Snow Hedge Design Guidelines
Preliminary Results and Implications

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ABSTRACT

A study was undertaken at the Ontario Ministry of Transportation (MTO), to determine whether the effectiveness and the set-back requirement of snow hedges varies with hedge height.

Snow accumulation was monitored through one winter season at a cedar hedgerow which was trimmed to heights of 2.3, 4.0, and 4.5 metres, and at a nearby snow fence.

The comparative growth of snow drifts indicated that all three hedges were more effective than the snow fence, and that the effectiveness of the hedges increased with height. Comparisons of drift lengths and cross-sectional areas over one winter season suggest that set-back factors less than the MTO standard of 15 × H can be used where the expected annual volume of drifting snow results in a drift which is at an early stage of development.

INTRODUCTION

Roadside windbreaks are used by the Ontario Ministry of Transportation (MTO) to prevent drifting snow from reaching the driving surface of Ontario highways. The windbreaks include seasonally erected snow fences, or permanently installed snow hedges of several rows of shrubs or trees. Snow hedges are generally regarded as the more effective treatment, but have a greater capital cost and typically interfere to a greater extent with roadside land use [Brubacher et al, 1992].

Considerations in windbreak design include barrier geometry and spatial relationship to the road. Barrier geometry, including height and porosity, controls the degree of protection provided, and the dimensions of the snow storage area required. The barrier design should provide a snow accumulation capacity equal to the annual volume of snow expected to drift across the site, and should store that snow in an area upwind of the highway (Figure 1).

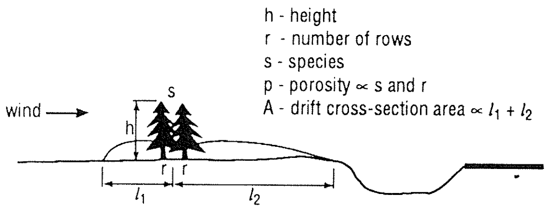

Figure 1. Snow hedge geometry

MTO design guidelines specify that snow hedges should be set back from the road shoulder by 15 times the mature height of the hedge [MTO, 1981], and Ministry practice is to acquire the land between the hedge and the road. Strict adherence to this guideline precludes the use of snow hedges in many areas because of the prohibitive cost of acquiring the land, since species commonly used for snow hedges in Ontario reach heights of 8 to 10 metres.

The set-back guideline was derived primarily from experience with snow fences which have different aerodynamic properties from snow hedges and may develop drifts of different dimensions. This project was undertaken to re-examine the relationship between the height of a snow hedge and the shape of the resulting snow drift, to more accurately define the required set-back distance from the highway.

APPROACH

The relationship between the height of a snow hedge and dimensions of the resulting snow drift were studied by measuring snow drifts accumulated by an existing, cedar snow hedge which had been trimmed to allow comparisons of different heights. The hedge was comprised of three, staggered rows of Eastern White Cedar (*Thuja occidentalis)* planted at 1 metre spacing. Since planting in the early 1960's, the trees have grown to heights of 4.5 to 5.5 metres and provide a dense windbreak with a crown base at ground level. The hedge was trimmed in 50 metre sections to heights of 2.3, 4.0 and 4.5 metres. A 1.2 metre, wood-slat-and-wire snow fence was also installed adjacent to the hedge to provide a standard for comparison.

Snow depth was measured using graduated rods on profile lines perpendicular to each hedge, from 6 metres upwind of the hedge to the road shoulder, approximately 35 metres downwind. Snow depth profiles were measured before and after each major snowfall or drifting event, and at least weekly between events, during the winter of 1991/92. Wind speed and direction, and air temperature were recorded hourly through the winter at a temporary weather station 75 metres upwind of the hedge. Diurnal snowfall data were obtained from nearby Environment Canada weather stations. The weather data were used to define weather events and to determine the suitability of test conditions during each sample period. Brush which had grown at the base of the snow hedge and within the right-of-way was cleared prior to the first snowfall.

The test site was located on Highway 26 in southern Ontario (Figure 2). The site is in a region of heavy snowfall due to proximity to Lake Huron to the west, Georgian Bay to the north and Lake Simcoe to the east. Prevailing winter winds are from the northwest.

The region has an average of 24 days per year with blowing snow [AES, 1984], and an average snowfall of 2.8m [Brown, McKay and Chapman, 1980]. Snowfall for 1991/92 was 1.9m [AES, 1992], or 68% of the normal value.

ANALYSIS

Profiles of snow depth were constructed for each sample period through the winter; drift lengths were measured and cross-sectional areas were calculated from the plotted profiles. Upwind and downwind drifts were included in the calculation of areas. Drifts extended upwind of the measuring rods on the north side of the snow hedges in some cases, and these areas were not included in the calculations. Areas shown for the hedges should therefore be considered minima.

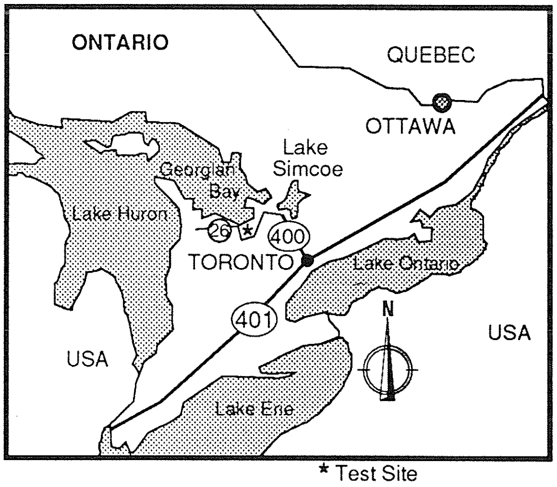

Figure 2. Test Site

Comparisons were made of the relative effectiveness of the hedges at trapping snow, and of the required set-back distance as determined by the length of the downwind drift.

Effectiveness was defined as that proportion of the total volume of snow drifting past the wind barrier, which was trapped by the barrier and accumulated in a drift on the ground. It was not possible to measure the total volume of snow drifting past the barriers and therefore, effectiveness was expressed as a percentage of the snow trapped by an adjacent, standard snow fence.

The downwind extent of snowdrifts was difficult to define in some cases because a uniform snow depth did not occur downwind of the drifts. Differences in snow depth may have occurred due to small topographic variations or to differences in effectiveness among windbreaks. In addition, some drift tails extended beyond the test area into the highway ditch. In these cases, the slope of the drifts and the depth of snow at the end of the measurement area were negligible and the drift lengths were taken as the length of the measurement area. The downwind drift length was defined as the distance from the windbreak to the lowest snow depth.

Comparison of the capacity of snow hedges, which requires that each accumulate snow to the point of saturation, was not included in the analysis.

Set-back requirements of different height snow hedges were evaluated by comparing the relationship between hedge height, drift lengths and volume of snow trapped. Drift length was measured from plotted profiles of snow depth, and drift volume was expressed as the cross-sectional area upwind and downwind, within the definition of drift length. Drift length was expressed as a multiple of hedge height to provide a direct measure of set-back requirement.

Hedges were expected to be more effective than the snow fence because they were taller and intercepted a larger volume of wind, and because their three-dimensional geometry was expected to be a more effective barrier to the wind. The effectiveness of hedges was expected to increase with height for similar reasons.

Effectiveness was compared on the basis of the seasonal maximum accumulation of snow, and also on the basis of the sum of the volumes accumulated during each storm. The seasonal maximum provides the most direct comparison, but is subject to error from several sources. These are changes in drift volume due to snow melt and evaporation, redistribution by subsequent winds, and initial deposition by winds from adverse directions. Each of these can mask the direct effect of the snow hedge under wind conditions for which it was designed. Summing the growth from each storm minimizes these sources of error.

Set-back requirements were compared for the annual maximum drift, and also for several sample periods which met ideal test criteria of: heavy snowfall, sub-freezing temperatures, and winds out of the north with speeds above 10 km/h. Four sample periods met these criteria. Profiles from these periods were illustrative of the effects of the stage of drift growth on drift capacity and dimensions.

RESULTS

The cross-sectional areas of the snow drifts accumulated by each hedge and the snow fence are shown in Table 1. Data are provided for the largest drift of the season, and for the sum of drift growth in all sample periods. The sum of drift growth indicates the total quantity of snow trapped over the winter season, and is a measure of the relative effectiveness of each windbreak. Drift capacity was not compared. As expected, the hedges had larger drifts than the fence, and snow accumulation increased with hedge height. The data indicate that the effectiveness of the cedar hedges relative to the snow fence was 127%, 142% and 145%, for the 2.3, 4.0 and 4.5 metre hedges, respectively.

Relationships between hedge height, drift area and drift length are shown in Figure 3. Data are provided for the largest drifts of the season and for four sample periods. The largest drifts of the season were included because they were expected to have the longest dimensions.

Table 1. Cross-sectional area of snowdrifts, 1991/92.

	Fence	*Hedge height*		
	1.2 m	*2.3 m*	*4.0 m*	*4.5 m*
Seasonal Maximum (m^2)	19.6	27.8	29.5	31.5
(%)	100	142	149	159
Sum of Drift Growth (m^2)	38.3	48.8	54.4	55.6
(%)	100	127	142	145

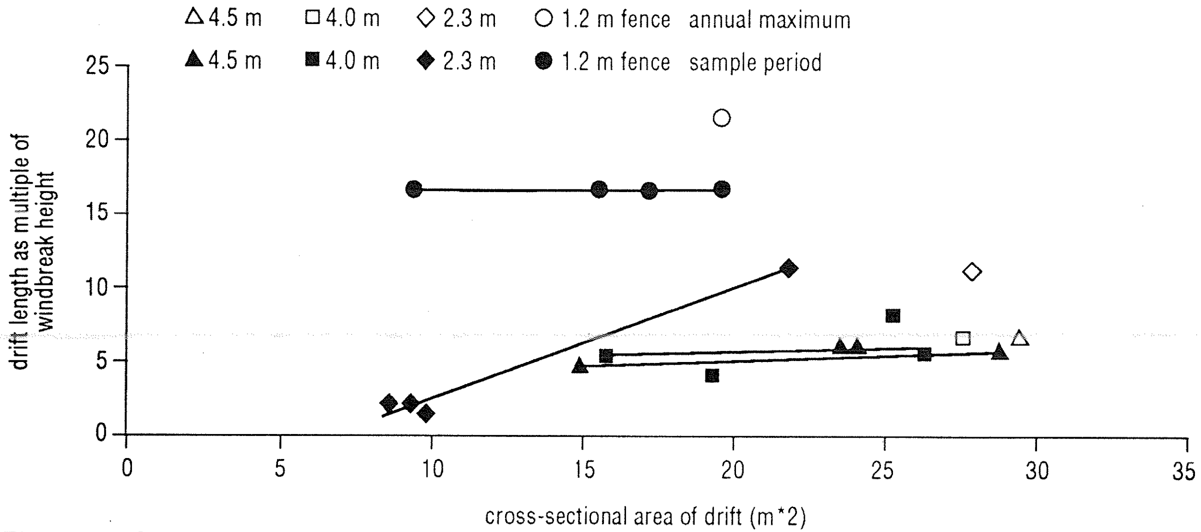

Figure 3. Set-back requirements.

However, they do not allow comparison of lengths for drifts of comparable cross-sectional area. Therefore, data from four sample periods were included. The sample data were from profile measurements following major winter snowdrifting events with winds predominantly from the north.

The annual maximum data show an inverse relationship between windbreak height and set-back requirement. Considering the longest drift at each hedge section, the set-back requirement for the 4.5 metre hedge was 5 times the hedge height, for the 4.0 metre hedge was 6 times the hedge height, and for the 2.3 metre hedge was 11 times the hedge height. The factor for the snow fence was 22 times its height.

The sample period data show that, for similar sized drifts, the set-back factor decreased as windbreak height increased.

The snow depth profiles suggest two reasons for the inverse relationship between hedge height and set-back factor (Figure 4). These are: the relative volume of the upwind drift and, the stage of development of the downwind drift. In all cases, the profiles for the tall hedges show large snowdrifts upwind of the hedge in comparison with those for the short hedge and the snow fence. The larger upwind drift accounts for the increase in total drift volume without a corresponding increase in the length of the downwind drift.

The slope of the downwind drift tail is shallower at the snow fence than the snow hedges in all of the profiles, and is shallower at the short hedge than at the tall hedges in all but the earliest profile.

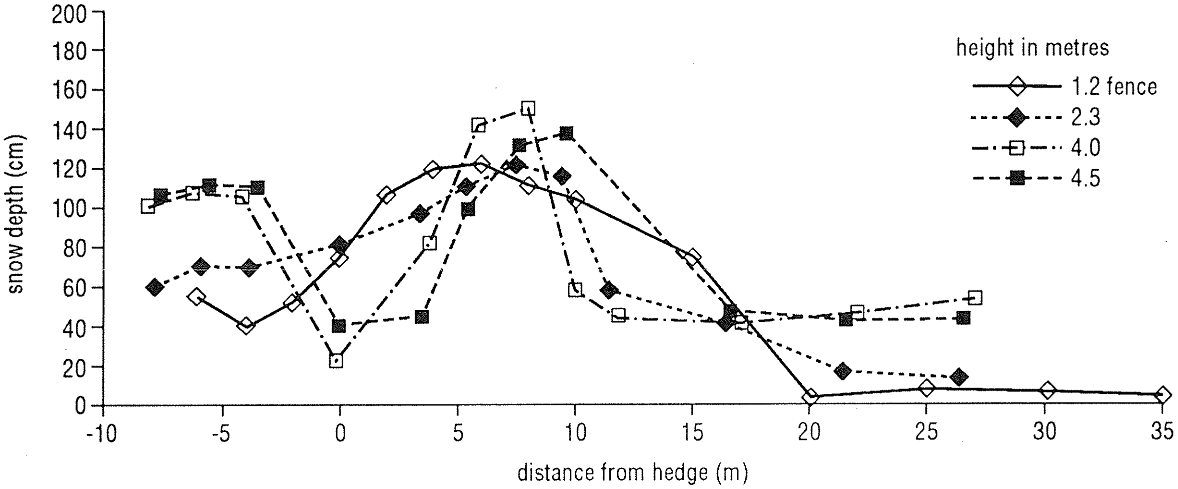

Figure 4a. Snow depth profiles, Jan. 15, 1992.

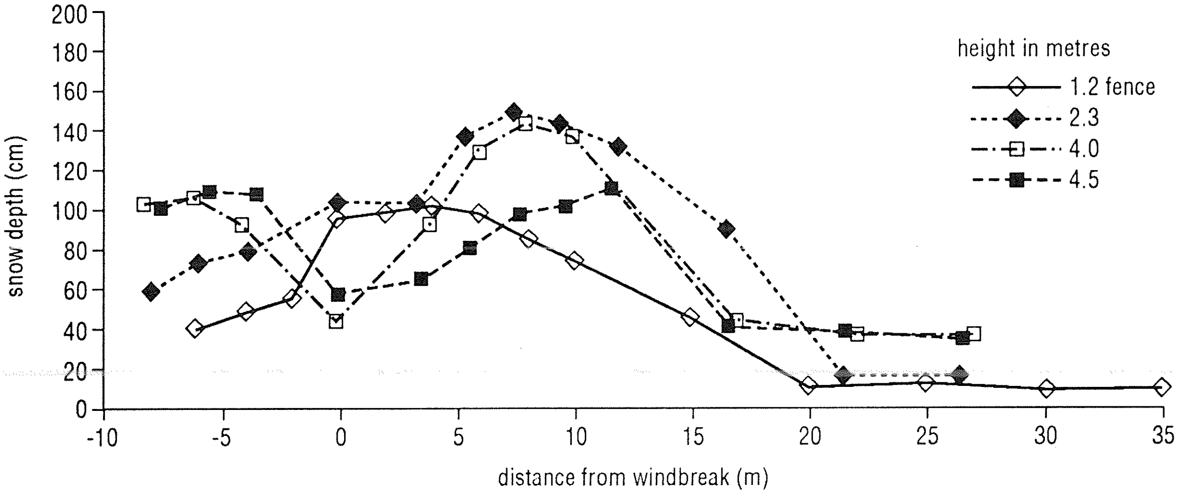

Figure 4b. Snow drift profiles, Feb. 12, 1992.

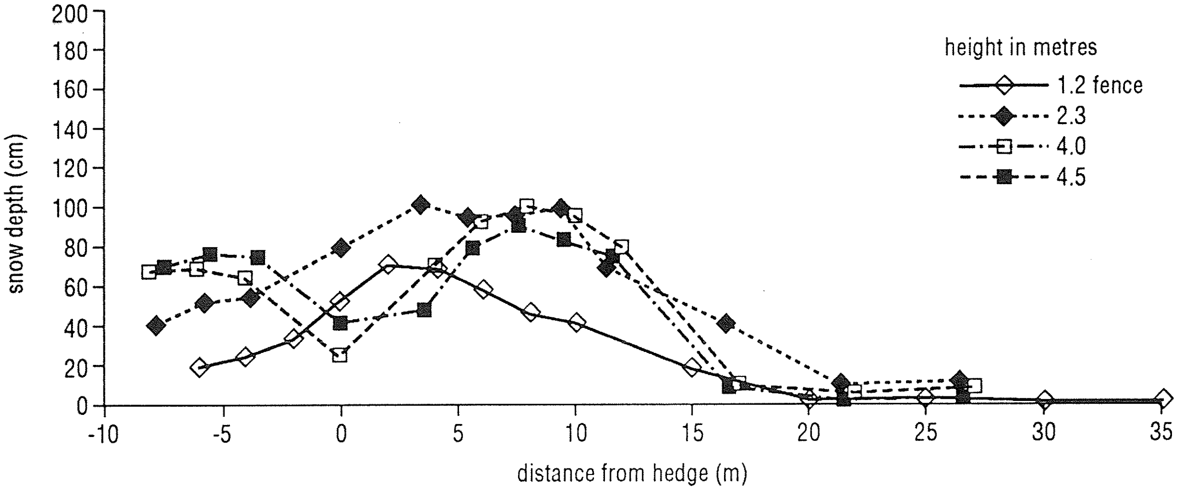

Figure 4c. Snow depth profiles, Mar. 11, 1992.

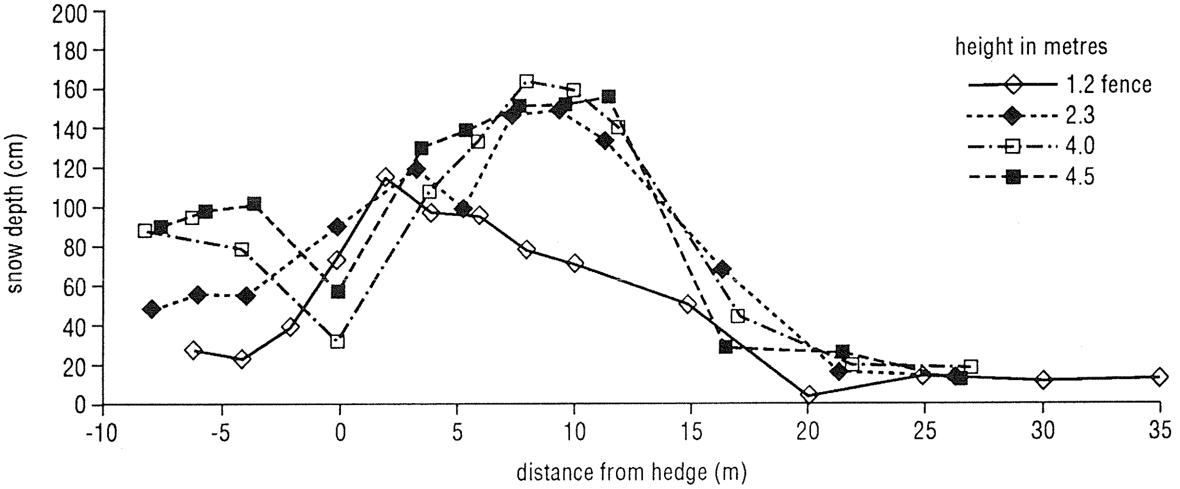

Figure 4d. Snow depth profiles, Mar. 12, 1992

The shallow tail slopes are characteristic of drifts in a late stage of development and near saturation. The steep tail slope of the drifts at the tall snow hedges suggests that they are at an early stage of development [Tabler, 1992]. Thus, the stage of drift development has an effect on the set-back factor, as shown by the curves in Figure 3. This implies that, if snow accumulation at the tall hedges was to continue until the downwind drifts were fully developed, the length of the downwind drifts would increase relative to their cross-sectional area, and the set-back factor would then increase.

The differences in drift saturation may also explain why the level snow depth downwind of the fence and the short hedge are greater than at the tall hedges. Tabler [1990] showed that windbreak effectiveness decreases as saturation level increases. Snow may have remained entrained on the downwind side of the shorter barriers, to be deposited beyond the main drift. The higher efficiency of the taller hedges trapped all of the drifting snow so that little remained to be deposited downwind of the main drift.

CONCLUSIONS

This study showed that the effectiveness of dense snow hedges at trapping drifting snow increased with the height of the hedge. It also showed that the hedges were more effective than a standard snow fence. A 4.5 metre tall hedge trapped up to 45% more snow than a 1.2 metre tall snow fence over one winter season.

A comparison of drift lengths and volumes over a winter season showed that the downwind length of the snow drift did not increase directly with windbreak height. The maximum length of the downwind drift at a cedar snow hedge was 5 times the height for a 4.5 metre hedge, 6 times the height for a 4.0 metre hedge and 11 times the height for a 2.3 metre hedge. These values are less than the 15 times height factor presently recommended in MTO guidelines. They suggest that the set-back factor can be reduced where the annual volume of drifting snow results in an early stage of drift development. Reduction in the set-back factor will result in corresponding reductions in property requirements for snow storage along highways, thereby increasing the feasibility of snow hedges as a highway safety treatment in Ontario's snow belt.

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