

QUANTIFYING THE RATE AND EFFECTS OF WIND DAMAGE IN SPECIAL
MANAGEMENT ZONES (SMZs) IN THE ST. MARY'S RIVER, GUYSBOROUGH
COUNTY, NOVA SCOTIA.

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EXECUTIVE SUMMARY

Special Management Zones (SMZs), also known as Riparian Buffer Zones, are important terrestrial areas adjacent to streams, rivers, lakes, ponds and wetlands influenced by both the terrestrial and aquatic environments. The province of Nova Scotia requires that all watercourses greater than 50 cm width have at least a 20 m wide SMZ left on either side of the watercourse adjacent to forest harvesting activities. Although SMZs offer ecological and recreational values, they are very susceptible to wind damage (i.e., blowdown) that may reduce their overall effectiveness. This study in the St. Mary's River watershed, Guysborough County, Nova Scotia, was conducted to evaluate blowdown over a 10 year time frame (2000-2010) following forest harvesting in order to understand cumulative wind damage effects over time. Forty locations were surveyed for: (1) diameter of living species, (2) diameter of standing dead snags, (3) SMZ slope, (4) SMZ width, (5) dimensions of uprooting of windthrown trees, (6) dimensions of exposed soil of windthrown trees, (7) height of damaged trees, (8) surface stoniness class, (9) location of damaged trees within the SMZ, and (10) dominant damaging wind direction. SMZ edge exposure, SMZ slope, SMZ soil moisture content and SMZ surface stoniness classes were the dominant observed site specific variables contributing to wind damage in Special Management Zones. The majority of the wind damaged trees either experienced stem breakage, partial windthrow or uprooting within the first 5 m of the SMZ along the harvest boundary. As slope increased, the frequency of these three damage classes was reduced. Increased slope offers a degree of protection on the downward slope of the harvest edge. Soil moisture contributed to 88% uprooting and 90% partial windthrow when the depth to water was less than or equal to 2 m depth below soil surface level. Surface stoniness sites experienced the greatest frequency of uprooting, and partial windthrow while ultimately contributing to the maximum area of exposed soil.

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1.0 INTRODUCTION

Special Management Zones (SMZs), also known as Riparian Buffer Zones, are important terrestrial areas adjacent to streams, rivers, lakes, ponds and wetlands influenced by both the terrestrial and aquatic environments. These transitional zones are maintained during forest harvesting activities to protect water quality and maintain elements of terrestrial and aquatic habitat. Ecologically, they are important to protect the integrity of watercourses, act as filters against surface flow of sediments from adjacent areas, provide canopy cover to maintain cool water temperatures, and supply organic litter required by primary producers. These areas also act as travel corridor for wildlife between diverse habitats at the landscape level. By protecting these areas, a visual quality is also maintained to provide recreational value within watersheds.

Currently, the province of Nova Scotia requires that all watercourses greater than 50 cm width have at least a 20 m wide SMZ left on either side of the watercourse adjacent to forest harvesting activities. Where the average surface slope within the 20 m boundary is greater than 20%, the width of the SMZ is to be increased 1 m for each 2% increase in slope, to a maximum of 60 m. No forest operator shall reduce the basal area of living trees within the required width of the SMZ to less than 20 m²/ha. Motorized vehicle travel within 7 m of the watercourse requires Department of Environment approval for the purpose of crossing. These regulations apply to private lands, industrial holdings and crown managed lands, and became law on January 14 2002. Under the Forests Act, Wildlife Habitat and Watercourse Protection Regulations, stream width is determined by measuring the width of the watercourse bed at 10 equidistant locations to determine the average width. These 10 measurements are to extend the entire watercourse length adjacent to areas scheduled for harvest operations. If the watercourse averages less than 50 cm, no forest operator shall operate within 5 m of the watercourse unless approved by the Department of Environment for the purpose of crossing installation.

Although SMZs offer ecological and recreational values, they are very susceptible to wind damage (i.e., blowdown) that may reduce their overall effectiveness. With increased wind exposure following harvesting activities, many shallow rooted tree species (e.g. spruce (*Picea* spp.) and balsam fir (*Abies balsamea*)) may be at risk of wind damage. Along with other stand and site variables, the severity of wind damage may be related to the physical structures of the site and species composition. The Nova Scotia Department of Natural Resources (NSDNR) conducted forest research in the Pockwock Bowater watershed in 2008 (McCurdy and Stewart, 2008). Their study was to assess wind damage in managed streamside management zones. Eight first order watercourses were measured to quantify wind damage one year after harvest activities. Watercourses sampled consisted of four 20m commercial thinnings, two 30 m commercial thinnings and 2 control areas. Damage consisted of 88.9% uprooted trees and 11.1% snapped. Damage in thinned SMZ's almost doubled with an average of 92 trees/ha uprooted with 49 trees/ha. in unthinned SMZ's. Damage in flow accumulation zones was more than double that of non-flow accumulation zones (96 trees/ha. vs. 48 trees/ha.). The highest concentration of wind damage occurred along the harvest edge. The occurrence of wind damage within 5 m of harvest edge ranged from 1.1 m²/ha. to 9.1 m²/ha. Of the 8 watercourses sampled, 7 experienced the greatest degree of wind damage along the harvest edge. One of the 20 m thinned watercourses experienced the majority of wind damage within 0 – 1 m from stream edge. Soil disturbance followed similar patterns in regard to harvest edge and location within the flow accumulation zone. Soil exposure was most prominent in the first 5 m of the SMZ where it ranged from 147

m²/ha. to 1,308 m²/ha. Soil disturbance also doubled in flow accumulation zone with 303 m²/ha. exposed, while the rest of the SMZ had an average of 124m²/ha.

The study reported here was conducted to extend the one year assessment of McCurdy and Stewart (2008) to a 10 year time frame (2000-2010) following forest harvesting in order to understand cumulative wind damage effects over time. Specifically the objectives of this research were to:

1. Determine the incidence and severity of wind damage in SMZs within the St. Mary's River watershed over a ten year period to assess the longer term efficiency of Provincial Riparian Guidelines.
2. To assess soil exposure as a result of uprooting in riparian zones over a ten year period.
3. To assess the influence of local SMZ physical site characteristics on the rate of wind damage.

2.0 STUDY AREA

The St. Mary's River watershed is located in the north eastern section of Nova Scotia where its boundaries overlap with the five counties of Guysborough, Antigonish, Pictou, Colchester and Halifax (Figure 1) for a total area of 152,660 ha. There are three principle branches to the river: North Branch, East Branch, and West Branch St. Mary's River, with an estimated 118 tributaries ranging from first to fourth order that collectively flow to create the river continuum where the main St. Mary's River empties into the Atlantic Ocean in the Sonora area of Guysborough County. The watershed lies within four terrestrial Ecoregions of the province identified by NSDNR; the Nova Scotia Uplands, Eastern, Northumberland Bras D'or and the Atlantic Coastal Ecoregions. These larger regions are comprised of eleven ecodistricts (Figure 1). The watershed is predominately forested with spruce spp. and balsam fir with a mix of tolerant and intolerant hardwoods depending on the locations within the ecoregion. Patches of older growth red spruce (*Picea rubens*), eastern hemlock (*Tsuga canadensis*) and eastern white pine (*Pinus strobus*) are present, being most noticeable adjacent to the lower sections of the West Branch St. Mary's River. Soil texture ranges from poorly drained to imperfect to well drained depending on location. Topographic terrain within the watershed is dominated by hummocky to hilly terrain with lower frequency of drumlins and smooth terrain.

Land use within the watershed is primarily forestry and agriculture (agriculture largely confined to the East Branch and lower portions of the river below the junction of the East and West branches at Glenelg). Human density is low. Forest activities within the watershed include small private, industrial private, industrial freehold and Crown managed lands. Pulsifer et al. (2004) reported land use type within 500 m of the St. Mary's River was predominately forested land. (Table 1).

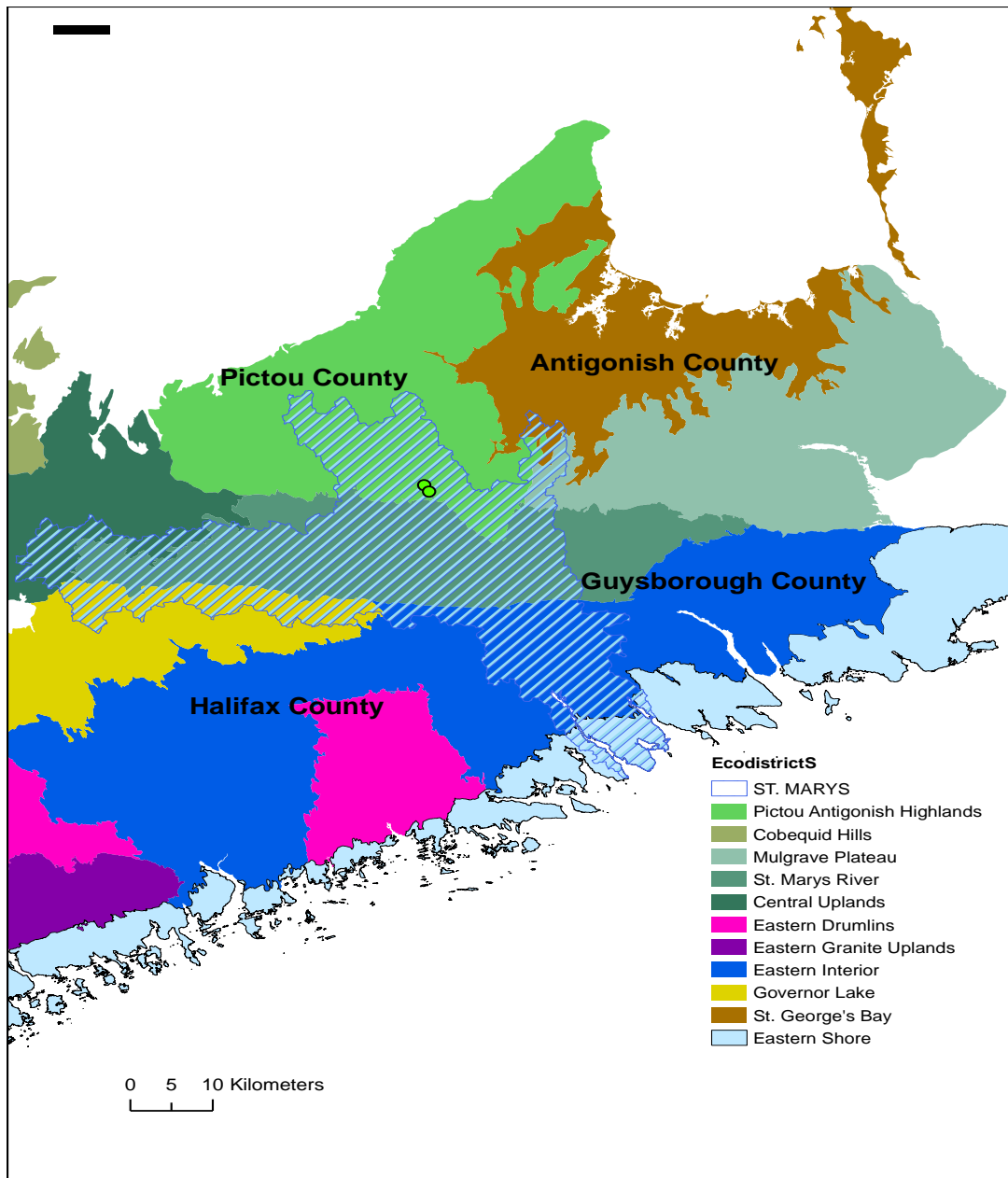


Figure 1: Location of the St. Mary's River watershed along with the 11 associated ecodistricts.

3.0 METHODS

Sample areas were located on lands under three classes of ownership: (1) Northern Pulp Nova Scotia Corporation's Freehold, (2) New Page Port Hawkesbury's Crown Managed Lands, and (3) small private lands. Forty harvest areas were selected among the three ownership classes (15, 15 and 10, respectively) where clearcut harvesting had been conducted in the period of 2000 - 2010. Sampling methodology was adopted from the NSDNR Operations Manual for assessing Wildlife Habitat and Watercourse Protection Regulations. SMZ assessment procedures require completing 10 equidistant fixed area transects running perpendicular from the harvest edge to the watercourse edge. The width of these fixed area plots was constant at 5 m, with the length

varying depending on the SMZ width left after harvest. Field data collection was completed between August and October 2010.

Table 1: Land Classification within 500 m of the St. Mary's River (data from Pulsifer et al., 2004).

Land Classification	Area (ha.)
Forested	4,057
Unclassified	806
Regenerating forest stands	779
Wetland	618
Agriculture	280
Aldergrounds	199
Urban	113
Old field	76
Brush	28
Gravel pit	11
Barren	6
Total	6,973

Assessment at each sample SMZ included: (1) diameter of living species, (2) diameter of standing dead snags, (3) SMZ slope, (4) SMZ width, (5) dimensions of uprooting (length \times width) of windthrown trees, (6) dimensions of exposed soil (length \times width) of windthrown trees, (7) height of damaged trees, (8) surface stoniness class, (9) location of damaged trees within the SMZ, and (10) dominant damaging wind direction. Diameter classes for all trees ≥ 8 cm diameter were by species living, standing dead snags, mechanical breakage, partial wind throw and uprooting; diameter measurements were made using calipers. Ground slope was calculated with a Suunto clinometer, and SMZ widths were measured with a hip chain. Height of uprooted and broken trees, dimensions of uprooting and soil exposure were all measured with a field tape. Blowdown was classified as uprooted when the rooting structure was completely torn through the LFH soil horizon, exposing underlying mineral soil. Partial wind throw trees evidently had some wind damage as evidenced by their leaning. These trees haven't experienced enough force to expose their roots above the duff layer and so create a measurable exposed soil dimension. Stem breakage was tallied for surface level damage, mid bole and crown breakage.

Canopy dominance and surface stoniness were assessed at each SMZ. Surface stoniness classes were based on classification procedures used in the Forest Ecosystem Classification for North Eastern Nova Scotia (NSDNR Ecosystem Management Group 2007) (Table 2). Soil texture, topography and drainage classes were referenced from GIS data layers at the ecosection level. SMZ exposure to wind was estimated from GIS data where the face of the SMZ edge was that dominantly exposed. Damaging wind direction was tallied for each wind damaged tree within the SMZ.

Table 2. Surface stoniness classes for stones ≥ 25 cm. (From NSDNR Ecosystem Management Group 2007).

Stoniness Class	Distance Between Stones
Non Stoney (NS)	> 30 m apart
Slightly Stony (SS)	10 - 30 m apart
Moderately Stoney (MS)	2 - 10 m apart
Very Stoney (VS)	1 - 2 m apart
Exceedingly Stoney (ES)	0.2 - 1 m apart
Excessively Stoney (XS)	< 0.2 m apart

Arcpad© Geographic Information System (GIS) with a Garmin© Bluetooth Global Positioning System (GPS) was used to reference the location of each wind damaged tree within the SMZ. Wet Area Mapping (WAM) shape files were also referenced in ArcGIS to determine soil moisture within the SMZ where damage was most frequent. WAM is a tool used by forest managers to predict where hydrologically sensitive areas are expected to occur.

4.0 RESULTS

SPECIES COMPOSITION

The 40 SMZ areas sampled were predominately balsam fir, red maple (*Acer rubrum*), red spruce and snags (Figure 2). On average, standing dead snags comprised about 14% of areas sampled. Black spruce (*Picea mariana*) comprised about 10% of the sample size. Three of the areas sampled were plantations of Japanese larch (*Larix leptolepis*), jack pine (*Pinus banksiana*) and red pine (*Pinus resinosa*). These areas exhibited very little damage. Site specific results for each individual SMZ can be found in Appendix 1. Other species occurring to a minor extent included tolerant and intolerant hardwoods with other scattered softwood species (Figure 2.)

SITE DESCRIPTION

Surface stoniness classes ranged from non-stony in the eastern section samples of the watershed to a transition into very stony to excessively surface stoniness in western sample areas. The majority of the sample areas (52%) were slightly stoney or non stoney (Figure 3). Very stoney and excessively stoney sites occupied the least amount of sampled area, at 15% and 10%, respectively. Sample areas were dominated by well to imperfectly drained medium to coarse textured soils on hilly to hummocky terrain (Figure 4.)

Species Composition of Sample Areas

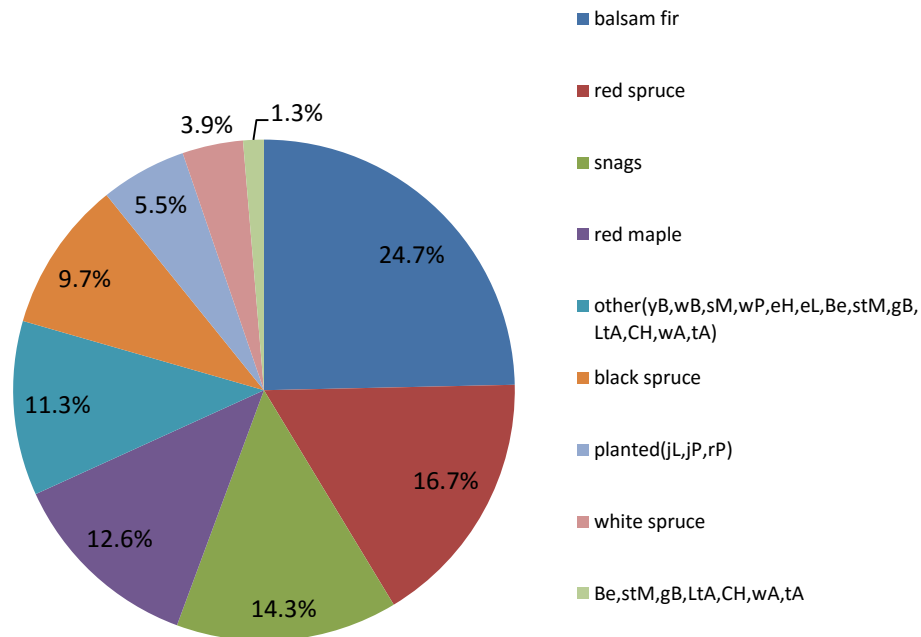


Figure 2: Tree species composition of 40 SMZ sample areas in the St. Mary's River watershed

Wind damage to trees was variable across sample areas. Frequency of uprooting was in the range of 0–241 trees/ha, partial windthrow 0–121 trees/ha., and stem breakage from 0–162 trees/ha. Calculated means (\pm SD) of all 40 sample areas yielded a total damage frequency of 111 ± 67 trees/ha, uprooting of 54 ± 53 trees/ha, stem breakage of 35 ± 30 trees/ha., and partial windthrow 22 ± 28 trees/ha. Wind damage occurred as 49.7% uprooting, 18.7% partial windthrow and 31.6% as stem breakage (Figure 5). Species showing stem breakage were comprised mainly of balsam fir (43% occurrence), black spruce (20%) and red spruce (14%). Partial windthrow species were 50% balsam fir, 22% red spruce and 9% black spruce. Species subject to uprooting were similar although black spruce dominated with 32% occurrence; balsam fir and red spruce had similar uprooting at 28% and 26%, respectively. The average height to diameter ratio (HDR) for all stem breakages was 73.1 across all of the 40 SMZ's sampled.

Slope varied widely across the sample areas, with an average minimum slope of 0% (or level terrain) to a maximum of 46%. The average for all areas was a slope of 15%. Damage frequency of uprooting and partial windthrow followed a decreasing trend with increased slope (Figure 6). Breakage frequency peaked between the 16 – 20% slope with 68 trees/ha. damaged and then followed a similar pattern to partial windthrow and uprooting.

Similar to slope, SMZ width varied considerably, from 16 m to 81 m. The mean of all areas was 29 m. Variability in the SMZ widths reflect operability constraints (either slope or wet areas), to merchantability issues. Damage frequency patterns were similar between the three damage types with increased SMZ width (Figure 7). Once SMZ width was greater than 35 m, all three damage classes followed a decrease in trees/ha. damaged, although even with a 40 m wide SMZ, uprooting still occurred to a moderate degree.

Surface Stoniness

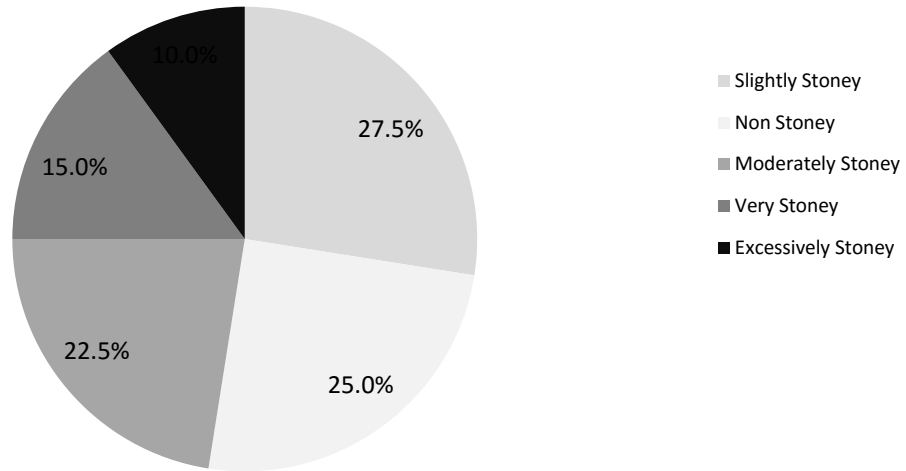


Figure 3: Surface stoniness classes at SMZ sample areas in the St. Mary's watershed

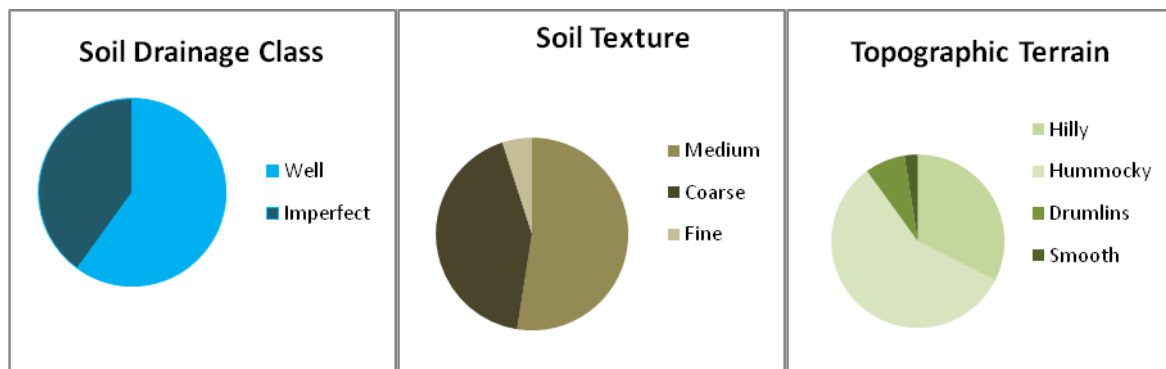


Figure 4: Soil drainage, soil texture and topographic terrain at SMZ sample areas in the St. Mary's River watershed.

Proportion Of Damage

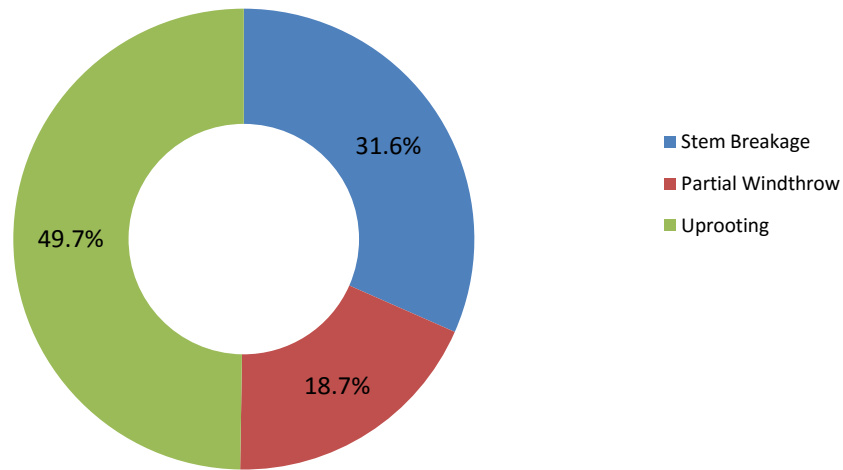


Figure 5: Proportion of wind damage in 40 SMZ plots of the St. Mary's River watershed.

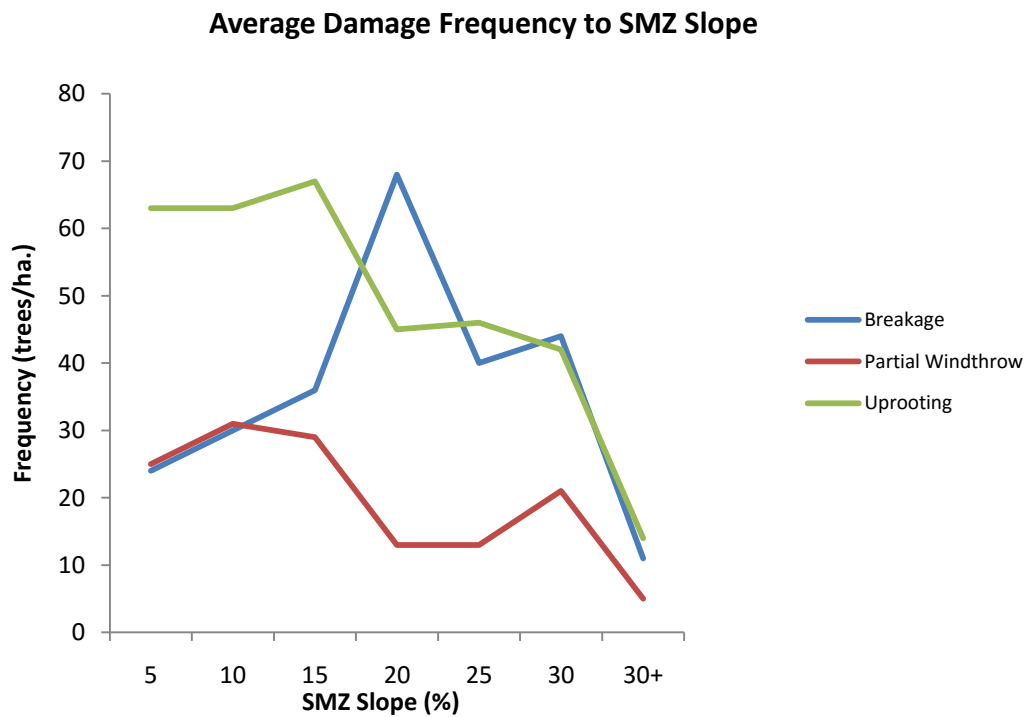


Figure 6: Average damage frequency in relation to SMZ slope in the St. Mary's River watershed.

Tree density ranged from 450 to 2450 trees/ha. The average density of all sample areas was 1280 trees/ha. Unlike increases in slope and width, damage frequency increases with an increase in SMZ density (Figure 8). Trees showed virtually no uprooting or partial windthrow damage at low densities and increased to 94 trees/ha. uprooted and 43 trees/ha. partial windthrow. Stem breakage remained relatively constant over the range of densities

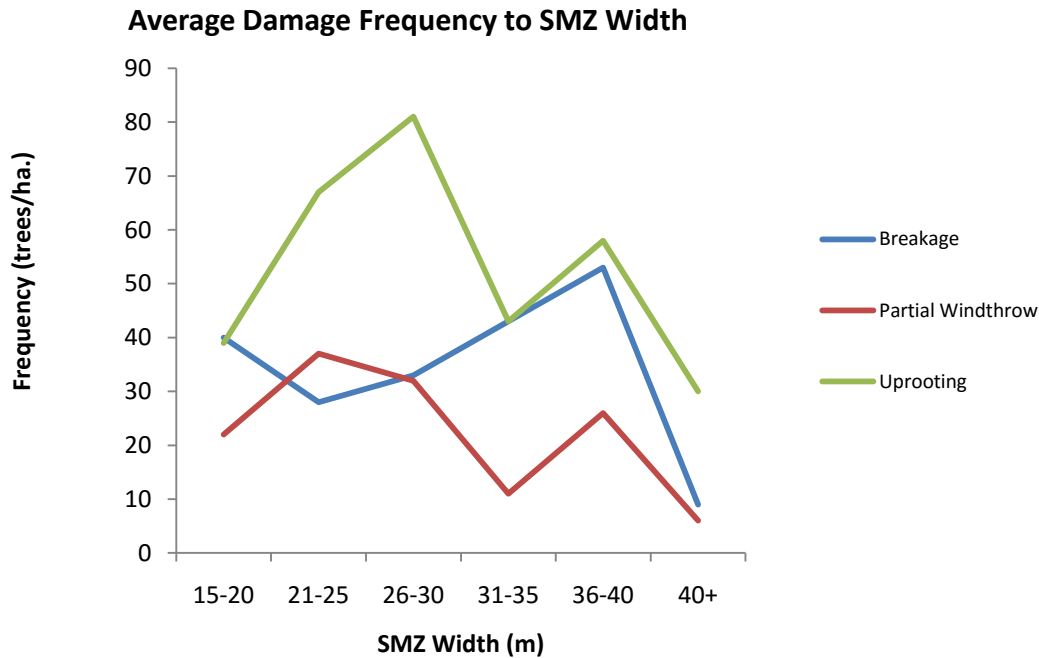


Figure 7: Average damage frequency with increase in SMZ width in the St. Mary's River watershed.

SMZ's facing the southeast experienced the greatest overall damage at 169 trees/ha (Figure 9). The greatest rate of stem breakage (69 trees/ha.) occurred when the SMZ edge was exposed toward the south. Although uprooting also showed high frequency at other SMZ exposures, the dominant damaging winds were from the south. The majority of SMZ edges (30%) were facing east and the dominant damaging wind direction (79%) was from the south (Table 3).

Very stoney and excessively stoney sites comprised the least area of the 40 sample sites (15% and 10%, respectively). Although these surficial classifications were a minimal local landscape feature of the SMZ's sampled, they had a dramatic effect on the rate of wind damage (Figure 10.). Average wind damage at very stoney sites was 113 trees/ha. uprooted and 70 trees/ha. in partial windthrow condition. Excessively stoney sites had the second most damaging effects at 126 trees/ha. Although non-stoney, slightly stoney and moderately stoney sites experienced uprooting and partial windthrow, frequency of occurrence was considerably less (Figure 10).

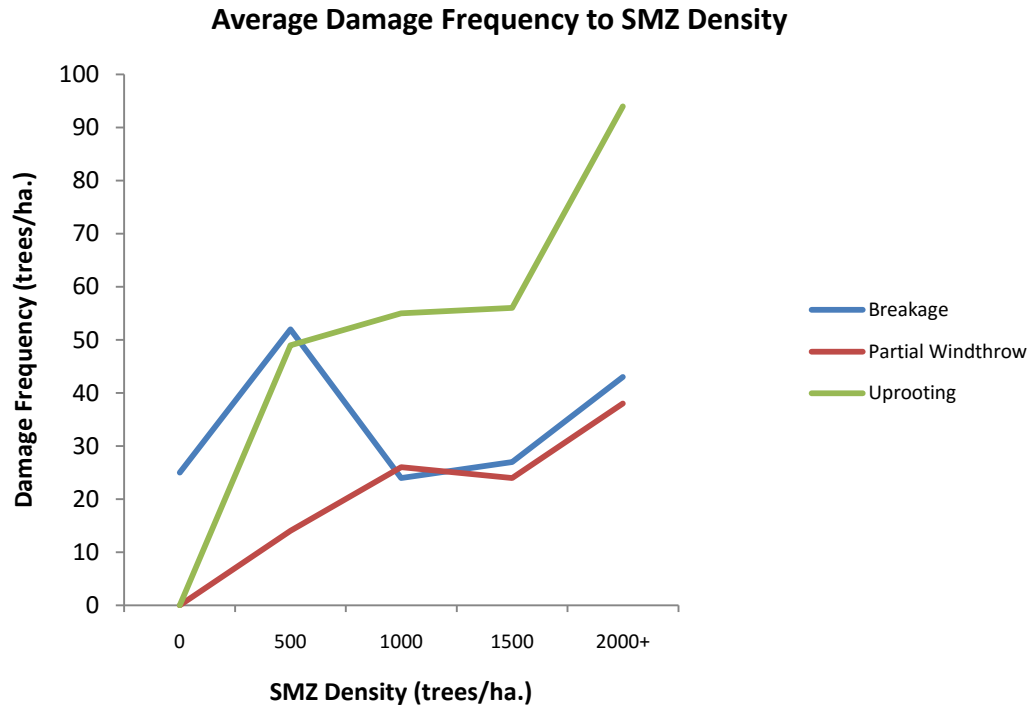


Figure 8: Average damage frequency to increase in SMZ density in the St. Mary's River watershed.

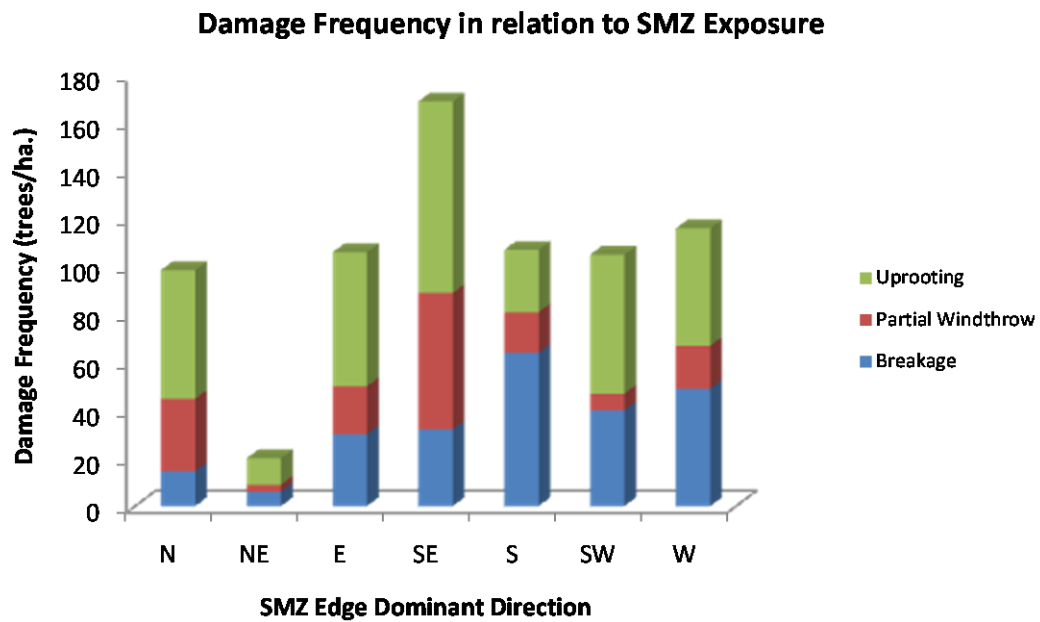


Figure 9: Average damage frequency at various SMZ edge exposures to wind in the St. Mary's River watershed

Table 3: SMZ face exposure and damaging wind directions at 40 SMZ's of the St. Mary's River watershed.

SMZ Face Exposure (Direction)	Sample Area Occurrence (%)	Dominant Damaging Wind Direction(%)
North	15	6
Northeast	10	
East	30	7
Southeast	7.5	
South	7.5	79
Southwest	12.5	
West	17.5	8

Uprooting, partial windthrow and stem breakage were influenced by distance from the harvest boundary (Figure 11). Most of the total basal area damaged was in the first 5 m of the SMZ (i.e., within 5 m of the harvest cutblock edge). The average total basal area damaged across all sites was 3.4 m²/ha. Uprooted trees comprised the bulk of this total with an average of 1.6 m²/ha. The average total basal area damage ranged from 1.4 m²/ha along the edge of the harvest boundary, to only 0.2 m²/ha. adjacent to the watercourse. Damage followed a decreasing trend as distance increased from the harvest boundary. Total basal area damage was variable across all SMZ's sampled. It ranged from virtually no damage at one location to a maximum of 13.5 m²/ha. It is important to note that this maximum damage occurred at a site with a gentle slope of 7% with excessive surface stoniness.

With soil exposure being a direct result of uprooting, higher levels of soil exposure can ultimately be expected within the SMZ where uprooting frequency is greatest. Soil exposure was variable among the sample areas, ranging from 0 that yielded no uprooting to a maximum value of 577 m²/ha. This latter site was very stoney, exposed to the north with a gentle slope of 3%. Drainage was imperfect with medium to coarse textured soils located on hilly terrain. Species composition was dominated by balsam fir and black spruce. Figure 12 illustrates the relationship between soil exposure and distance from harvest edge. Average soil exposure of all sample areas was 100.1 m²/ha. The first 5 m section yielded 39 m²/ha. while area adjacent to watercourses was 3.4m²/ha.

With the assistance of wet area mapping, damaged tree locations were mapped in relation to estimated depth to water. The areas that experienced the most damage for both uprooting and partial windthrow was in the zone where depth to water can be expected to be 0.51 – 2 m (Figure 13). This area is generally upslope from the watercourse edge typically adjacent to harvest edge boundary. Soil moisture content however was a contributing variable within these zones. Partial windthrow occurred 90% of the time when the depth to water was less than 2 m, while uprooting occurred 88% of the time in these areas with greater soil moisture content. Figure 14 illustrates an example of wet area mapping and identification of tree damage within that area. It is evident where windthrow occurrence is most prominent within the SMZ. The majority of damage for this

particular SMZ was located where depth to water was expected to be between 0 – 0.5 m below soil surface. These localized areas experience higher water tables with greater soil moisture content that ultimately decrease overall rooting depths.

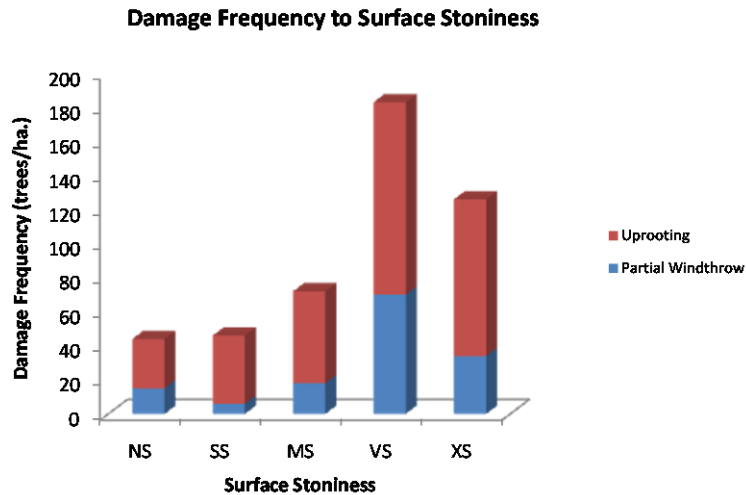


Figure 10: The effects of surface stoniness on rates of wind damage in 40 sample SMZ's of the St. Mary's River watershed.

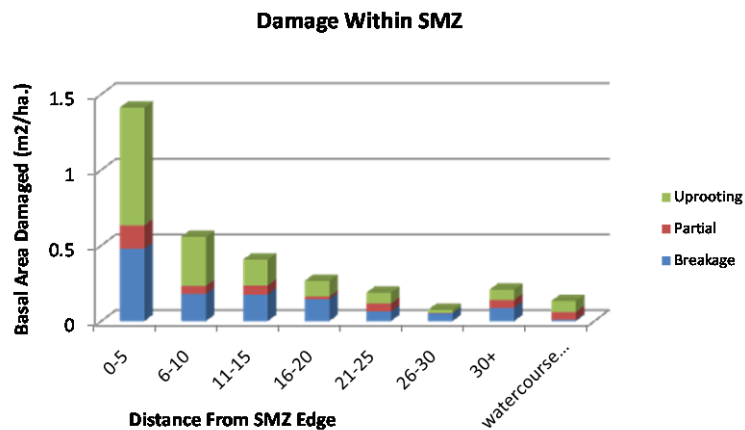


Figure 11: Basal area damage within 40 SMZ sample areas of the St. Mary's River watershed.

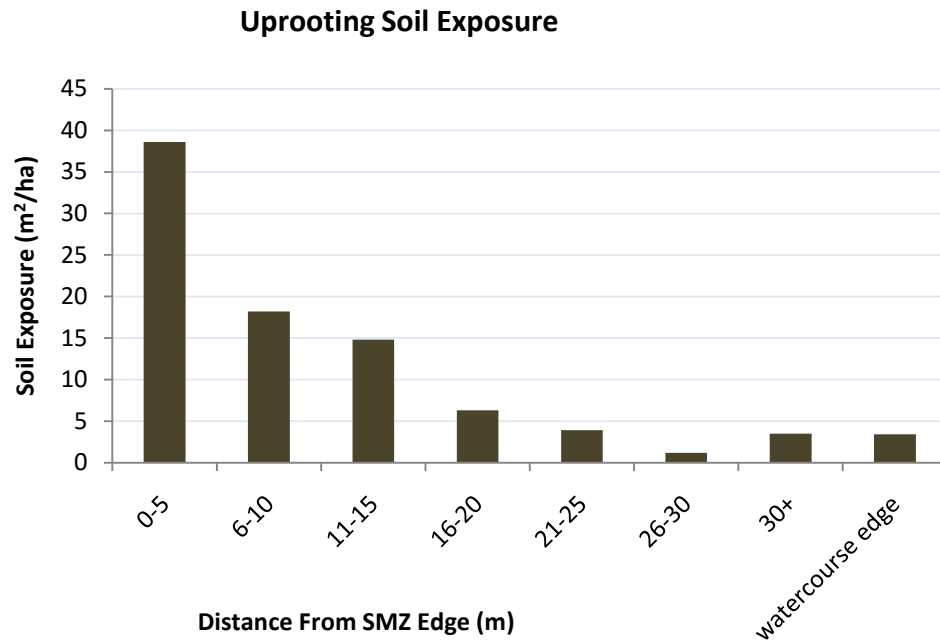


Figure 12: Soil exposure within 40 SMZ sample areas of the St. Mary's River watershed.

Cumulative wind damage over time since harvest year was variable. One would assume that damage frequency would increase as time passed. The results indicate otherwise. Harvest areas in the year 2003 had the highest total frequency of damage in the SMZ with 171 trees/ha. damaged. This harvest year also experienced the highest degree of uprooted trees at 122 trees/ha. Areas harvested in the year 2010 illustrated the second highest average damage with a total of 170 trees/ha., 90 of which were uprooted. Partial windthrow in harvest year 2010 was the highest of all sampled areas with 60 trees/ha. damaged (Figure 15.). The harvest year 2000 experienced the least amount of average total damage at only 41 trees/ha.

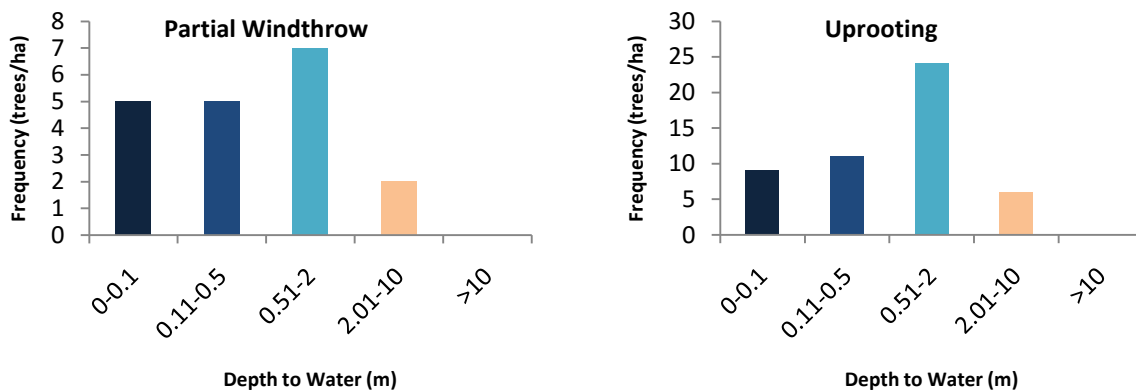


Figure 13: Frequency of wind damage in areas with locally higher soil moisture content in the St. Mary's River watershed.

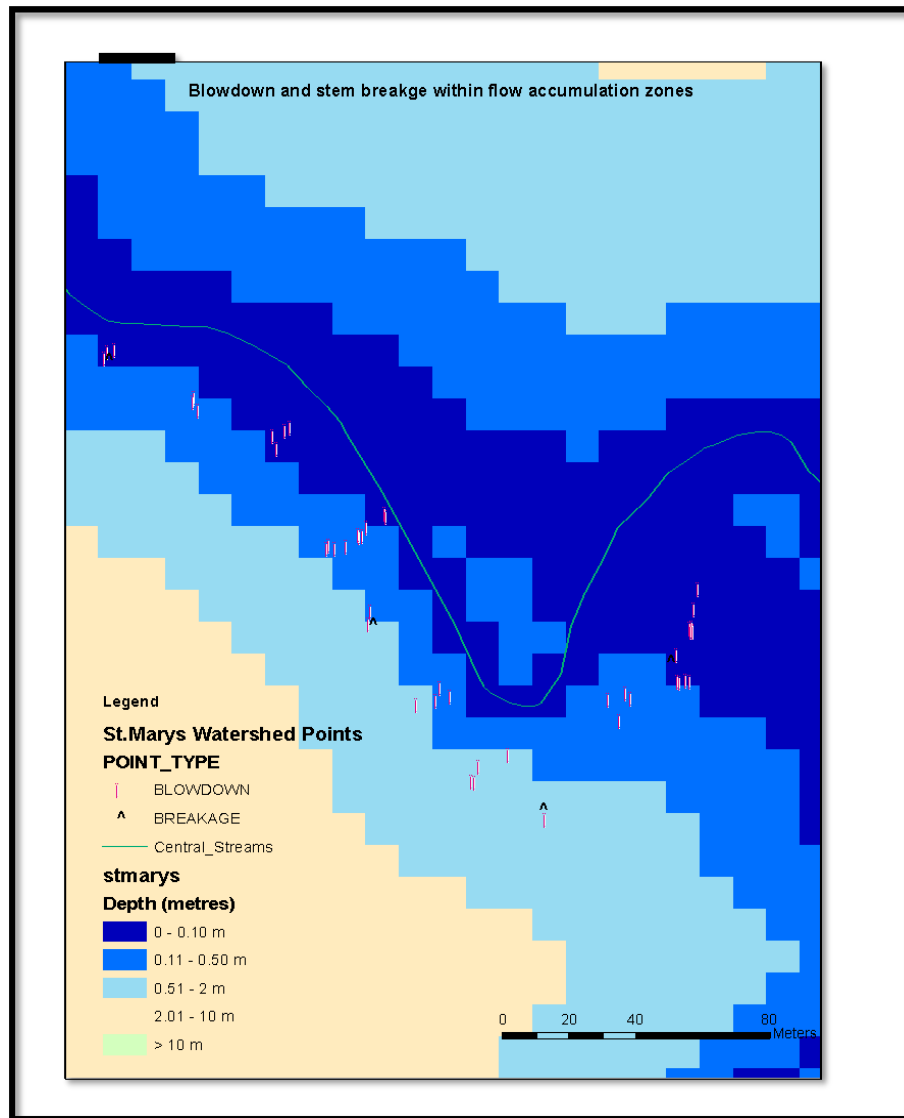


Figure 14: Wind damage in relation to expected depth to water (Porcupine Lake Outflow, September 2010).

Total average soil exposure by harvest year was also variable over time (Figure 16.). Areas scheduled for harvest in 2010 had the highest average amount of exposed soil at 250m²/ha. The year 2000 which was the oldest of the sample had the least amount of average exposed soil with only 4 m²/ha. Although the year 2003 had the highest frequency of uprooting, on average, it has relatively low soil exposure at 65 m²/ha.

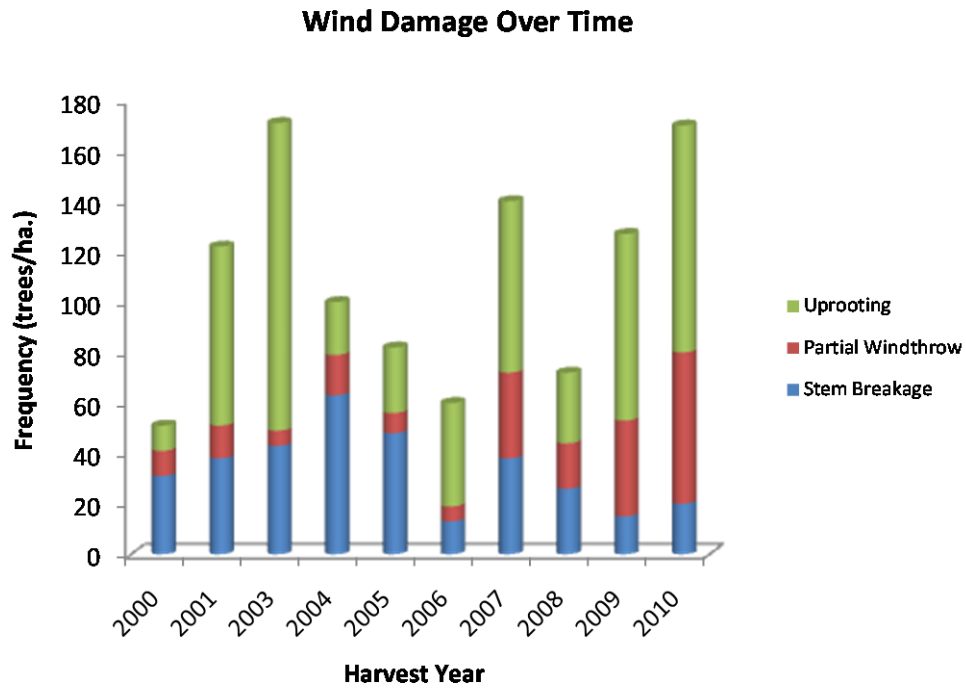


Figure 15: Cumulative wind damage since harvest year in SMZ's of the St. Mary's River watershed.

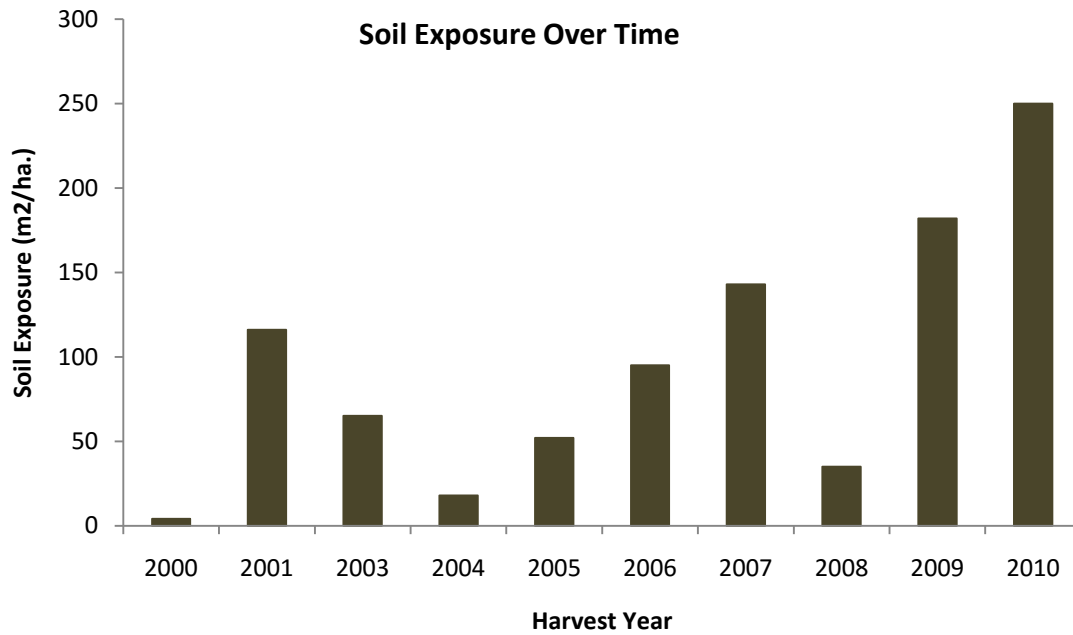


Figure 16: Cumulative soil exposure since harvest year in the St. Mary's River watershed.

5.0 DISCUSSION

Wind damaged species were dominated by balsam fir, red spruce and black spruce. Damages consisted of 49.7% uprooting, 31.6% stem breakage and 18.7% partial windthrow. The Pockwock – Bowater watershed study revealed that uprooting dominated (88.9%) the sample areas and 11.1% as snapped trees (McCurdy and Stewart, 2008). Similar to this study, uprooting was most frequent within the first 5 m of the SMZ, while uprooted trees mostly occurred in flow accumulation zones. Their study consisted of similar species composition and also found that red maple and other minor species had a lower proportion of wind damage. Hardwood species in the St. Mary's River watershed that were uprooted were located on wet areas while stem breakage was typically mid bole or at crown level. McGrath and Ellingen (2009) found damage in commercially thinned stands with a HDR between 70 – 75 damage started at 50% removal. Although the SMZ's sampled in the St. Mary's River watershed study weren't commercially thinned, as HDR increases, one can conclude that trees will become more susceptible to breakage.

SMZ slope appears to have an effect on the rate of all three damage types. As slope increases, the frequency of damaged trees per unit area decreases. It appears an increase in slope offers some wind protection from prevailing forces. These areas are likely to experience less of an impact from soil moisture as higher water potential will be flowing down slope to the toe or depression area of the catchment basin; areas that offer the greatest degree of protection from the wind.

It appears that SMZ width also has an effect on damage frequency as SMZ's become wider. SMZ widths ranged from 16 – 81 m with an average width of 29 m. These results are slightly misleading because it was found that 44% of the average wind damage occurred within the first 5 m from the harvest boundary. Figure 7 showed that uprooting peaked at 81 trees within the 26 – 30 m width of which dominated the sample size. It may however be possible that increased widths offer some protection for trees at increased distances from the harvest boundary edge.

Damage frequency increased with SMZ stand density. This is also an effect of the stand conditions that were present at these particular densities. One would expect wind damage to decrease as SMZ stand density increased, due to more trees per unit area that would offer shelter and decrease total frequency of damage. This increasing trend is a result of smaller diameter trees 8 cm and greater with no damage, occupying the understory of larger diameter damaged trees. Other site specific variable at different density classes are also a determining factor on the rate of wind damage.

Damage frequency occurred due to winds from the south 79% of the time, while SMZ's exposed to the southeast had the greatest occurrence of average total damage at 169 trees/ha. This high frequency of damage experienced from the south may be related to hurricane tracks that typically move north to a northeast direction either along the coast of Nova Scotia or some that make landfall. These southern facing SMZ's cumulatively account for the severity of wind damages of all face exposures sampled.

An extreme example of these southerly winds is Hurricane Juan which struck Nova Scotia in 2003. Figure 17 presents a graphical illustration showing Hurricane Juan travelling northward from the south. This was the worst recorded hurricane to hit a population centre of Atlantic

Canada in over 100 years. It made landfall on September 29, 2003 with winds that toppled trees, damaged property, and accounted for eight casualties. The strongest one minute sustained winds were recorded at 158 km/hr. It is estimated to have been responsible for the loss of 100 million trees in Nova Scotia and destroyed 90% of the mature growth in Halifax's Point Pleasant Park (CHC 2003).

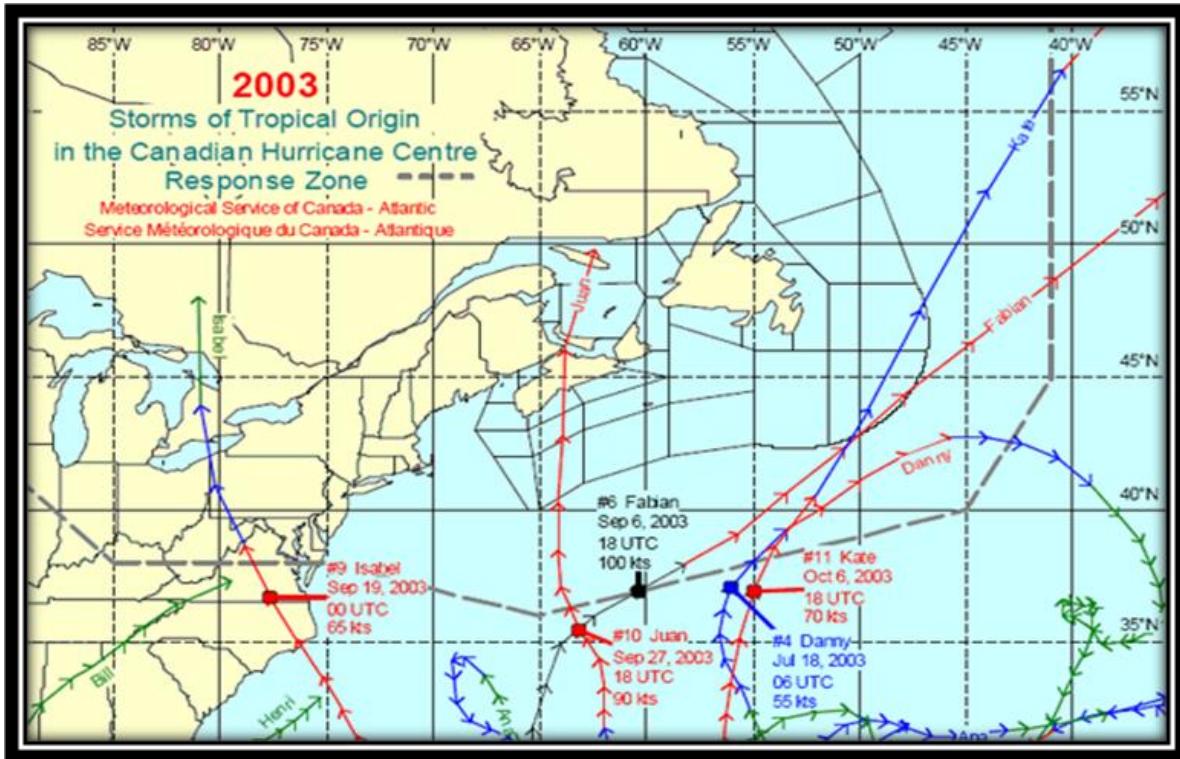


Figure 17: Track of Hurricane Juan on September 29, 2003.

The total average wind damage experienced in areas scheduled for harvest in 2003 would also lead one to believe that Hurricane Juan was a contributing variable to the maximum sustained damages of all other harvest years sampled. Harvest areas sampled in 2010 had the second highest average wind damage with 170 trees/ha. SMZ's that were sampled in 2010 were mostly comprised of very stoney to exceedingly stoney sites that were shown to be a contributing factor to higher rates of partial windthrow and uprooting. The soil structure on these sites has a higher composition of coarse fragments with a high surface stoniness. Fine textured soils tend to become more massive in structure with depth, thereby reducing potential rooting depth. Also, clayey soils lack shear strength, particularly when wet. Sandy soils, although usually deep, lack cohesiveness making them more susceptible to windthrow than loamy soils (Zelazny et al., 1989). Surface soil depths appeared to be shallower on sites with a high degree of surface stoniness. The high composition of stones seems to impede strong rooting structures of the already high composition of the shallow rooted species sampled. Plate 1 shows an example of uprooting on an excessively stoney site where uprooting occurred along the edge of the SMZ.



Plate 1: Uprooting as a result of surface stoniness and exposure along the SMZ edge (Crooked Brook #2, August 2010.)

Wind damages by distance from harvest edge were most prominent in the first 5 m of the SMZ. McCurdy and Stewart (2008) found similar traits in their sample areas. Total average basal area was highest adjacent to harvest boundary in all four of their sample areas by treatment (20 m no thin, 20 m commercial thin, 30 m commercial thin and control with no thin.) Only one watershed in the 20 m commercial thin treatment experienced a higher degree of basal area damage adjacent to the watercourse. SMZ edges are areas that offer the least amount of protection from the wind and therefore experience a higher force than other areas of the SMZ that offer some degree of wind protection. Trees that were damaged within wind protected areas typically had a high HDR for stem breakage. Trees experiencing partial windthrow or uprooting were typically larger diameter trees with crowns exposed and dominating the average canopy height. These taller trees appear to experience a greater degree of force from above the canopy level.

Soil exposure was also most evident in the first 5 m of the SMZ. Similar results were discovered in the Pockwock – Bowater Watershed Study (McCurdy and Stewart 2008). With soil exposure being a direct result of uprooting, these values can be expected. Soil exposure over time in the St. Mary's River watershed, were decreasing with time since harvest year. This is mainly a reflection of the successional stages of the development of grasses, herbaceous vegetation and seedlings occupying the disturbed area. Harvest areas in 2009 - 2010 have the greatest area of exposed soil because of the relatively short duration since time of initial disturbance. Harvest year 2003, that initially had the most wind damage of all, is yielding a total exposed soil of only 65 m²/ha.

Partial windthrow and uprooting frequency within each SMZ were influenced by the depth to water in relation to surface soil levels. Partial windthrow and uprooting dominated these areas with 90% and 88% respectively of all damage trees sampled. These localized areas are where soil moisture can be expected to be greater at some time of the year. The physical properties of soils at these areas contained higher moisture content reducing the overall strength for stable rooting structures. McCurdy and Stewart (2008) also found that wind damage frequency in flow accumulation zones was more than double that of non - flow accumulation zones. Plate 2 illustrates uprooting along an SMZ edge in an area with locally higher soil moisture content.



Plate 2: Uprooting as a result of SMZ edge exposure and locally higher soil moisture content (Nelson River # 1, September 2010)

These areas typically have visibly different local site conditions than an area adjacent within close proximity. Soil moisture content due to drainage class or seepage from an upslope position, generally are the main contributing factors. Ground vegetation in these localized areas will also be variable, comprised of species that prefer moist soil conditions such as sphagnum (*Sphagnum* spp.), grasses, sedges (*Carex* spp.) and cinnamon ferns (*Osmunda cinnamomea*). It is important to recognize that sample SMZ's in this study were limited to 40. SMZ's varied considerably in relation to species composition, soil and site conditions and relative exposure in relation to slope position. Damaged trees used in developing the results were believed to have relatively overall good health at time of wind damage; free from any insect or disease. Although average patterns were experienced in relation to contributing variables for the total sample (e.g. edge exposure, slope, surface stoniness, etc.), site specific factors such as tree species, tree health and overall

wind exposure are important variables when assessing wind damage at the site specific stand level.

Future recommendations would be to classify undisturbed areas at the stand level. From this, a sample area could be developed to assess wind damage for site specific variables. Areas with similar soil types, soil textures, drainage, seepage classes and surface stoniness along with terrain and vegetation differences could be used to develop a quantitative analysis for site specific comparisons that exhibited similar structure.

6.0 CONCLUSIONS

From this study, it was determined that SMZ edge exposure, SMZ slope, SMZ soil moisture content and SMZ surface stoniness classes were the dominant observed site specific variables contributing to wind damage in Special Management Zones. The majority of the wind damaged trees either experienced stem breakage, partial windthrow or uprooting within the first 5 m of the SMZ along the harvest boundary. As slope increased, the frequency of these three damage classes was reduced. Increased slope offers a degree of protection on the downward slope of the harvest edge. Soil moisture contributed to 88% uprooting and 90% partial windthrow when the depth to water was less than or equal to 2 m depth below soil surface level. Surface stoniness sites experienced the greatest frequency of uprooting, and partial windthrow while ultimately contributing to the maximum area of exposed soil.

7.0 REFERENCES

Ellingsen, J., and McGrath, T., 2009. The effects of Hurricane Juan on managed stands commercially thinned in Central Nova Scotia. Nova Scotia Department of Natural Resources. Timber Management Group. Report FOR 2009 – 4 No. 89.

Keys, K., 2007. Forest soil types of Nova Scotia. Identification, description and interpretation. Nova Scotia Department of Natural Resources. Manual FOR 2007 – 2.

Keys, K., Neily, P., Stewart, B., and Quigley, E., 2007. Forest Ecosystem Classification for Nova Scotia. Nova Scotia Department of Natural Resources, Ecosystem Management Group.

McCurdy, D., and Stewart, B., 2008. Pockwock – Bowater Watershed Study. Wind damage in streamside management zones. Nova Scotia Department of Natural Resources, Ecosystem Management Group. Report FOR 2008 – 6 No. 86.

Pulsifer, M., J. MacEachern and L. Allen. 2004. A preliminary assessment of demographic and morphological characteristics of the St. Mary's River wood turtle (*Glyptemys insculpta*) population (2003). Unpublished Nova Scotia Department of Natural Resources report. [www.ec.gc.ca/ouragans - hurricanes/](http://www.ec.gc.ca/ouragans-hurricanes/)

www.gov.ns.ca/natr/forestry/maps-and-forest-info.asp

Zelazny, V.F., Ng, T.T.M., Hayter, M.G., Bowling, C.L., and Berwick, D.A. 1989. Field guide to forest site classification in New Brunswick: Harvey – Harcourt, Fundy Site Regions. New Brunswick Dept. Nat. Resourc. & Energy, Timber Mgmt. Branch.

Appendix 1: Data used to generate statistics and findings of this report

Plot#	Location	Species Comp.	Year	Slope (%)	Width (m)	Exp.	Stone	Density	Soil Exp. (m ² /ha.)	Break Freq. (trees/ha.)	Part. Freq. (trees/ha.)	Uproot Freq. (trees/ha.)	Sample Size (ha.)	Total BA Damage (m ² /ha.)
1	Gorman Brook	rSbFrM	2007	17	33	S	MS	970	117.0	161.6	33.7	60.6	0.15	8.1
2	Crooked Brook #1	rSrMbF	2007	8	26	E	XS	722	509.8	54.9	70.6	188.2	0.13	13.5
3	Bryden Brook Upper Bryden	jLrPwB	2007	8	32	N	NS	1244	0.0	0.0	0.0	0.0	0.16	0.0
4	Brook #1 Upper Bryden	rPrMyB	2008	38	29	S	SS	1170	6.7	0.0	6.8	6.8	0.15	0.3
5	Brook #2	jPrMtA	2007	10	34	E	SS	1728	16.8	5.9	17.8	29.6	0.17	0.6
6	Castley Brook	bSrSbF	2008	15	33	NE	SS	895	43.7	42.0	6.0	36.0	0.17	2.5
7	South Brook Head	rSbFrM	2007	6	20	N	MS	1374	20.4	20.5	51.3	30.8	0.10	2.1
8	Black Brook #1	bFrSwB	2006	36	49	N	XS	1812	32.7	0.0	8.2	20.4	0.25	0.9
9	Crooked Brook #2	rSbFrM	2010	23	27	W	XS	1112	141.9	14.9	14.9	82.1	0.13	2.1
10	Nelson River #1	bFrSrM	2008	13	27	SE	VS	1363	58.8	14.7	44.0	36.6	0.14	2.4
11	Nelson River #2 Nelson Lake	rSbFrM	2010	11	22	SE	VS	1722	490.5	18.5	120.4	111.1	0.11	6.6
12	Outflow	bFrSrM	2009	5	28	E	ES	1463	97.2	21.2	28.3	35.3	0.14	2.1
13	Honeymoon Bog	rSbFrM	2010	7	32	NE	XS	1861	117.9	25.2	44.2	75.7	0.16	1.4
14	South Brook Porcupine Lake	rMrSbF	2007	5	44	N	VS	955	14.9	13.6	9.0	13.6	0.22	1.8
15	Outflow	bFbSrS	2007	3	27	N	VS	1035	576.8	21.3	113.5	241.1	0.14	5.5
16	Campbell's Brook	bFrMyB	2000	25	20	S	SS	1415	4.1	30.8	10.3	10.3	0.10	2.8
17	Ross Brook	bSbFrM	2003	24	28	NE	SS	1473	40.9	21.4	7.1	92.5	0.14	2.3
18	Clark Brook	bSbFeL	2001	4	33	E	MS	967	39.9	24.2	12.1	54.4	0.17	2.3
19	Sutherland Brook	bSrMeL	2001	18	26	SE	MS	848	138.9	62.3	7.8	93.4	0.13	4.5
20	Indian Man Brook	bSwSrS	2008	20	81	E	SS	1053	36.9	9.9	2.5	12.3	0.41	0.8

Appendix 1 (Cont'd)

Plot#	Location	Species Comp.	Year	Slope (%)	Width (m)	Exp.	Stone	Density	Soil Exp. (m ² /ha.)	Break Freq. (trees/ha.)	Part. Freq. (trees/ha.)	Uproot Freq. (trees/ha.)	Sample Size (ha.)	Total BA Damage (m ² /ha.)
21	Beaver Brook	rMrSwS	2007	21	34	NE	SS	988	2.3	29.2	0.0	5.8	0.17	2.7
22	Black Brook Lakes	rSbFrM	2001	6	17	W	VS	2023	345.4	34.5	34.5	126.4	0.09	12.6
23	West River Inflow #1	bFrMbS	2001	15	24	SW	SS	1120	53.5	33.2	8.3	66.4	0.12	3.8
24	West River Inflow #2	bFbSrS	2009	22	21	E	MS	1364	266.5	9.3	46.7	112.1	0.11	6.3
25	West River St. Marys	rMbFwS	2005	46	25	N	SS	1466	23.9	31.9	0.0	15.9	0.13	2.2
26	MacDonald Brook	rMeLbS	2008	18	33	W	SS	878	18.3	36.6	6.1	12.2	0.16	1.5
27	Barren Brook	bFbSrM	2003	15	34	SW	SS	1703	88.5	64.1	5.8	151.6	0.17	5.2
28	Black Brook #2	bFbSrS	2006	12	32	E	MS	1969	51.9	25.2	6.3	31.4	0.16	2.2
29	Mitchell Brook	rSbFrM	2005	26	27	W	MS	1546	10.3	36.6	0.0	22.0	0.14	1.9
30	MacQuarrie Brook	rSbFyB	2006	5	42	E	MS	971	199.3	14.4	4.8	71.8	0.21	5.5
31	Cross Brook	bFrMwS	2005	9	34	E	SS	843	20.1	17.8	5.9	35.6	0.17	1.0
32	North River St. Marys	rMbFeL	2005	14	38	W	NS	1121	120.5	52.6	26.3	57.9	0.19	5.1
33	Black Brook #3	rSbFrM	2001	25	16	E	MS	1780	3.1	36.6	0.0	12.2	0.08	1.5
34	East River St. Marys	rMrSbF	2005	24	31	E	NS	545	63.2	89.7	0.0	25.6	0.16	7.2
35	Black Brook Inflow	wSbFrM	2005	21	17	W	NS	1265	127.2	84.3	24.1	24.1	0.08	6.0
36	Black Brook #4	wSyBbF	2004	7	27	W	NS	844	4.8	81.5	22.2	14.8	0.14	4.5
37	Leitch Lake Brook	bSrMeL	2004	5	22	SW	NS	769	30.6	45.2	9.0	27.1	0.11	1.0
38	MacKay Brook Inflow	bFrMsM	2007	11	17	SW	NS	1920	25.8	34.5	11.5	46.0	0.09	1.1
39	Archie Lake Brook	eLrMbF	2005	0	16	SW	NS	456	0.0	25.3	0.0	0.0	0.08	0.4
40	MacKay Brook	bFwSeH	2008	26	19	E	NS	2454	45.1	51.5	41.2	61.9	0.10	3.3