Review of January 1, 1997 Windthrow in MacMillan Park

Prepared for

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ABSTRACT

The January 1, 1997 windthrow event was caused by a strong 'Qualicum' wind funneling through the narrow bend in the Cameron Valley where MacMillan Park is located. Qualicums occur when low pressure systems moving across northern Vancouver Island pull southwesterly winds through the cross island gap from Barkley Sound to Qualicum Beach. The wind event occured four days after a major snowfall when soils were wet, but the presence of snow in the canopy and its role in the damage is uncertain. The Cameron Valley has a history of endemic and catastrophic wind damage. Catastrophic wind events like that of January 1 appear to have a return period of 30-40 years. Douglas-fir, western hemlock, western redcedar, grand fir, big leaf maple and red alder will regenerate in the heavily damaged areas. In the moderately damaged areas, include some portions of the main trail area, existing sapling communities of hemlock, redcedar and big leaf maple will release filling in the sub canopy. The sheltering effect of stands to the south and west of the park should be maintained. Trees in the vicinity of roads, trails, and facilities should be routinely inspected and if necessary topped, pruned or removed. If this is not desirable, facilities should be relocated or public access limited. The park should be closed to visitors if winds exceed 40 km/h or if damage commences. Park interpretation should be extended to include the dynamic nature of this ecosystem and the role of wind, flooding and fire in initiating and modifying plant communities.

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INTRODUCTION

Project Objectives

This project was initiated as a result of discussions following the windthrow event of January 1, 1997 in MacMillan Park. The principle objectives were to:

i. review the damage pattern and conditions leading to the January 1997 event;
ii. discuss the role of wind as a factor in the Park's natural processes;
iii. assess of the potential for future events to occur and their severity;
iv. identify ways to reduce the impact of future events within the Park.

Project Approach

Given the quality of information and resources available, this project is an overview of the January event and its implications, rather than a detailed study. The observations made in this report are an interpretive rather than a quantitative analysis of the information obtained from the sources noted below and identified in the reference list and appendices. The intention is to set the January event in context and discuss its implications for future park management.

METHODS AND LIMITATIONS

Nature of Windthrow and its Assessment

'Windthrow' or 'blowdown' results when trees are broken or uprooted by wind. Windthrow is a common form of forest disturbance but is poorly understood due to its episodic nature and due to the large number of factors which contribute to each event. While the primary cause of windthrow is high winds, the sequence of events leading to stem or root failure and the contribution of biophysical and management factors varies from event to event, and in space and time within a particular event. A quantitative system has been developed for use in Britain in managed, single species stands. Elsewhere, forest managers use observational -interpretive approaches in assessing and predicting wind damage, and in designing prescriptions for damage reduction.

Methods Used in this Report

In this project, five major sources of information were used: interviews, field inspection, aerial photographs, climate data and published articles. A summary of people interviewed is provided in Appendix 1. Principle references are listed in the Reference section. Climate data was obtained from the Atmospheric Environment Service (AES). MacMillan Park was visited on February 14, November 8, and December 18, 1997. Site information is primarily from 'Ecosystems of MacMillan Park'. Some of these ecosystem associations have since been combined and renamed, but the original names are used in this report. BC Parks provided a series of aerial photographs of Cameron Valley and MacMillan Park taken between 1951 and 1997 (Appendix 2).

The 1991 and 1997 aerial photographs were viewed using a mirror stereoscope and the proportion of damaged trees was visually estimated. Boundaries were drawn around areas with 'heavy' damage (more than 30 percent of trees missing from canopy) and 'moderate' damage (between 5 and 30 percent of overstory missing). Remaining areas were considered to have 'minimal' damage. The orientation of windthrown trees visible on the photographs was recorded. The windthrow boundaries were then transferred onto the topographic base map. Representative portions of each damage class were inspected on the ground. Considerable crown damage and loss of foliage was observed in some areas classified as minimal damage from the photographs.

To enable interpretation of biophysical and management variables, the windthrow and ecosystem maps were overlayed. Sample points were obtained by placing a 100m*100m grid on the overlay and recording biophysical and management attributes of each gridpoint. Contingency tables enabled preliminary analysis of the association of damage class with each variable. The sampling intensity could be increased, and more sophisticated analyses could be conducted to determine multiway associations, but these were considered beyond the scope of this project.

RESULTS AND DISCUSSION

Biology of Windfirmness

Trees acclimate to routine windloads through gradual form modification as they add new layers of growth each year. In locations with prevailing growing season winds like MacMillan Park, stems grow with asymmetric cross sections, thicker on the leeward side. Flagging of crowns where branching is heavier on the leeward side is another response to high wind loads, and can be seen on the east side of the Cameron River near the main trail area. That Douglas-fir trees can grow to heights of 70 metres in this windy location with restricted rooting is a testimony to the effectiveness of these internal design mechanisms (Appendix 10 - Photos 1 and 2). Trees remain vulnerable however to extreme weather events, sudden changes in canopy condition due to defoliation or tree loss, and changes in soil conditions due to flooding, soil compaction or excavation. As trees age they are less able to repair damage and resist decay, leading to weakened stem and roots.

Sources of Peak Winds

In coastal BC there are two major sources of peak winds which cause windthrow, Pacific Lows and Arctic Outbreaks. Pacific Lows are low pressure systems which move in off the Pacific. Winds spiral anti-clockwise around the center of the low. As the low moves into the coast, winds align with the southeast-northwest orientation of the coast resulting in strong southeasterly winds (winds are named according to the direction they come from). Windspeeds are highest when the low is deep and is travelling quickly from the southwest. Low pressure systems moving down from the gulf of Alaska occasionally produce strong northwest winds. Arctic Outbreaks occur when high pressure systems with cold arctic air move down over the BC interior and spill out onto the coast through coastal inlets. The Fraser Valley, Howe Sound and Bute Inlet are well known for strong, cold northeasterly outflow winds, which occasionally travel as far as Vancouver Island. Both Pacific Lows and Arctic Outbreaks occur annually along the BC coast.

Endemic and Catastrophic Windthrow

Damage caused by routine peak winds is termed 'endemic' damage (1-5 year return period), and that caused by infrequent peak winds 'catastrophic'. Endemic winds cause considerable damage in coastal BC each winter, primarily to trees along freshly exposed stand edges, or trees which have become unstable due to decay or loss of root/soil anchorage. In forestry, prediction and management efforts focus on endemic windthrow, and are still in the early stages of development.

Historic Catastrophic Winds on Vancouver Island

There have been a number of windstorms on Vancouver Island which have caused catastrophic wind damage over large areas within the period of historical record. All of these are believed to be the result of deep low pressure systems. A windstorm in 1880 caused damage in the Pacific Northwest and southern Vancouver Island. The 1906 windstorm damaged thousands of hectares of forests on the north Island near Quatsino Sound and Port Hardy. A windstorm in 1921 was recorded by a survey party working in the Cameron Valley. This event damaged forests in central Vancouver Island including 1200 hectares in the Nitinat Valley. 'Hurricane Frieda' in 1962 caused damage in the Pacific Northwest, southern Vancouver Island and the Lower Mainland.

Qualicum Winds

Cutting through the northwest running mountain ridges which form the backbone of Vancouver Island is an opening which extends from Barcley Sound past Port Alberni, Cameron Lake to Qualicum Beach. When low pressure centers pass over Vancouver Island north of the valley, southwesterly winds are drawn through this gap resulting in a local wind known as the 'Qualicum' (Appendix 3). MacMillan Park is located at a bend in the Cameron Valley where the valley swings from southeast-northwest to west-east. Southwesterly winds funnel around this corner. Qualicum winds are experienced in Coombs and Hilliers on the coastal plain to the east, but Parksville and Qualicum are somewhat sheltered being slightly lower in elevation. The winds drop down to sea level over Georgia Straight and are best detected by the Sisters Island weather station north of Lasqueti Island. Summer Qualicum's occur on hot afternoons when daytime heating and turbulent mixing, bring strong westerly winds from aloft down to the surface. The bole asymmetry and flagging of Douglas-fir in the park indicates prevailing growing season winds from the southwest.

Historic Windthrow Events in the Cameron Valley

In addition to the 1921 event recorded by the survey party, there are two patches of windthrow typical of catastrophic damage immediately south of the park, one dating from the mid 1950's which was salvaged in 1958, and another from the late 19th century just west of the 'Hump' which has become a uniform thrifty-mature stand. Edge windthrow salvage areas at various locations in Blocks 35 and 1324 in the Cameron Valley were removed in 1974, 1977, 1978, 1980, 1981, 1983, 1986 and 1991 (Appendix 4). The timing, size and orientation of these areas suggest a pattern of endemic southerly windthrow associated with Pacific Lows and southeast flow channelled by the Cameron Valley.

Approximately 8.6 hectares, including 6 hectares of heavy damage, was windthrown in the winter of 1990/91 in the southeast corner of the park. Damage was reported as occurring in November 1990, and in January and February 1991 at times when there was extensive flooding within the park. Monthly wind summaries for Sister's Island show peak winter winds of 61-71 km/h from southeasterly flow in these months.

Climate Conditions During the January 1997 Event

Surface Plots

Surface Plots produced at 6 hour intervals show isobars of atmospheric pressure at sea level. Lows with central pressures below 980 millibars produce extensive areas of storm force winds (89 -118 km/h, and lows less than 960 millibars can produce hurricane force winds (>119 km/h). The surface plot of the windstorm of December 31, 1996/January 1, 1997 shows the typical pattern of a Qualicum wind. The low moved from the Pacific, west across the north end of Vancouver Island. At 10 pm on December 31st, the low had a central pressure of 956 millibars and was located several hundred kilometers offshore. At 4 am on January 1st, the center of the low was above the north end of Vancouver Island and by 10 am the low had crossed to the mainland and weakened. As the low crossed northern Vancouver Island, winds in central Vancouver Island peaked and shifted from the southeast to the southwest and then back to southeast (Appendix 5).

Monthly Climate Normals

The 1961-1994 monthly climate records for Sisters Island station contain peak hourly sustained windspeed and direction. No gust data is available. The period of record for this station is 1975 to 1992 with wind data missing for some months in the years 1975, 1982-84, 1986-88, 1990 and 1992. The strongest winds at Sisters Island are typically from the southeast or east for any month of the year. Since only the peak wind of the month is contained in the records, strong southeasterlies obscure weaker southwesterlies in the monthly summaries. The return period of southwesterly winds could be determined from the complete hourly data set for the station but these are expensive to obtain (Appendix 6).

Hourly Climate Records

Hourly records for Sisters Island were obtained for December 31, 1996 to January 2, 1997. Strong winds from the southeast began at 10 am on December 31 building up to sustained winds of 74 km/h from the southeast at 1am on January 1 with gusts to 87 km/h at 2 am. The records clearly show the sudden swing in wind direction from southeast to southwest commencing at 7am on January 1 and continuing until 10 am at which point windspeeds subside and shift back to southeast flow. Peak sustained southwest winds of 57 km/h occurred at 7 am and again at 8 am, gusting to 91 km/h between 7 and 8 am (Appendix 7).

Sustained winds of 68 km/h have a one year return period at Sisters Island, but as noted above, these are primarily southeasterlies. Peak southwest winds in excess of 57 km/h occurred at Sisters Island in May 1980, June 1983 and July 1984 over the period of record. These winds likely represent strong summer Qualicums during the season when southeasterly flows are typically slower. While it is known that Sisters Island detects Qualicums, the correlation between windspeeds at MacMillan Park and Sisters Island is unknown. Windspeeds may be much higher through the valley gap.

A heavy snowfall occurred on December 28. Temperatures in Port Alberni were at 0 C in the morning of December 31 and beginning to warm in the afternoon. Reports from people travelling through the Park on December 31 and January 1 indicate that there was still in excess of 30 cm of snow on the ground. Responses were mixed as to whether there was still snow in the canopy at the time of the windstorm, but with the low temperatures in the preceding days it is possible that there was. Snow in the canopy would greatly increase the drag on the crown and the weight of the crown once displaced. Unless the snow was frozen onto the crowns as a result of freeze-thaw cycles, it would be shed rapidly once windspeeds picked up due to inter-branch and inter-crown contact. Snow related damage would likely be highest from the southerly winds early in the storm.

High soil moisture content reduces root/soil cohesion. Precipitation data for Port Alberni airport indicates 69 mm in the 24 hour period preceding 11 pm on

December 31, peaking at 5 pm on December 31 at 10 mm/h. Precipitation data includes rain and melting snow. This is a large amount of precipitation in 24 hours, but is not unusual for Port Alberni. In approximately 40 % of winter months in the years 1983-1992, monthly extreme daily rainfall exceeded 60 mm. Reports from people in the area indicate that soils were wet, but flooding was not noted as it had been in the 1990/91 wind damage events.

Description of Damage

Timing and Extent of Damage

BC Ministry of Highways reported that the peak winds occurred at about 8 am on January 1 lasting 20-30 minutes with falling trees blocking the highway through MacMillan Park. This would coincide with the swing of winds to the southwest. Within MacMillan Park 12 hectares were heavily damaged and 24.7 hectares were moderately damaged. Damage from this storm was reported on the north side of Sproat Lake, along Cameron Lake, Little Qualicum Falls, Hilliers, Coombs, and along the new Island Highway near the Qualicum Bay junction (Appendix 9).

Distribution of Damage

There is minimal windthrow and less crown damage in the western one third of the park. The main trail area falls within minimal and moderate damage areas. There is an area of heavy damage in the southeast corner of the park adjacent to the area damaged in 1990/91. Two narrow fingers of heavy damage extend towards the main trail area (Appendix 8). There is considerable loss of foliage and some uprooting on the shoulder across the Cameron River east of the park. There are several areas of heavy crown loss and uprooting along the south side of Cameron Lake, east of the park. The stands between the highway and Cameron River south of the park were also damaged and had been partially salvaged at the time of the 1997 photos.

Orientation of Damage

The mean orientation of damage and range in orientation varies with location. Damage south of the park is oriented from 180 degrees. Damage in the two fingers of heavy damage within the park is oriented from 195 degrees. The damage east of the Cameron River within the park is oriented from 240 degrees. In these more strongly oriented areas the majority of damage is oriented within plus or minus 20 degrees of the dominant direction. Damage on the shoulder northeast of the park is oriented from the southwest but shows more variability in direction than elsewhere. Damage along the south shore of Cameron Lake is oriented from the west.

Association with Environmental and Management Variables

In assessing windthrow, climatic, biophysical and management variables are considered. The 'biophysical' variables of interest are broadly grouped into topographic, soils and stand attributes. Topography modifies windflow, influencing windspeed, gustiness and direction. Soil texture, depth and drainage affect root configuration and root/soil cohesion. Stand composition, structure and density affect the wind acclimation of individual trees within the stand.

Topography

The regional topography and its role in producing 'Qualicums' has been described above. As noted MacMillan Park is located at a right-angle bend in the Cameron Valley which forms a pass between the west side and east side of Vancouver Island. Significant topographic features within the immediate vicinity of the park include the plateau southwest of the park over which the highway passes, the 'Hump' immediately south of the park on the east side of the Cameron valley and the shoulder adjacent to the northeast corner of the park where the Cameron Valley swings to the east. The valley floor is at 190 m above sea level. The Hump and the plateau rise to 420 m. The valley wall rises steeply to 700 m immediately northwest of the park and 900 m immediately southeast of the park (Appendix 3).

The majority of the park is on the flat valley floor. The portion of the park west of the highway is on rising ground on the lower slopes of the valley wall, as are small areas of the park east of the Cameron River. The park is exposed to southerly winds funnelling up the Cameron Valley. The Hump likely disrupts windflow from the south causing more turbulent winds and the plateau would behave similarly with westerly winds. The west side of the park along the valley wall is likely partly sheltered from westerly winds. Southwesterly winds would be highest across the shoulder on the northeast boundary of the park. Based on the amount of crown damage to standing trees, it appears that the highest windspeeds were experienced in the eastern half of the park.

Soils

The soils of the park are described by ecosystem association in 'Ecosystems of MacMillan Park'. On the floodplain, soils are moist to wet fluvial soils, with textures ranging from silts to gravels, with seasonally fluctuating watertables providing rooting depths up to 2 m on some of the higher terraces and less than 30 cm on low terraces and poorly drained areas. On the lower slopes soils are moist colluvial blankets with a high coarse fragment content and good drainage. On these soils rooting is typically limited by high bulk densities at depths of 1-2 m. Periodic winter flooding is a feature of low lying areas of the park, and the Cameron River channels are actively migrating at the south end of the park flooding some areas and leaving others high and dry.

Damage appears highest in the wetter ecosystem associations. The slightly dry 'sword fern - Oregon grape' association is the driest association and shows the least damage. This association is primarily located on the lower slopes of the west valley wall on colluvial blankets. The heaviest damage occurred in the moist to very moist 'lady fern - devil's club' association which is located on the flood plain, primarily on islands within the current Cameron River channels and on old channels cutting through the fluvial terraces. Damage was also relatively high in the moist 'enchanter's nightshade - salmonberry' association which is on the annually active floodplain adjacent to the Cameron River with a predominantly deciduous overstory. The slightly dry to moist 'vanilla leaf - sword fern', 'foam flower - sword fern' and 'maidenhair fern - sword fern', associations show intermediate levels of damage (Appendix 9).

While the trend of lower damage on better drained, deeper soils is consistent with windthrow observations elsewhere, it is likely confounded in this case by differential topographic exposure. Windspeeds appeared to be highest in the eastern half of the park, which coincides with the Cameron River channel and wetter ecosystems.

Stand

The stand characteristics are described for each ecosystem association in 'Ecosystems of MacMillan Park'. Forest cover was mapped using a simplified labelling system which identifies composition (conifer/deciduous), age class (immature/ mature/overmature), and stocking (open/sparse/partial/full) along with structure (uniform/irregular) (Appendix 9).

There were no obvious trends in damage by stand composition or structure. Pure conifer, pure deciduous and conifer-deciduous mixed stands showed similar levels of damage, as did uniform and irregular structured stands. Damage appears to decrease with age of dominants, with overmature stands showing the least damage. The majority of immature stands within the park are on the active Cameron River floodplain. The immature 1958 origin conifer stand immediately south of the park had little damage. Partially stocked stands appear to be more heavily damaged than either sparsely or fully stocked stands.

The presence of *Phellinus weirii* (laminated root rot) and *Polyporus schweinitzii* (brown cubical butt rot) in the Douglas-fir in the park is well documented. A number of uprooted or snapped trees showed extensive decay and this likely contributed to the intensity of damage. Some of the snapped off trees in the main trail areas had sound shells as thin as 20cm with evidence of past vertical stress fractures. However, uprooted trees were observed which showed no external evidence of root or stem decay. It was pointed out by one interviewee that many trees previously identified as hazard trees survived the windstorm. This underlines the difficulty in predicting tree failure based on readily observable features.

Summary of Biophysical Variables

Topographic exposure and soil moisture regime appeared to influence the broad pattern of damage within the park. An unusual feature of the damage pattern are the two long fingers of damage extending from the south through areas of relatively undamaged stands. These fingers do not appear to be associated with local ecosystem or stand features. They likely resulted from wind channeling along the fingers within the canopy during the storm event (Appendix 9).

Role of Climatic Conditions During Windthrow Event

The dominant orientation of damaging winds can be estimated by examining the shape of windthrow openings, and by mapping the orientation of downed stems. In the 1997 damage, both openings and downed trees range in orientation from 180 to 240 degrees, with orientation from the southwest stronger in the northern part of the park. The change in orientation may reflect wind funneling around the valley corner, or it may reflect the swing in wind direction during the storm event as wind shifted from southerly to westerly. Given the latter alternative, the heavy damage in the fingers likely happened early in the storm while winds were still southerly and when snow may still have been in the canopy.

The large amount of crown damage at the north end of the park and along the south shores of Cameron Lake indicate very high wind speeds in these areas. That fewer trees were uprooted reflects either improved anchorage or reduced drag, perhaps due to a lower snow load by the time westerly winds hit. Wider range in orientation on the shoulder northeast of the park may reflect exposure to changing dominant wind directions during the course of the storm, or to higher levels of turbulence.

Management Variables

Large canopy openings enable the horizontal wind speed profile to move downward, bringing higher winds to canopy level. Small openings increase the roughness of the canopy leading to increased turbulence. Excavation for roads and trails can disrupt root systems and change drainage patterns.

There does not appear to be any local increase in wind damage associated with trails, roads and railway right-of-ways within the park. The role of the openings to the south of the park is clearly a contentious issue, and is one which is difficult to determine with certainty. The pattern of endemic windthrow and salvage in the valley to the south indicates that opening edges with southern exposure have been vulnerable to southerly winds, with damage extending for one or two tree lengths during endemic events. The pattern of historic damage indicates that catastrophic events have damaged stands where there was no harvesting in the vicinity.

The 1990/91 damage is concentrated in the southeast corner of the park downwind of windthrow salvage openings to the south in an area with high topographic exposure and wet soils. While there is a concentration of heavy damage downwind of the 1990/91 windthrow opening, the 1997 damage is widespread. The western extent of the 1997 damage within the park is not downwind of recent openings, neither is the damage at the north end of the park, that on the shoulder east of the park, nor that along the south side of Cameron Lake.

Wind as a Factor in the Park's Natural Processes

Ecology of Coastal Western Hemlock Drier Maritime Subzone

MacMillan Park is located in the Coastal Western Hemlock Drier Maritime (CWH xm) biogeoclimatic subzone. This is the driest variation of CWH and has growing season water deficits on zonal sites (sites where downslope groundwater inputs balance outputs). Climax forests on zonal sites would be dominated by western hemlock. The boundary with the drier Coastal Douglas Fir (CDF) zone where Douglas-fir dominates climax forests is just east of Cameron Lake, indicating a climate gradient. Because the park is located on lower slopes and alluvial flats, most ecosystems in the park are wetter than zonal. The constant inputs of groundwater nutrients and fluvial sediments make for rich growing sites.

Silvics of Douglas-fir

Without periodic disturbances, shade tolerant western hemlock and western redcedar would dominate these ecosystems, while shade intolerant Douglas-fir would decrease in abundance. In drier ecosystems, Douglas-fir will regenerate under a canopy, but on the moister ecosystems of the park, it requires large canopy gaps. The preferred seedbed for Douglas-fir is exposed mineral soil. Once mature, it is thick barked and can withstand surface fires. It is generally considered more windfirm than other tree species, often shedding foliage and branches during storm events rather than uprooting. Being very long lived (up to 1000 years), it can dominate a stand for centuries following initiation. Trees over 90 m tall have been found growing on moist rich sites in sheltered locations. On the rich but windy sites of MacMillan Park, heights of 65-70 m are reached.

The current view is that the 800 year old and 300-400 year old cohorts in the park were initiated following catastrophic fires. Given the evidence of repeated catastrophic windthrow in the valley, catastrophic windthrow events may also have enabled Douglas-fir regeneration. Accurate dating of a larger number of trees and fire and wind history reconstruction could clarify this question. Channel migration of Cameron River and periodic inundation of the floodplain is another major source of disturbance and stand initiation within the park.

Implications of 1997 Event for Future Stand Structure

Windthrow is a major agent of natural disturbance in coastal forests, adding considerably to structural diversity. Uprooted stems will decay and contribute to the woody debris reserve which is a feature of old growth forests. This woody debris provides a variety of habitats for terrestrial and riparian plants and animals and increases stream channel complexity. The upturned roots and associated pits produce a hummocky soil microtopography which produces a diversity of drier and moister microsites. The turning over of mineral and organic horizons increases the rate of decomposition and breaks up compact soil horizons. Exposed mineral soil is rapidly colonized by understory plants and tree regeneration.

The loss of branches and foliage in some areas was considerable, perhaps as much as 50 % of the pre-storm level. Many of the overstory trees will refoliate, with Douglas-fir being particularly well adapted to rebuilding crown. For trees in advanced state of decay, the loss of vigour will further reduce resistance to fungal attack. Root, stem and crown damage will enable entrance of decay fungi. Outbreaks of Douglas-fir bark beetle which breeds in windthrown or weakened trees and spreads to and kills more vigorous trees have occurred recently in the CWHxm subzone on the Sunshine Coast. If there is no history of attack in the valley then bark beetles should not be a problem here.

Plant communities tend toward full occupancy of a growing site. When individuals are lost due to disturbances, regeneration occurs through the release of remaining individuals and establishment of new individuals. Regenerating plant communities require a source of propagules (seed fall, seedling/root/shoot bank), appropriate climate conditions (light, temperature, humidity) and appropriate seedbed conditions (substrate, inter/intra species competition). The wind damage within MacMillan Park ranges from nearly complete loss of overstory stems to reduction in canopy density due to defoliation.

Most damaged areas will have adequate supplies of propagules, but climate and seedbed conditions vary with level of disturbance. The less disturbed areas will regenerate to shade tolerant, later successional tree species such as western hemlock, western redcedar and grand fir. The more heavily disturbed areas will include shade intolerant, fast growing, early successional tree species such as alder, big leaf maple and Douglas-fir along with the hemlock, cedar and grand fir. The species mix, and rapid growth of the regeneration in the 1990/91 damage indicates the kind of stand to be expected within the more heavily damaged 1997 areas.
In the less disturbed areas, the current sapling layer of western hemlock, big leaf maple and redcedar will release and go through a period of very rapid height growth and crown expansion, slowing down once the overstory refoliates. There will be considerable germination of hemlock on upturned rootwads and downed logs, but this cohort will be suppressed in time by the re-invigorated sapling layer. Douglas-fir germinants are present on upturned rootwads near the main trail area in canopy gaps created by one or two uprooted trees. Because Douglas-fir needs high light levels for successful recruitment, the germinants in these small gaps are unlikely to survive once the sapling and overstory canopies close in (Appendix 10 - Photos 3-6).

Assessment of the Potential for Future Events to Occur

Periodicity of Similar Wind Events

With the climate data obtained, it is not possible to estimate the periodicity of an event of similar magnitude to the January 1997 event through calculation. The masking of westerly winds by stronger southeast winds at the Sister's Island station mean that the summary datasets can not be used to calculate return periods for strong Qualicum winds. They could be calculated if complete hourly data sets were obtained, but the period of record at Sister's Island is short and there are many years with missing data. Snow in the canopy may have contributed to higher levels of damage in the early stages of the storm. The coincidence of extreme wind and extreme snow events would have an even longer recurrence.

There are other approaches to estimating the recurrence of windthrow events. Combining historical records and observations of stands initiated by windthrow in the Cameron Valley, catastrophic windthrow events occurred circa 1880, 1921, circa 1950 and 1997 suggesting a recurrence interval of 30-40 years. Growth patterns of individual stems can be examined for evidence of past defoliation or stem tilting. Brief examination of three Douglas-fir stems which had been sectioned along trails indicated as many as 8 pulses of ring asymmetry and compression wood formation on the lee side during a 240 year period. Aging cohorts of trees within the stand would enable estimation of the dates of past disturbances which have lead to regeneration and recruitment.

Future endemic winds may cause some damage along the edges of 1997 windthrow openings. When the next catastrophic event occurs, further extension of the heavily damaged zone to the north should be expected. This is likely because the north end of the park is similar in topographic exposure, soils and stand attributes to the area already damaged. The western portion of the park does appear to be less vulnerable with greater topographic shelter from westerly winds and better drainage on the lower slopes.

Consequences of Future Events for Ecology of the Park

Wind Damage

In the long run, without catastrophic disturbance removing considerable numbers of trees, Douglas-fir will be replaced by hemlock, cedar and grand fir. The 1990/91 and 1997 events are sufficient to re-initiate a new generation of Douglas-fir in the more disturbed areas. The site remains extremely fertile, and in the absence of long term climate change should continue to produce rapid growing stands of Douglas-fir capable of growing to very large sizes.

Flooding and Channel Migration

The very active channel migration and flooding at the south end of the park and the role of windthrow in flow diversion is described in the hydrological assessment by

Hay and Company Consulting. Channel movement will result in further changes in forest cover and has implications for facilities development and park interpretation.

RECOMMENDATIONS

Reducing the Impact of Future Events within the Park

There are three separate phases in managing windthrow: prediction of windthrow occurrence, assessment of potential impacts, and design of treatments to reduce windthrow and its impacts. The limitations on our ability to predict windthrow are noted above. In a park setting, potential impacts include loss of desired stand structure, disruption of services, damage to facilities and injury to people. In developing strategies to reduce windthrow and its impacts it is necessary to consider whether actions can be taken to prevent or reduce occurrence, and whether it is socially and economically acceptable to take these actions.

Windthrow Reduction

Designated groups of trees can be partly sheltered from strong winds by retaining windfirm stands to windward. Newly exposed stand edges can be 'feathered' by removing a portion of the less windfirm trees. This technique is used where stands are moderately windfirm and partial damage from endemic winds is expected. If partial damage has occurred along an edge, feathering can be maintained by removing down or damaged trees only. Topping or pruning are methods of improving the windfirmness established trees, but they are expensive and can reduce tree vigour. None of these techniques may be sufficient when winds are catastrophic or when trees are decayed or have restricted anchorage.

Sheltering reserves, partial cutting and partial salvage techniques have been used on the east side of the river south of the park but have not prevented wind damage. For the stands in the western third of the park where current damage is low, the sheltering effects of the stands to the south and west should be maintained. This could be accomplished by acquisition of adjacent lands as noted in the park Master Plan, or through the establishment of special management zones in cooperation with adjacent landowners. In such special management zones, harvest entries should be infrequent, with a high proportion of overstory trees retained. The retention of surviving overstory trees in the 1997 salvage area south of the park is a good practice and will help to shelter the stand to the north. Removing trees which are already down will not affect canopy properties provided the stems and root systems are not damaged during yarding.

The north-south axis of the opening for the proposed visitor center and parking lots south of the park should be kept as narrow as possible. Trees adjacent to or within the opening should be assessed and treated if necessary. It is technically possible to prune old growth trees to improve their windfirmness but would be expensive and impractical to treat all of the vulnerable trees in the park east of the highway. It also represents an intervention which may not be consistent with a desire to let natural processes continue. Pruning may be desirable for some of the large old trees in the main trail area and for trees at the north end of the fingers of heavy damage. An arborist should be consulted.

Protecting Facilities

Because of the large number of old trees with varying degrees of decay within the park, the high winds through this area, the history of wind damage and the high visitor use of the park, a more active approach to visitor and facilities management is warranted. Trees which could fall or drop branches onto roads, trails or structures should be regularly inspected by qualified arborists, and treatments such as topping, pruning or removal of such danger trees may be necessary. If treatment of danger trees is not consistent with park management philosophy, an alternative is to keep facilities and people away. This can be done by temporarily closing trails and by building new facilities in areas free of danger trees.

Moving the visitor center and parking areas to leased land south end of the park into the younger stand is wise. Danger trees near road ways or structures near this new facility should be treated. Trails, bridges and viewing platforms located in the park east of the highway are at risk of future damage and may need to be reconstructed following future wind events. Channel migration could also jeopardize facilities. Recommendations for management of windthrow in stream channels are discussed in the hydrological assessment by Hay and Company Consultants.

Protecting Visitors

The current warning signs informing the public of the nature of the stand and the risk of falling trees and limbs should be made larger and placed at all park entry points. Because of the advanced state of decay of some trees, failure could occur at any time without warning even with no wind. A park closure plan should be implemented when southerly or westerly wind speeds exceed 40 km/h or if damage commences. Because of the 'Qualicum' wind effect, winds of this speed can occur in any season including peak summer visitor months on warm sunny afternoons. Meteorological offices should be able to provide some advance warning of when such conditions are likely. Gates and appropriate signage at park entry points could indicate to the public when the park is closed and why. The trail areas should be inspected for hazardous trees and suspended debris after damaging wind events before the park is opened. (Appendix 10 - Photos 7 and 8).

Interpretation Strategy

Cathedral Grove, the stand of large old individual Douglas-fir trees in the northern portion of the park, is the principle attraction for visitors as it has been since the turn of the century. The grove is identified as a 'special feature' in the park Master Plan and is considered an internationally significant example of Douglas-fir old growth forest. Conversations with visitors during the field visits indicated that while people are still awed by the size of the trees in the grove, they are also impressed with the power of nature displayed in the huge broken and uprooted trees. The loss of aesthetic appeal from further loss of large old trees will perhaps be compensated for by a heightened appreciation for the complex and dynamic nature of forest ecosystems and the power of natural forces.

The new visitor center provides an opportunity for additional interpretive displays. Present signage along trails indicates that interpretation is extending from emphasis on individual large old trees, to the ecosystem as a whole. This should include discussion of the dynamic nature of this ecosystem and the role of wind, flooding and fire in initiating and modifying plant communities. A graphic of the sequence of successional stages showing overstory and understory structure and composition at each stage would be useful for displaying temporal changes. Photographs or drawings of various parts of the park which represent each stage could be linked with the graphic (e.g. islands or sandbars, regenerating windthrow areas, regenerating partially wind damaged areas, each with different ages of communities). The discussion of windthrow should include the role that rotting logs and pit-mound microtopography play in the terrestrial communities, and the role of large woody debris in stream systems. Trails and signage should be designed so that these features can be observed.

Where trails are to be fully accessible it may be necessary to cut through windthrown trees to permit passage. It would give a different perspective if some trails were bridged up and over or along windthrown logs. Viewing platforms give visitors a different perspective and construction of a high tower which would enable viewing within the canopy should be considered. Bear in mind however, that bridge and viewing structures may be damaged during future wind events. A polished stem cross section from one of the large windthrown Douglas-fir would be a valuable addition to the visitor center. Sections of hemlock may show past release and suppression episodes.

CONCLUSION

Although individual trees in MacMillan Park have reached great age and size suggesting permanence on a human time scale, disturbance and change are key features of this forest. Catastrophic in our terms, the wind storm of January 1, 1997 is one of many storms which have blown through the Cameron Valley over the centuries, and which along with fire and flooding, have left their mark on the form of individual trees, the structure and composition of plant communities and the distribution of these communities within the park. While celebrating the grandeur of the large old trees, we need to incorporate the notion of change into our understanding and management of the ecosystems which produce such trees. In a small park such as MacMillan Park, situated on a major travel corridor near expanding populations, with high visitor use, influence of human activities is inevitable. These effects can be mitigated to some degree through application of our growing knowledge of ecosystem function, and through long term cooperative planning with managers of adjacent lands.

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APPENDIX 1

SUMMARY OF INTERVIEWS

Interviewee(s)	Summary of comments (in my words)
Rik Simmons (Resource Officer) and Staff BC Parks Strathcona District October 11, 1997 November 7, 1997	- indicated principle contacts and reports; provided maps, aerial photographs and copies of reports - indicated areas of known damage in Parks in the Cameron Valley, Qualicum area - provided history of windthrow in the Park since 1990 - indicated locations of damage from New Years event - January 14 1991 flood damage in park - January 16 observed blowdown at SE end of park; estimated 6 hectares - February 4, 1991 more flooding and trees down in the trail area; high winds and too hazardous to assess - February 6, 1991 assessed damage from February 4 storm, more trail and flood damage, twice the number of trees down in Cameron River - March 12, 1991 tree removal in flood channel due to concerns about highway bridges, using Coulson Aircrane - January 1, 1997 major blowdown, snow on the ground, do not recall snow in trees, ground wet, felled hazardous trees and cleaned up trails with FRBC crews - major flooding in park every 2-3 years

Interviewee(s)	Summary of comments (in my words)
John Eden, Area Engineer MacMillan-Bloedel Northwest Bay Division November 4, 1997 and December 18, 1997	- has worked in Cameron valley since 1977 - provided annotated map and history of windthrow in valley - valley funnels wind and some windthrow occurs yearly, winds locally called 'Qualicums' - discussed historic windthrow events in valley - on west side of Cameron river, west of the 'Hump' is patch of second growth initiated from windthrow about 100 years ago - windthrow patch immediately south of park boundary in mid 1950's, salvaged in 1958 - hurricane Frieda 1962 caused damage in valley - discussed current salvage strategy south of Park - area north of 1976 opening was partially cut, about 50% basal area removed - south portion of partial cut area salvaged in 1978 after blowdown - north portion of partial cut salvaged in 1981 after blowdown - area north of road salvaged in 1986, down and damaged only - wind damage in November 1990 and February 1991, salvaged in 1991; - the southeast corner of park is in a topographic funnel - New Years Eve/Day 1997 wind caused damage in Coombs and Hilliers also - RCMP officer trapped on road in park - snow was present on ground but not sure about in canopy

Interviewee(s)	Summary of comments (in my words)
Kerry Joy, Retired Parks Forester and Ecosystem Specialist October 29, 1997 December 16, 1997	- event in November, 1990 caused damage along SE edge of park - valley funnels westerly winds, particularly between bulge immediately S of park and E wall of Cameron Valley - toured valley in late 1980's with Bill Beese of MB - referred to MB's feathering strategy along opening edges to the south - observed scattered tree failures in park over the years, some associated with endemic Phellinus and Schwienitzii root and stem rot in these old trees
Shelley Higman, Geoscientist MacMillan-Bloedel LUPAT Nanaimo December 10, 1997	- was in Port Alberni on New Years Eve during event; peak damage in Park about 8am on January 1, road closed until noon - was overcast, windy but not particularly rainy - temperatures above freezing, roads wet but not icy - big snowfall on December 28,snow on ground, possibly snow still in canopy immediately prior to event - observed high intensity damage on S. Side of Cameron Lake above highway
Jamie McDuff Manager Vancouver Island Office AES Environment Canada December 15, 1997	- strong winds through Cameron Valley from west known as 'Qualicums' are produced when low pressure center passes north of the valley pulling winds from the west - the winds break over the mountains on western Vancouver Island and begin dropping down over the central and east side funnelling through Cameron Valley - Parksville and Qualicum are sheltered by the higher plain immediately to the west - Sisters Island is the only East Coast station which picks up these winds, once they have dropped down to sea level over the Straight of Georgia - the December 31/January 1 low was a deep low - large snowfall occurred on December 28

Interviewee(s)	Summary of comments (in my words)
Hamish Kimmins, Professor of Forest Ecology University of BC Department of Forest Sciences December 18, 1997	- toured the area in mid-1980s with Jerry Franklin and others looking at feathering and management adjacent to park - Karl Klinka identified 3 major age classes of trees indicating 3 fires - referred to Ministry of Environment report of wind flow through valley between Mt. Arrowsmith and Mt. Wesley

APPENDIX 2

LIST OF AERIAL PHOTOGRAPHS PROVIDED BY BC PARKS

Photo Series	Photo Numbers	Date
BC 1421	92-95	Sept 13, 1951
BC 2089	46-48	May 6, 1957
BC 5101	111-113	July 5, 1964
BC7079	162-164	Jul.24, 1968
BC 7400	132-134	Jul 2, 1972
BC5498	289-291; 241-244	Aug 4, 1972
BC 7765	067-069	Jul 26, 1975
BC 84025	075-078	July 14, 1984
BCC 91003	1-76	May 19, 1991
STD 97014L	1-9 odds	April 11, 1997

APPENDIX 3

GEOGRAPHY OF CENTRAL VANCOUVER ISLAND
QUALICUM WINDS
TOPOGRAPHY OF CAMERON VALLEY

APPENDIX 4

WINDTHROW SALVAGE IN CAMERON VALLEY

APPENDIX 5

SURFACE PLOTS DECEMBER 31, 1996-JANUARY 2, 1997
(Note: 12Z=1200h GMT subtract 8 hours for PST)

APPENDIX 6

PEAK MONTHLY SUSTAINED WINDS - SISTERS ISLAND

APPENDIX 7

HOURLY RECORDS - SISTERS ISLAND AND PORT ALBERNI
DECEMBER 31, 1996-JANUARY 2, 1997

APPENDIX 8

1991 AND 1997 AERIAL PHOTOGRAPHS SHOWING WIND DAMAGE

APPENDIX 9

OVERVIEW MAP OF DAMAGE LOCATIONS AND DIRECTION
WINDTHROW MAPPED ON TOPOGRAPHIC BASE MAP 1:5000 Scale
ECOSYSTEM AND FOREST COVER MAP 1:5000 Scale

APPENDIX 10

PHOTOGRAPHS

Photo. 1 Flagged Douglas-fir Crowns

Photo. 2 Rooting Restricted by Fluctuating Water Table

Photo. 3 Douglas-fir Germinant on Rootwad in 1997 Canopy Gap

Photo. 4 Douglas-fir Seedling in 1990/91 Damaged Area

Photo. 5 Area Heavily Damaged in 1997   (Note defoliated crowns)

Photo. 6 Area Heavily Damaged in 1990/91 (Note refoliating crowns)

Photo. 7 Snapped Douglas-fir with Advanced Cubical Rot

Photo. 8 Warning Sign and Damaged Outhouse