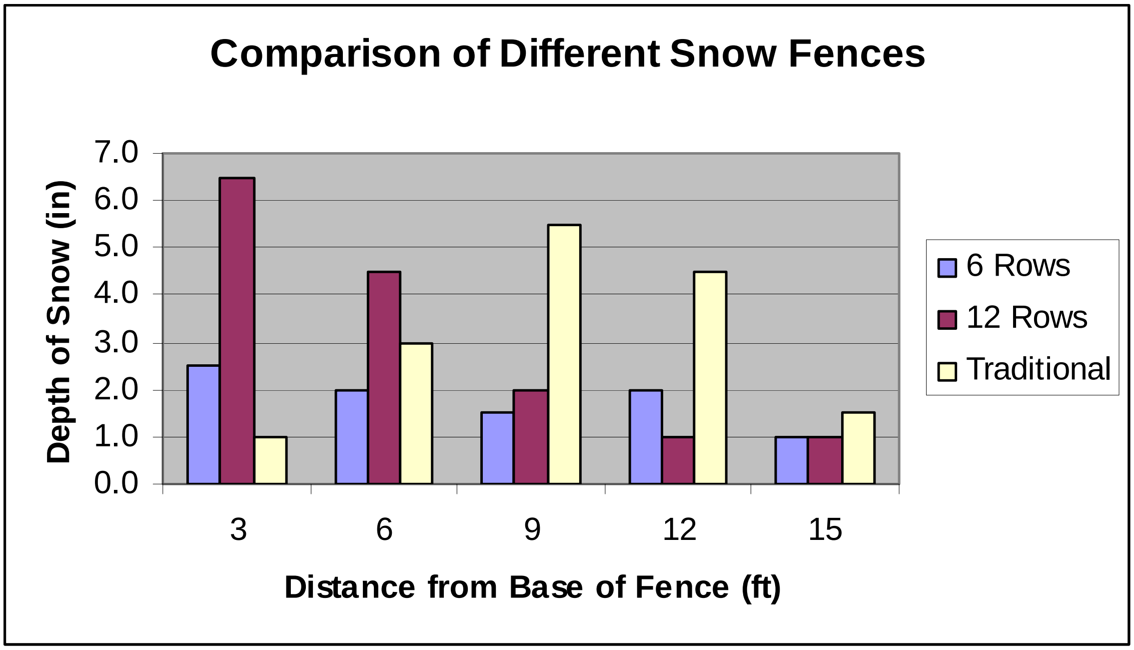

Figure 3.18: Snow Depths on February 17, 2003

Figures 3.19, 3.20, and 3.21 illustrate the small amount of snow stored by the three different snow fences. Figure 3.22 shows the snow stored between the rows of corn.

Combined with the above measurements of snow depth downwind of the various fences, it is apparent that the corn rows store snow differently from a traditional fence, thus confirming the results from the previous season. Further, analysis of the snow depths above, indicate that the 12 corn row snow fence stores approximately the same volume of snow downwind as the traditional snow fence (although it must be noted this was for a low snow fall). The analysis is to simply consider the cross sectional area of the snow drifts as in the above figures. In both cases, an approximately triangular distribution of snow storage is evident, although the traditional snow fence triangle rises to an apex at about 9 feet from the fence, while the 12 rows of corn gives the greatest depth of snow directly downwind of the rows of corn.

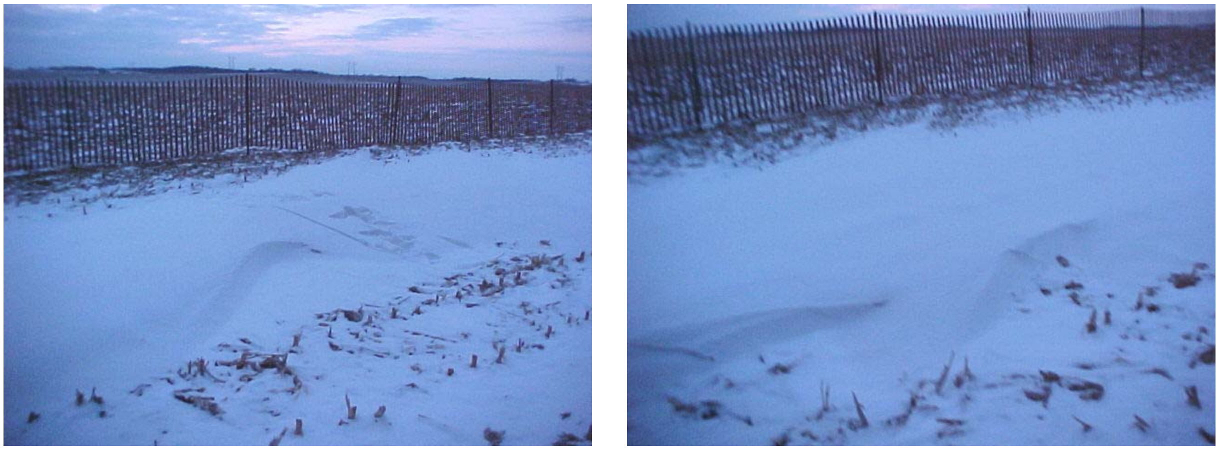

Figure 3.19: Traditional snow fence

Figure 3.20: Six rows of corn

Figure 3.21: Twelve rows of corn

Figure 3.22: Snow deposition between rows of corn

Given the distribution of snow observed during the second winter of testing, it was decided that in the third field test the ability of the corn rows to trap snow within themselves should be further examined. To this end, two segments of corn rows, each fifty foot long, were left unharvested for the third winter season. One segment had 16 rows of corn, the other had 8 rows. Both segments were located at the extreme edge of the field, in essence adjacent to the right of way for the highway (route 38) that the rows of corn were intended to protect. Figure 3.23 shows this layout schematically. The hypothesis to be tested in this case was that if indeed the rows of corn stored snow as well as a traditional snow fence, but stored the snow between the rows of corn, rather than downwind of them, then the rows of corn could be placed right at the edge of the right of way, rather than somewhere between 100 and 200 feet back from the right of way.

The benefit of such a placement adjacent to the right of way is that it is considerably easier to leave corn unharvested at the edge of a field, as opposed to leaving it in the center of a field. This could prove to be a critical factor for some farmers from whom the Department of Transportation is seeking to lease some fields for snow drift prevention.

The snow fall in the third season of testing was slightly greater than the average, and the two corn snow fences trapped all the snow that fell, and prevented any significant drifting across the road. Some of the corn in both snow fences was damaged by high winds, and for this reason it would seem that the 16 row arrangement would provide greater protection against high winds. Nonetheless, the key finding of the third season of testing was that a configuration of either 8 or 16 rows of unharvested corn was able to prevent any significant drifting on or across the highway, during a year with slightly higher than average snow fall. The additional finding was that the rows of corn stored almost all the snow that they trapped within the rows of corn. Thus, their placement at the edge of the field, directly adjacent to the right of way did not diminish their effectiveness in any observable way.

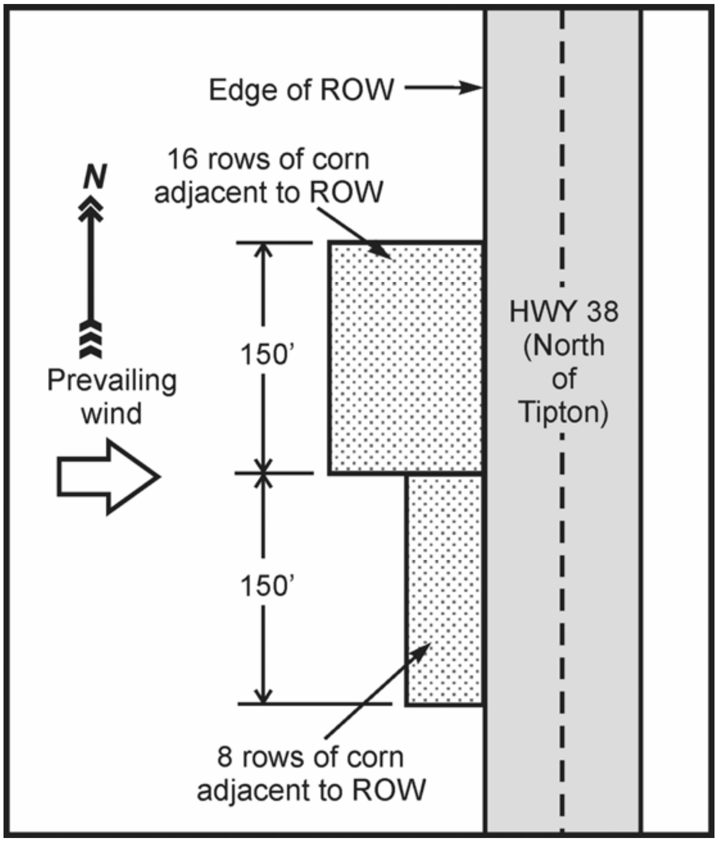

Figure 3.23: Schematic of Fence Layout for Year 3 Testing (note: in year 3 of testing, fences were placed relative to the right of way (ROW) and not the edge of the pavement)

The results of the three seasons of testing can thus be summarized as follows:

- Rows of unharvested corn (between 6 and 16 rows) stored as much snow during the three winters of testing as traditional four foot or six foot high artificial fences.
- The corn rows stored the snow in a different manner from traditional fences. Specifically, rather than storing snow downwind of the corn, the rows of corn stored snow within the rows. This suggests that they do not need to be placed as far from the road or right of way being protected as a traditional snow fence.
- Testing during a winter season with slightly above average snow fall showed that 8 and 16 rows of corn placed adjacent to the right of way were able to prevent any significant observable drifting across the road being protected.

These results have been compiled below into a proposed design for the use of corn stalk rows as snow fences.

3.4 The Use of Switch Grass as a Living Snow Fence

The Iowa Department of Transportation conducted an extensive field study of the use of wildflowers and switch grass (specifically blue stem grass) on sections of IA 3 and IA4. The test sections were each half a mile long, and in their width they comprised two parts. The first, which extended from the edge of the right of way for a distance of 60 feet, comprised wild flowers. The second section, which was next to the wildflower section, was 40 feet wide, and was planted with tall grass. This worked very well as a storage area for snow during the 2002-03 winter, and by July of 2003 the blue stem grass had grown to a height of six feet.

In the 40 foot wide section (the snow fence area) three tall grasses were used: Big Bluestem, Indian Grass, and Switch Grass. These were seeded at rates of 2.75 lbs per acre for the Bluestem and Indian Grass, and 1.8 lbs per acre for the Switch Grass. In the 60 foot wide section (the snow storage area) two shorter grasses (Little Bluestem and Side Oats Grama) were used, seeded at rates of 3.5 lbs per acre and 4.5 lbs per acre respectively. In addition, various wild flowers (termed forbes) were also used, specifically Pale Purple Coneflower, Black Eyed Susan and Partridge Pea (all seeded at 1 oz. per acre); Prairie Blazing Star and Gray-headed Coneflower (2 oz. per acre); and Purple Prairie Clover (6 oz. per acre).

Clearly one of the challenges of such an approach to living snow fences is that they cannot be done on a yearly basis. For the two Iowa Fences described above, the land for the grasses (approximately 6 acres for each site) was leased for a ten year period. At: http://www.sddot.com/fpa/lga/docs/Living_SnowFence_Lease.pdf a typical lease document can be found. Clearly, paying for such a lease of land can be expensive, but it appears that there may be a way to address these costs.

Specifically, the US Department of Agriculture Farm Service Agency operates the Conservation Reserve Program (CRP) which will lease land from landowners to protect the land from erosion. Details of the program can be found on the Farm Service Agency web site at: http://www.fsa.usda.gov/FSA/webapp?area=home&subject=copr&topic=crp and it appears that this program can be a very effective way to lease land for grass based living snow fences. The program will pay the yearly lease costs, along with up to 50% of the costs involved in establishing approved conservation practices. The local agency would presumably have to cover the rest of these "set-up" costs. This program is already in place in Iowa, as explained in an Iowa Department of Natural Resources brochure at: http://www.iowadnr.com/forestry/pdf/CRPLivingsnowfen.pdf Given the benefits and the effectiveness of these living snow fences, this program should be used as much as possible and appropriate by all agencies charged with winter maintenance responsibilities that face problems with snow drifting.

4. PROPOSED DESIGN FOR CORN STALK SNOW FENCES

4.1 Purpose

The purpose of this section of the report is to present a design guide for using corn stalk snow fences in Iowa. To that end, it is necessary to consider how much snow can be stored in a typical corn stalk snow fence, and compare that with the amounts stored in a more traditional snow fence. In addition, the placement of the corn stalk snow fence must also be considered. The fence must be placed in such a location that snow stored by the rows of corn does not impinge on the highway being protected by the rows of corn.

4.2 Snow Storage in Traditional Snow Fences in Iowa

Traditional snow fences in Iowa typically are four to six feet tall. This is in keeping with the need to store about 20 tonnes per meter of width of the snow fence. The value of 20 tonnes per meter of width derives from the average Iowa snowfall of about 30 inches per year. Using the design guidance offered by Tabler (1991), the average precipitation translates into a relocated precipitation of about 2.1 inches, suggesting a maximum snow storage need of approximately 20 tonnes per meter, based on figure 6 in Tabler's report (1991). The average density of the snow stored by this size of fence is approximately 490 kg/m^3 or a little more than half the density of ice. This is found by using equation (3) above, and approximating the cross sectional area of the snow stored as a right triangle, with a base 35 times its height (Tabler, 2003). There is no basis to assume that the density of snow stored in a traditional snow fence will be any different from that stored in a corn row snow fence. Thus the same density of snow will be used in the design calculations below.

4.3 Snow Storage in a Corn Row Snow Fence

The distribution of snow in a corn row snow fence is approximately at a uniform depth within the corn rows. At both the upwind and downwind side of the corn rows, the snow slopes fairly rapidly to the ground level. The angle of slope here is approximately thirty degrees above the vertical.

Given that rows of corn are spaced typically 22 inches apart (55.9 cm or 0.559 m) and that the observed height of snow within the corn rows was approximately 5 feet or

1.5 meters, it is relatively easy to develop an expression for the snow stored within the corn rows. This can be given as:

$$Q_{in-row} = \rho_{snow} \times (N-1) \times (0.559) \times H_{in-row} \tag{4}$$

In this expression, N is the number of rows of corn, $H_{in\text{-}row}$ is the height of the snow stored within the rows of corn (m), ρ_{snow} is the density of snow (kg/m^3), and $Q_{in\text{-}row}$ (tonnes per meter)is the amount of snow stored per unit length of the corn fence. If we take the value of 1.5 meters for the snow height, and the density noted above (490 kg/m^3) then we find that for 8 rows of corn, we can store about 2.9 tonnes per meter of width of the snow fence, while for 16 rows of corn we can store 6.2 tonnes per meter of width of the snow fence. Both of these are significantly less than the snow stored by a traditional, artificial fence, but this calculation does not take into account the additional storage both upwind and downwind of the corn rows. This would add approximately an additional 2.2 tonnes per meter of width for a total of 5.1 tonnes for the 8 rows of corn and 8.4 tonnes for the 16 rows of corn.

Indeed to obtain a full 20 tonnes of snow storage per meter width of snow fence, we would need to use about 45 rows of corn, which is probably impractical. Nonetheless, it should be noted that the 20 tonnes of snow stored by a traditional artificial fence (per meter width of fence) is the maximum amount that such a fence can store.

4.4 Design Guidance

An extremely conservative design for a snow fence based on rows of standing corn would be to allow for 45 rows of unharvested corn to be placed at the edge of a field, for the typical snowfall experienced in Iowa. However, the experience in the field tests, and particularly in the third year of the field tests, suggests that this is overly conservative.

That third year of testing saw an annual snowfall of approximately 32 inches, which is slightly more than the average snowfall for Iowa, yet neither the 8 row fence nor the 16 row fence allowed any impingement of snow upon the highway being protected. Both fences were right at the edge of the field and thus directly adjacent to the right of way.

Accordingly, it is recommended that an effective snow fence (for Iowa climatic conditions) based upon rows of unharvested corn can be made by leaving either sixteen or twenty four rows of unharvested corn at the edge of the field directly upwind of the road to be protected. Sixteen rows should be used when fetches are less than 5,000 feet, while for fetches greater than 5,000 feet, twenty four rows should be used. Experience suggests that in average winters this will be more than sufficient to protect the road from any snow drifting or blowing snow events.

It should be noted that this design has been tested by the Iowa Department of Transportation, in District 1, along Highway 65 between US 30 (at Colo) and Highway 330. At several points along this route, during the 2004-05 and the 2005-06 winters, either 16 or 24 rows of corn have been left standing on the upwind side of the road, directly adjacent to the right of way. As reported (Deaton, 2006, personal communication) these corn fences performed well during the two winters, allowing no snow to drift across the road in the locations where the corn fences were located. This provides a significant field test of the design suggested herein, and further indicates that, at least for winters similar to those of the past two years, this design philosophy is effective for the state of Iowa.

4.5 Implications of the Design Guidance

The design guidance given in 4.4 above has one extremely important implication. Discussions (of an informal nature) with a number of farmers indicated that while they would be willing to leave rows of unharvested corn at the edge of their fields, they would be very unlikely to leave rows of unharvested corn in the middle of a field, because of the inconvenience that this represents for the harvesting process. Thus it is possible that this design approach would allow many farmers to participate in a living snow fence program, who would otherwise have been unwilling to do so.

To confirm the design recommendation given herein it is strongly suggested that the department of transportation conduct a number of field trials around the state where they use 16 or 24 rows of corn as recommended above, for a number of winters. As noted above, tests to date along Highway 65 confirm the effectiveness of this approach. Further testing will allow a more complete determination of the effectiveness of this design recommendation. This should not be viewed as additional research, however, but rather as a limited implementation of the recommended action.

5. CONCLUSIONS

On the basis of three years of field testing, it has been shown that snow fences based upon rows of unharvested corn can effectively store snow. During the three field seasons, the rows of corn were at least as effective as more traditional artificial fences of four or six feet in height.

The corn row fences store snow rather differently from more traditional fences, storing the snow within the rows of corn, rather than downwind of the corn rows. This suggests that it may be possible to place rows of corn at the edge of a field directly upwind of the road to be protected, and that in such a location the rows of corn would effectively stop snow from drifting onto or blowing across the highway. This has the advantage that farmers are more willing to leave rows of corn at the edge of the field, rather than in the center of the field.

Specifically, it is recommended that 16 or 24 rows of unharvested corn left at the edge of a field, directly upwind of a highway will serve as an effective snow fence for the climatic conditions that hold in Iowa. It is further recommended that this be tested by a series of field evaluations over a number of winters, by way of a trial implementation of the design.

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