FOREST PRACTICES CODE

of

BRITISH COLUMBIA

This Forest Practices Code Guidebook is presented for information only.
It is not cited in regulation. The Forest and Range Practices Act and its regulations took effect on Jan. 31, 2004. This replaced the Forest Practices Code of British Columbia Act and regulations. For further information please see the Forest and Range Practices Act.

Generic Forest Health Surveys Guidebook

Second edition

February 2001

BRITISH COLUMBIA
Ministry of Forests

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Preface

This guidebook has been prepared to help forest resource managers plan, prescribe, and implement sound forest practices that comply with the Forest Practices Code.

Guidebooks are one of the four components of the Forest Practices Code. The others are the ***Forest Practices Code of British Columbia Act***, the **regulations** and the **standards**. The *Forest Practices Code of British Columbia Act* is the legislative umbrella authorizing the Code's other components. It enables the Code, establishes mandatory requirements for planning and forest practices, sets enforcement and penalty provisions, and specifies administrative arrangements. The regulations lay out the forest practices that apply province-wide. The chief forester may establish standards, where required, to expand on a regulation. Both regulations and standards are mandatory requirements under the Code.

Forest Practices Code guidebooks have been developed to support the regulations, but are not part of the legislation. The recommendations in the guidebooks are not mandatory requirements, but once a recommended practice is included in a plan, prescription, or contract, it becomes legally enforceable. Guidebooks are not intended to provide a legal interpretation of the *Act* or regulations. In general, they describe procedures, practices, and results that are consistent with the legislated requirements of the Code.

The information provided in each guidebook is to help users exercise their professional judgement in developing site-specific management strategies and prescriptions to accommodate resource management objectives. Some guidebook recommendations provide a range of options or outcomes considered acceptable under varying circumstances.

Where ranges are not specified, flexibility in the application of guidebook recommendations may be required to adequately achieve land use and resource management objectives specified in higher-level plans. A recommended practice may also be modified when an alternative could provide better results for forest resource stewardship. The examples provided in many guidebooks are not intended to be definitive and should not be interpreted as the only acceptable options.

If you have any questions about any of the information presented in this guidebook, please contact:

Cariboo Forest Region, Williams Lake	(250) 398-4345
Kamloops Forest Region, Kamloops	(250) 828-4131
Nelson Forest Region, Nelson	(250) 354-6200
Prince George Forest Region, Prince George	(250) 565-6100
Prince Rupert Forest Region, Smithers	(250) 847-7500
Vancouver Forest Region, Nanaimo	(250) 751-7001

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Introduction

This guidebook is intended to assist field practitioners in determining forest health issues and the incidence of forest health factors in high-hazard forest ecosystems. These are forest ecosystems that are constantly being adversely affected by forest health factors. Consult the Glossary for the meaning of specialized words or phrases and Appendix 1 for a list of acronyms used in this guidebook.

The *Operational Planning Regulation* (*OPR*) requires an evaluation of forest health issues relevant to the area under the forest development plan (FDP). Where there are significant risks to resource values identified in the plan, appropriate management strategies to deal with those effects must be undertaken during the term of the plan. Additionally, subject to district manager requirement, a forest health assessment to determine the nature and extent of forest health factors must be completed for the area under the plan.

FDP forest health assessments (typically hazard or risk surveys requested by the district manager) will be undertaken for areas where the licensee expects to be operating over the period of the plan. Usually, the district manager will require surveys if significant pest problems affect the implementation of the plan within a reasonable time period.

The process in the FDP of conducting a forest health assessment for possible treatment action is described in Figure 1. Landscape-level surveys and their relationship with operational and stand-level forest health surveys are shown in Figure 2. A complete list of all landscape- and stand-level forest health surveys is described in Table 1.

The district manager may also request a pest incidence survey of forest health factors in a cutblock or silvicultural opening described in the FDP. Typically, this involves an assessment of specific factors. Survey procedures related to specific factors are included in the guidebooks, describing bark beetles, defoliators, dwarf mistletoes, pine stem rusts, root diseases, terminal weevils, and tree wounding and decays. The district manager may set the scope and attributes of each requested survey.

In addition, some regions have standard operating procedures for specific forest health factor surveys unique to those regions provide more detail than is included in this guidebook.

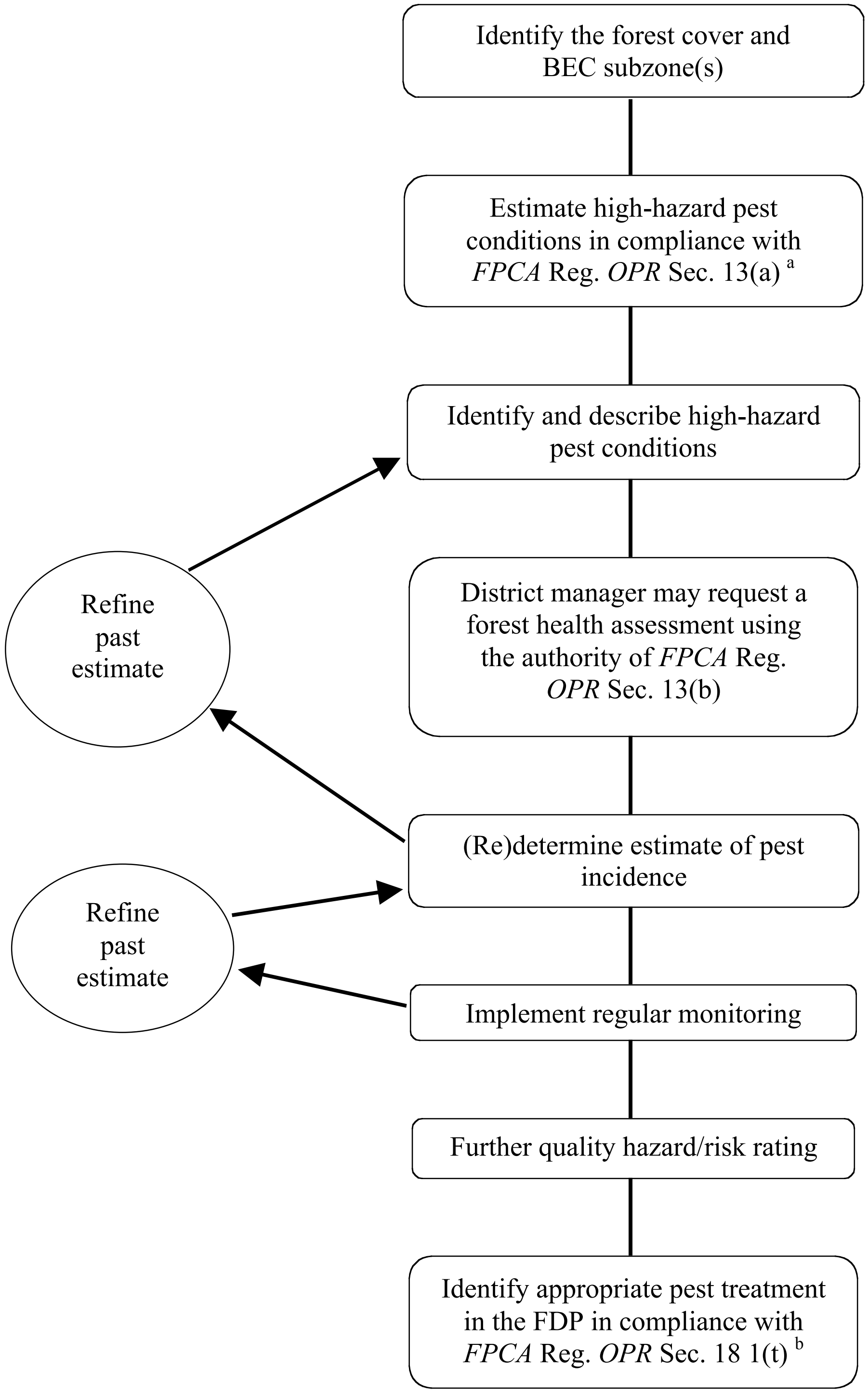

Figure 1. Process of pest hazard or risk rating related to Forest Development Planning.

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a See regional forest health charts listed at the end of the introduction section
b See relevant forest health guidebooks

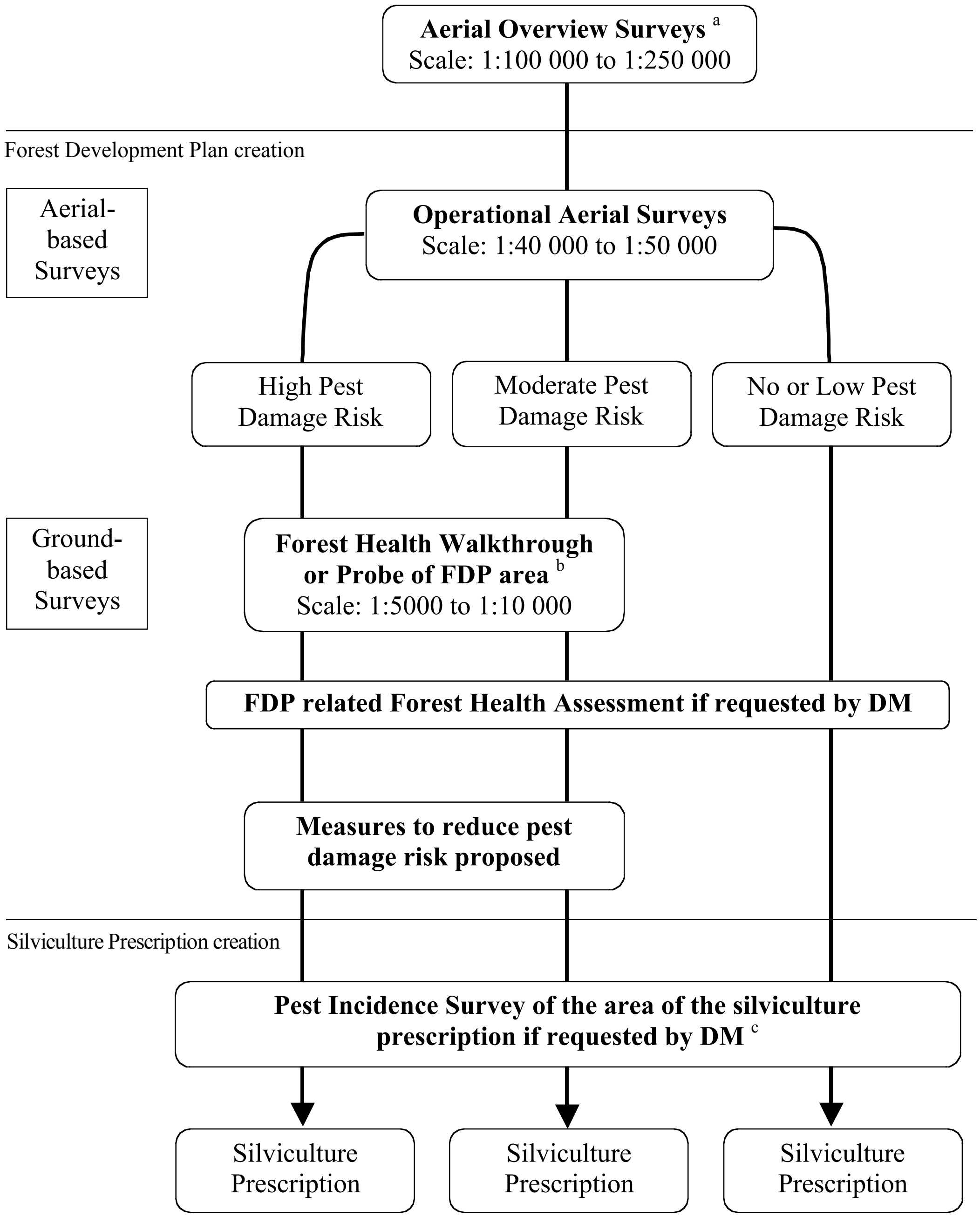

Figure 2. Landscape-level forest health surveys and their relationship with operational and stand-level surveys.

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a Conducted by the BCMOF.

b Assumed that no ground-based surveys or walkthroughs are considered necessary at the landscape level for low damage risk situation. A determination that an area is at low risk could be made from a review of forest charts for the area and with assistance from the aerial overview survey.

c Expected that pest incidence surveys are particularly useful for moderate pest damage risk areas. Treatments associated with high pest damage areas are expected, and treatments associated with low pest damage risk areas are expected to be uncommon.

Table 1. Summary of forest health surveys for Forest Practices Code plans and prescription-level surveys

Survey	Reference	Status
I. Forest Health Inventory		
Aerial Overview Surveys (≥1:100,000)[a]	Forest Health Surveys Guidebook	established
Survey for Pest Incidence[b]	Forest Health Surveys Guidebook	new
II. Operational Surveys		
A. Landscape-level[c] Surveys		
Operational Aerial Surveys (1:50,000)	Forest Health Surveys Guidebook	established
Forest Health Walkthrough	Forest Practices Branch	available[d]
Bark Beetle Damage Probes	Bark Beetle Management Guidebook	established
Defoliator Damage Prediction Egg mass survey for:	Defoliator Management Guidebook	
– Douglas-fir tussock moth		established
– eastern spruce budworm		established
– western black-headed budworm		established
– western hemlock looper		established
– western spruce budworm		established
Adult monitoring for:	Defoliator Management Guidebook	
– Douglas-fir tussock moth		established
– western hemlock looper		established
2nd instar larval sampling for	Defoliator Management Guidebook	
– eastern spruce budworm		established
– western spruce budworm		established
B. Stand-level Surveys[e]		
1. Generic stand-level surveys:		
Multipest survey	Forest Practices Branch	available[d]
Silviculture surveys	Silviculture Surveys Guidebook	
– circular (3.99m) plots		established

[a] Conducted by the BCMOF.
[b] Background information for licensees and BCMOF.
[c] Related to FDP creation.
[d] Related to silviculture and stand management prescriptions.
[e] This survey is available from the Forest Practices Branch. It has been previously developed and has been rarely used in past years.

Survey	Reference	Status
B. Stand-level Surveys (Continued) [f]		
2. Specific stand-level surveys		
Root disease surveys	Root Disease Management Guidebook	
– Pre-harvest walkthrough		established
– 100% sketch map		established
– Pre–stand tending transect		established
– Post-harvest stump-top (for tomentosus)		established
– Pre-harvest transect (intersection length method)		established
Dwarf mistletoe surveys	Dwarf Mistletoe Management Guidebook	
– Hawksworth rating system		established
Stem rust surveys	Stem Rust Management Guidebook	
– Pre–stand tending rust assessment		established
Wound and decay surveys	Tree Wound and Decay Guidebook	
– Post-harvest tree damage assessment		established

f Related to silviculture and stand management prescriptions.

To identify potentially high-hazard forest ecosystems, refer to the regional forest health charts or contact regional forest health staff. Stand susceptibility maps relevant to the forest health factors available in some regions should also be consulted. These information sources must be considered together because there is no single reference listing forest health hazard levels for all forest ecosystems. Forest health charts available from regions are as follows:

- Lloyd, D. 1990. A guide to site identification and interpretation for the Kamloops Forest Region, conifer pests in the Kamloops Forest Region. Land Management Handbook No. 23, BCMOF, pp. 287–290.
- Braumandl, T.F. and M.P. Curran. 1992. A field guide for site identification and interpretation for the Nelson Forest Region. Land Management Handbook No. 26, BCMOF, Sec. 7, pp. 214–226.
- Banner, A. 1993. A field guide to site identification and interpretation for the Prince Rupert Forest Region. Land Management Handbook No. 26, BCMOF, Sec. 7, pp. 74–80.

- Green, R.N. and K. Klinka. 1994. A field guide for site identification and interpretation for the Vancouver Forest Region. Land Management Handbook No. 28, BCMOF, pp. 221–229.

Forest health charts are not published for the Cariboo and Prince George forest regions, although the information may be available from regional staff.

Where there are no high-hazard forest ecosystems within the FDP area, a summary note in the FDP should satisfy the *OPR* incidence reporting requirement.

When a high-hazard area is found, specific surveys should be conducted to quantify the incidence and hazard of the relevant forest health factors. An operational aerial survey of the FDP area is recommended. Additional surveys that may be prescribed are listed in Table 1.

As more information becomes available, the FDP may be updated through amendment, and treatments to minimize pest risk included in future site-specific prescriptions.

Recommended procedures encompassing forest health, and associated with the completion of a silviculture prescription, are found in the *Guidelines for Preparation of Silviculture Prescriptions*. Details concerning specific forest health surveys will be found either in this guidebook or in other forest health guidebooks devoted to specific damage agents. Silviculture surveys are used to measure the achievement of healthy free growing stands; the survey procedures are outlined in the *Silviculture Surveys Guidebook*.

Hazard and Risk Rating

Hazard and risk rating can be used to rank future monitoring, silvicultural treatments, or harvesting. The rating allows the identification of problem areas and to better focus limited time and resources.

A hazard assessment of forest health factors should be conducted in compliance with an FDP, or on a stand for which a prescription is being written. The results of the assessment can be used for predicting the future risk of pest caused damage.

Attributes of Hazard and Risk Rating

With regard to forest health factors, hazard and risk have separate and distinct meanings. Hazard means the degree to which the characteristics of the tree or stand make it vulnerable to damage. It is equivalent to the word "susceptibility." Risk is the probability and expected severity of tree or stand damage. Risk is a function of hazard, and also considers the pest pressure on the stand under consideration.

Attributes commonly used in hazard and risk rating systems:

Hazard

- BEC unit
- tree species
- species mix
- stand structure and density
- site factors
- tree vigour/stress
- tree age
- past forest practices
- current environmental conditions
- vegetation
- predator presence or absence

Pest pressure

- proximity to or presence of damage agent
- timing of next outbreak cycle (periodicity)
- point in outbreak cycle
- area or quantity of damage

Available Hazard and Risk Rating Systems

An evaluation or assessment of forest health factor occurrence or incidence must be incorporated into FDPs, silviculture prescriptions, and stand management prescriptions. For this purpose, a hazard (or risk) rating system is the most useful application. Hazard rating systems are available for some defoliators and some bark beetles. Only general guidelines can be offered for rating disease hazards. The hazard rating systems presently available are described in the guidebooks for defoliators and bark beetles.

The Forest Health Network Archives Pest Data for British Columbia website is available from the Canadian Forest Service at the following site: http://www.pfc.cfs.nrcan.gc.ca/health/pests. This web site contains the Forest Health Network aerial detection survey coverage for British Columbia. These pest coverages are stored as an ArcInfo coverage format and are converted to an ArcInfo export file (.e00) format for file transfer protocol (FTP) purposes. The coverages can be selected in four different ways: by mapsheet, by region, by region as historical summaries from 1911 to 1985, or for the whole of the province.

Forest Development Plan-level Surveys

Minimum Requirements for Forest Health Surveys

The minimum requirements for summaries of forest health survey information are:

- survey method, including sampling intensity and locations;
- forest health factor(s) detected and percentage incidence (ha, trees);
- forest health factor location(s); and
- expected impact on resource values and treatment recommendations.

Procedures for Landscape-level Forest Health Factor Surveys

The following methods are provided to assist in fulfilling the minimum requirements for creating FDPs.

Aerial Overview Surveys

Aerial surveys have provided an invaluable tool for detecting and monitoring forest health factors for many years. This section provides the standards for aerial surveys and how they should be conducted. It incorporates the aerial survey procedures for forest health provided in *Forest Health Aerial Overview Survey Standards for British Columbia, Version 2.0* (CFS and BCMOF 2000; Resource Inventory Committee [R.I.C.] approved). Training for aerial overview surveyors is conducted by the B.C. Ministry of Forests (BCMOF) and training materials are provided in the *Aerial Overview Surveys Training Program—Participants Guide* (BCMOF 1997a).

For operational surveys, surveyors should contact the regional forest health specialist for codes and mapping standards for that region.

Planning

Aerial overview surveys are generally conducted from early July through September to coincide with the optimum damage symptom expression of major forest pests and damage in British Columbia. By that time, sufficient knowledge about current pest conditions has been gained from early-season surveys and anecdotal reports to allow management planning. Occasionally, special flights are conducted to address specific pests that express themselves either earlier or later than the mid-summer period.

Co-ordinated planning is essential to a successful aerial survey. Generally, for overview flights being performed by the BCMOF, initial aircraft selection and charter arrangements are done by the BCMOF through the Regional Fire Centre, which will ensure that aircraft and pilots meet specific training and safety requirements. Reserve an aircraft well in advance of the expected flight, because planes could be in short supply during fire season and alternative arrangements may have to be made. Mapping personnel should also be given as much advance notice as possible to accommodate flight scheduling. Aircraft charter companies should be informed that surveys are weather-dependent and that final decisions on suitable flying conditions cannot be made until the day of flight. The aircraft user must also be aware that 'short-notice' cancellations may cause the air carrier to bill the Ministry a 'detention fee' or other charge as allowed for in their tariff schedule.

Flight Preparation

Maps

Map scale will be determined not only by availability, but also by product requirements. For both national and provincial overviews, pest information is usually recorded on coloured provincial or national topographic series maps of 1:100 000 or 1:125 000 scale, or on 1:250 000 when those scales are not available. While larger-scale maps allow for greater accuracy and detail, the use of scales such as 1:40 000 or 1:50 000 is more appropriate for operational surveys that require greater accuracy. The 1:100 000 topographic maps are produced by Canadian Cartographics Ltd. in Coquitlam, B.C. (1-877-524-3337). More lead time may be required to gather the necessary maps if they are scarce. If maps are unavailable, the last option is to order customized maps produced through a Geographic Information System (GIS). Availability of these maps is highly variable or may take a long lead time if workloads are high. Consult the local forest district office to determine if maps are available at the scale required.

At least two copies of each map are needed, one as a working map and the other as a clean summary for digitizing. As an aid to detection, the working copy may include the previous year's infestations plotted by GIS. This enables the observer and pilot to plan the flight efficiently and accurately locate areas where pest damage is to be mapped. It also allows any more expansions and changes over time to be checked and better identified. Flight lines with directional arrows are recorded on the map as the flight progresses. The date of the survey and the names of observers should also be noted on the map. Since space in an aircraft is at a premium, excess paper on the map edges is often trimmed away and the maps are folded.

Equipment

Each observer should be equipped with a supply of pens and sharp pencils, binoculars, camera, extra film, amber-tinted sunglasses, a lunch, and motion sickness medication if needed. The aircraft must be equipped with radio headsets. Communication with the pilot and other observers is very important. If radio headsets will not be worn throughout the flight, foam ear-plugs or some other form of hearing protection should be used. Aircraft must be equipped with a radio programmed for BC Forest Service District and Air Operations/Fire Centre check-ins.

Aircraft selection and safety

Aircraft selection may be largely determined by local availability, but should be of high-wing configuration for ease of lateral and downward viewing, have seating capacity for at least four, and be capable of sustained flight of 80–90 knots. In remote coastal applications and some northern locations, a float or amphibious version is often more desirable, due to better fuel availability and landing opportunities. In the central and southern interior of the province, wheeled aircraft with fixed or retractable landing gear are preferred.

Some phases of the aerial survey require ‘low-level’ detection or reconnaissance. This type of flying falls into a ‘speciality flying’ category for Forest Service flights. Low-level reconnaissance exposes both pilot and observer(s) to a higher degree of risk versus high-level mapping. This risk is deemed to be acceptable, given that the pilot has been trained and certified by the company in the operational and safety aspects of this activity, and that other Operations Manual requirements are met. Ministry Fire Centre staff should be able to assist in determining the certification status of a pilot. In addition, observers must be briefed on the operational and safety aspects of this procedure. As in any Forest Service flight, passengers on board shall be limited to pilot(s) and essential personnel only.

Type of terrain and area of coverage will determine performance characteristics of the aircraft. Over flat and rolling landscape or small drainages, a Cessna 180 or equivalent may be sufficient, while in mountainous terrain, an aircraft with stronger performance such as a Cessna 210 or twin-engine Cessna 337 may be more appropriate.

Although aircraft availability and type may be limiting factors, safety should never be compromised. To avoid fatigue and loss of concentration, daily flights should be limited to 5 hours duration. Also, ensure that you are well rested before flight and avoid changes in diet prior to flying. For overview surveys, helicopters are not cost-effective and are usually limited to the occasional pest identification or assessment in otherwise inaccessible areas or as a follow-up after the initial fixed-wing flight.

Weather

Weather is one of the most critical factors governing the success of an aerial survey and an essential part of pre-flight planning. Regardless of the prevailing weather, a daily weather forecast describing flying conditions should be obtained to ensure that there is good visibility and a minimum ceiling of about 1000 m (3000 feet). Local weather information can be obtained by calling the forest district office in the area scheduled for mapping. Clear and sunny days are preferred, to maximize detection of defoliation and bark beetle–killed trees for mapping and photography, but solid, high overcast, giving the forest a monochromatic look, is also acceptable. Broken cloud conditions, where one is constantly shifting between sun and shade, are extremely difficult to map under, as the eyes are forced to adjust every time the light changes. Such conditions are very fatiguing, and important infestations can be missed in the blind spots. Since shadow from low sun angle can obscure features early or late in the day, especially in areas of significant topographic relief, the optimum flight period is between mid-morning and mid-afternoon, when the sun angle is highest. Typically, some flight adjustments may be required when dealing with unstable air in the afternoon.

Pre-flight briefing

All BCMOF use of aircraft and the operational procedures associated with that use shall be planned comprehensively and in detail by the aircraft user, pilot/air carrier, flight watch authority, and/or local Fire Centre. Aircraft users must also receive adequate pre-job instruction, including safety procedures, before actual operations commence.

Prior to each flight, the pilot and observer(s) shall review the proposed mission. The material to be covered must include but is not limited to the following:

- general area of flight;
- specific map blocks and sequence they are to be flown;
- alternative area of flight, should weather, air, or visibility conditions cause the primary mission area to be aborted;
- planned fuel or rest stops;
- alternative landing areas;
- aircraft briefing re: location of emergency equipment such as a first-aid kit and emergency locator;
- briefing about emergency transmitter procedures and survival gear;
- discussion of operational and safety aspects of ‘low-level’ reconnaissance; and
- agreement to abort the current activity or flight should the pilot or observer(s) feel uncomfortable with the situation at hand (“one ‘no’ in the cockpit equals a ‘no go’!”).

Safety

All BCMOF personnel who use aircraft should be familiar with the BCMOF *Aviation Safety Manual* (1997b) produced by the Aviation Management Section, Protection Program. This document describes BCMOF policy on minimum requirements for air carriers, pilots, speciality flying, flight safety and guidelines, and other safety matters.

Prior to each flight, onboard personnel and the ground communications centre should know the intended flight plan and duration. Known as “positive flight following" or "flight watch," location updates are radioed every 30 minutes to either the BCMOF Fire Centre or the appropriate district office, depending on the local protocols. Radio headsets must be requested for both hearing protection and flight communication. At the very least, in the event the aircraft is not equipped with radio headsets, noise abatement equipment such as foam ear-plugs should be used.

Forest Service passengers travelling over remote areas of the province must wear the appropriate clothing and footwear needed to survive in the event of a forced landing. Passengers should avoid wearing synthetic fabrics such as nylon or polyester. Natural fibres such as wool and cottons offer some measure of protection. Employees who fly regularly in the course of their duties or are involved in low-level operations should consider wearing flame-resistant flight suits or coveralls.

Amber-coloured sunglasses are often used for both eye protection and to enhance colour differentiation on the ground. Be in frequent communication with the pilot regarding direction, altitude changes, air speed adjustments, fuel considerations, meteorological conditions, and ferry time estimates. Do not hesitate to ask questions or discuss with the pilot anything that causes you concern. While the observer who chartered the aircraft has jurisdiction over the basic flight procedure, the pilot is ultimately responsible for the aircraft and the safety of the passengers, and may overrule any aspect of the survey plan with respect to aircraft operation and safety. Conversely, if you feel that the aircraft is not being flown in a safe manner, you should terminate the flight and report the incident to the BCMOF Fire Centre and the charter company. Please forward an incident report to the Fire Centre, as described in the *Aviation Safety Manual* (BCMOF 1997b).

While the normal flying height is usually between 500 m (1500 feet) and 1000 feet (3000 m) above the terrain, a minimum flying height of 160 m (500 feet) above ground level must be observed as a safety precaution, such as when crossing ridges between drainages. Depending on the type of aircraft used, minimum airspeed should range between 70 and 90 knots.

Aerial Survey Procedures

Scope

The primary limitation of the overview aerial survey is one of perception, particularly as it pertains to bark beetles. Some forest managers may expect to be able to make stand-level decisions on the basis of the overview, when this is clearly beyond its scope. Generally, only estimates of current damage are given, while older tree mortality is usually not included in the total area figure. However, mortality estimates, if applicable, are made following the collapse of defoliator infestations. If the intent of the overview survey program has been consistently met, estimates can also be made of cumulative mortality caused by bark beetles in specific stands by overlaying successive years of damage. Additional ground survey assessments are needed to calculate the total extent of pest incidence and damage. In the absence of more detailed information, aerial-sketch mapping results should not be extrapolated beyond reasonable bounds and expectations.

Throughout the province, standardized coding of identified infestations is required to allow the creation of a provincial summary. The standardized procedure and codes are provided in *Forest Health Aerial Overview Survey Standards for British Columbia* (CFS and BCMOF 2000). Some regions and districts, such as the Cariboo Forest Region (Howse 1995), have specific aerial survey procedures that may exceed the provincial standard.

Mapping

Ideally, two observers are used, one on either side of the plane, to expedite coverage and improve accuracy. The forward observer is usually the more experienced individual for the particular area, and has the overall responsibility for flight direction, altitude, and speed. With attention to elevation, map contours, and natural features, the location, relative size, severity and damage, and probable cause are delineated on topographic maps. As infested areas are detected, they are plotted on the map, either as a polygon or as a dot representing infestations of less than 1 hectare. When two people are mapping, ensure that their field of view does not result in double mapping.

Plan a flight line that covers the survey area. Topography will usually have an influence on the route. Over level terrain, flight lines are usually flown on a parallel grid with some overlap, so that no area is missed. In mountainous terrain, contour flying is most efficient with one or more passes through a watershed, depending on its size and lighting. In some instances, a zigzag flight through a valley may be sufficient when only one pass is made. This action gives the opportunity to map pest damage behind and below the aircraft as well as laterally. Flight lines should always be marked on the map with arrows showing direction. Some oblique photography or video is recommended for a visual record, for a training guide, and occasionally to refine sketch maps and the assessment of damage. After each flight, both mappers are to compare their respective maps and produce a composite that later will facilitate GIS entry at the office.

The detection and location of damage should be accurate to the scale of the map used. However, when using smaller-scale maps such as 1:250 000, the size of infestations is frequently exaggerated, especially when small pockets comprised of 5–50 trees each are mapped. This was found to be true in comparisons of selected outbreaks shown on aerial photographs versus sketch mapping. Harris and Dawson (1979) found the total area sketch mapped to be 34% larger than measured on photographs, and similar results were obtained by Gimbarzevsky et al. (1992) in comparison data from ground plots, aerial sketch mapping, and various types of remote sensing. As a rule, the largest topographical map scale available should be used, normally up to 1:100 000. Occasionally, larger-scale maps up to 1:50 000 are used, but the large number of maps required for overview coverage makes organization and sorting in the cramped environment of a small plane difficult and time consuming.

Classification of Damage

While classification of damage is a subjective judgement by the observer, past surveys have shown that experienced personnel can estimate damage intensities fairly accurately. Help in maintaining accuracy and consistency can be obtained by referring to photo examples (CFS and BCMOF 2000), by taking periodic flights with others, and through quality check flights.

Observable damage symptoms can vary among the different bark beetles and between bark beetles and defoliators. Some defoliators can be differentiated by their damage patterns. It is important that the observer recognizes these differences. Some of the types of damage visible from the air include:

- defoliation (caused by budworms, loopers, tussock moths, tent caterpillars, larch casebearers, etc.);
- fading or discoloration of foliage (caused by aphids, climatic factors, needle miners, etc.);
- single or group tree killing (caused by bark beetles, flooding, lightning, porcupines, root rot, winter damage, etc.);
- flagging of foliage (caused by animals, fire, pine needle cast, etc.); and
- blowdown.

Bark beetles

Pine foliage killed by mountain pine beetle initially appears chlorotic, then gradually turns yellow and fades to red within 1 year of attack. Trees killed by Douglas-fir and spruce beetles have variable foliage colour, and red or brown trees can still contain live beetles. Consult the *Bark Beetle Management Guidebook* or a regional entomologist for more details on the colour changes of trees killed by bark beetles. Because new attacks are not detected by aerial surveys, ground assessments are made to determine current infestation status. For aerial survey purposes, a red tree is one that was attacked and killed the previous year. These are the trees that are mapped. Grey trees are those that have been dead for 2 or more years and that should have been mapped during a prior survey. Small infestations of up to 50 trees may be located on the map as a dot, with the number of trees and the abbreviation for the appropriate tree species beside it. All dots (point sources) are classified as severe. For GIS input, the following scale is applied to area estimates:

2–30 trees = 0.25 ha;
31–50 trees = 0.50 ha.

For larger areas, a polygon is drawn around the infested trees and marked with the appropriate damage classification, as follows (only red trees are recorded—or note if otherwise):

Light =	1–10% of trees recently killed
Moderate =	11–29% of trees recently killed
Severe =	30%+ of trees recently killed
***Grey** (Old)* =	tree mortality 2 or more years old (generally not mapped)

Defoliators

Defoliated trees, stands, or hillsides assume a reddish tinge as a result of active feeding on the foliage. Only the current year's feeding damage is mapped. In areas where severe defoliation has occurred for several years, trees with little or no remaining foliage may appear grey. In light infestations, close observation is necessary because defoliated trees do not readily stand out. Defoliation intensities also tend to fade into each other, and subjective delineations must often be hastily made between areas of differing intensity. When possible, ground checks should be done to verify identification of the defoliator, particularly in new infestations. Following are the severity classes normally used to help classify an infestation:

Light discoloured foliage barely visible from the air, some branch tip and upper crown defoliation.

Moderate pronounced discoloration, noticeably thin foliage, top third of many trees severely defoliated, some completely stripped.

Severe bare branch tips and completely defoliated tops, most trees sustaining more than 50% total defoliation.

Classification of tree mortality caused by defoliators is the same as that for bark beetles. Accurate classification of mortality for deciduous trees is difficult to achieve from the air unless the trees are obvious snags, the surveyor has prior knowledge about the previous year's defoliation, or a ground truthing is available.

Other pests and abiotic damage

While bark beetle and defoliator infestation assessments are the main targets of the aerial survey flights, other types of damage are noted if the observer considers this damage significant. Other forest disturbances mapped during regular aerial surveys include blowdown, winter damage, animal damage, flooding, foliage diseases, root rots, and pollution damage. Observable damage symptoms can vary considerably between each cause, or be very similar.

Whereas blowdown and flooding are usually easy to recognize due to their physical characteristics or association, others, such as winter damage and foliage diseases, are more difficult to identify because they can mimic other types of damage, such as defoliation (and vice versa). Root rot disturbances are also difficult to map, due to the scattered nature and various stages of decline of infected trees.

In summary, the following damage agents and conditions sometimes observed during aerial surveys can be confused with damage caused by insects:

- porcupine feeding;
- bear damage;
- herbicide application;
- weather-related damage (winter drying, hail, drought, sunscald, lightning);
- girdling of lodgepole pine for dwarf mistletoe control
- large cone crop;
- needle diseases;
- root rots;
- fire damage;
- flooding; and
- pollution (ground-level ozone).

Aerial Survey Timing

The overview aerial survey is designed to incorporate mapping of visible damage from as many forest pests as possible in one flight. However, the period when damage (primarily from insects) is most visible varies with the pest species and its geographic distribution. In most cases, there is sufficient overlap of defoliator damage and bark beetle–kill to properly schedule both types of damage in the same survey. The normal aerial survey period (the “biological window”) in British Columbia is between early July and late August, which provides maximum detection of common pests with a minimum of duplicate flying (Table 2). Winter moth, tent caterpillars, spruce aphid and lodgepole pine needle disease are examples of some common pests that do not fit the general biological window and that may require separate surveys prior to July 1.

Ideally, detection of damage should be performed during the optimum colour change or defoliation related to the pest. Delays in surveying may result in significant underestimation of damage levels. For example, wind, rain, or snow storms may remove red or damaged foliage, making accurate defoliator damage identification very difficult.

Table 2. General biological window for aerial survey mapping of bark beetle and defoliator damage in British Columbia

(Pest codes with a "?" indicates that a species code is not available).

Tree Species	Pest code	Pest	Peak period
Bark Beetles			
Pine:			
lodgepole pine	IBM	mountain pine beetle	July–early September
western white pine	IBM	mountain pine beetle	July–early September
whitebark pine	IBM	mountain pine beetle	July–early September
ponderosa pine	IBM	mountain pine beetle	July–early September
	IBW	western pine beetle	June–mid-August
lodgepole pine	IBI	engraver beetles (Ips spp.)	July–September
Spruce:			
Engelmann spruce	IBS	spruce beetle	mid-June–early September
white spruce	IBS	spruce beetle	mid-June–early September
Douglas-fir	IBD	Douglas-fir beetle	mid-June–early September
True firs:			
sub-alpine fir	IBB	western balsam bark beetle	anytime
grand fir	IBI	fir engraver	early July–late August
Defoliators			
Douglas-fir	IDW	western spruce budworm	early June–mid-August
	IDT	Douglas-fir tussock moth	mid-July–late August
	IDZ	false hemlock looper	mid-July–late August
Hemlock*:*			
western hemlock	IDH	western blackheaded budworm	mid-July–early September
	IDL	western hemlock looper	mid-July–early September
	IDG	green-striped forest looper	mid-July–early September
	?	saddleback looper	mid-July–early September
	?	phantom hemlock looper	early July–late August
	?	gray spruce looper	late Aug–early October
True firs:			
sub-alpine fir	IDB	2-year-cycle spruce budworm	June
	IAB	balsam woolly adelgid	Aug. through September
	IDE	eastern spruce budworm	late June–early July
amabilis fir	IAB	balsam woolly adelgid	Aug. through September
grand fir	IAB	balsam woolly adelgid	Aug. through September
Pine:			
lodgepole pine	IDI	pine needle sheath miner	late June–mid-August
	IDS	conifer sawfly	mid-July–late August
		pine butterfly	July through August
Spruce:			
Sitka spruce	IAS	spruce aphid	March through June
white spruce	IDB	2-year-cycle spruce budworm	June
	IDE	eastern spruce budworm	late June–early July
Larch*:*			
western larch	IDC	larch casebearer	mid-May–mid-June
	IDP	larch sawfly	late July–early September
		larch budmoth	early July–mid-August
Deciduous	IDF	tent caterpillar	early June–early July
	IDU	satin moth	early June–mid-July
	IDX	large aspen tortrix	early June–mid-July
	IDN	birch leaf miner	early June–mid-July
Other Damage			
Pine:			
lodgepole pine	DFL	pine needle cast	May through June
	?	winter drying	April through July

Map Processing

Composite map

Daily mapping results should be compared among observers, and a composite (master map) drawn after each flight while visual image retention is still good. The product should be a quality sketch map suitable for digitizing or photocopying. Each map should have a standard colour-coded legend representing each pest mapped. Additional data include date of flight, names of observers, type of aircraft used, and comments on weather and visibility. Upon completion of the composite map, current infestations and areas of damage are entered into a GIS, from which the completed data are ultimately distributed. Because GIS-generated maps appear clean and professional, it is easy to make assumptions about their veracity, but the results are only as good as the data entered.

GIS activities

Pest data from maps are recorded by digitizing the polygons and assigning attributes of pest severity, year, forest region, and map reference. From these data, searches or compilations of any combination of desired attributes can be made. During digitizing, the current and previous years' infestations can be viewed on the screen, providing an opportunity to make changes before entry into the database. A final edit of the digital map against the sketch map is required. A legend should be produced to accompany the map, according to the standards outlined in Appendix 2 of the aerial overview standards publication (CFS and BCMOF 2000). Observers should input their own data, so that errors and omissions can be minimized during digitizing. However, increasingly, the input of map data will be by people other than those participating in the actual mapping and this will leave little basis for decision making if discrepancies occur. GIS reproductions at various map scales are distributed to co-operating agencies such as the forest industry and BC Parks. Using report generators, area and polygon tallies can be derived for selected areas, map sheets, administrative regions, or the entire province/territory.

Data preparation, metadata, and data transfer

The BCMOF has now assumed the data custodianship responsibility for recording, reporting, and storing aerial overview survey information. A set of digital data standards has been produced that will be followed to facilitate the seamless roll-up of all new overview survey data collected throughout the province. As well, standards for metadata to accompany mapping data are available. Finally, data transfer standards should be adhered to.
This information is provided at the website address:
http://www.for.gov.bc.ca/ric/Pubs/teVeg/foresthealth/index.htm

Accuracy

Aerial surveying is not an exact science, but an observer should do everything to ensure that the best calls are made. Credibility comes from following established criteria:

- not missing extensive damage;
- getting the polygon or dot in the right geographic location;
- drawing polygons to accurately reflect infested areas on the ground;
- correctly identifying the tree (host) species;
- knowing and identifying the pest damage correctly; and
- accurately estimating defoliation or stand damage intensity and numbers of trees.

Aerial sketch mapping can be enhanced with the use of aerial photographs, especially in areas of extensive pest damage on even terrain with few geographical features. Up-to-date aerial photos can be useful in showing logging, burns, and other details that observers can delineate from infested timber. If available, custom-drawn GIS maps (scale 1:100 000) that highlight cutblocks, roads, water bodies, and other landmarks greatly improve the observer's ability to orient themselves quickly and thus enhance the accuracy of pest polygon placement.

Studies have shown (Harris and Dawson 1979; Harris et al. 1982; Gimbarzevsky et al. 1992) that defoliation estimates are frequently exaggerated during sketch mapping, while counts of bark beetle–killed trees are low when compared to aerial photographs, ground plots, and some remote sensing techniques. For a given area, assessment of aerial survey accuracy and presence of bias are best determined using a multi-stage sampling procedure, which is comparing sketch mapping, aerial photography, and ground plot data.

Check Flights

Periodic check flights of overview surveys should be done by experienced observers to maintain the accuracy and precision of pest assessments within acceptable parameters such as the qualitative and quantitative criteria listed above. The recommended process is as follows:

1. Make a flight audit no more than 2 weeks after the initial survey and remain within the biological window of the pests mapped.
2. Identify the pests to be assessed from the map legend.
3. Use the same map scale and any previous data.
4. Randomly select sample polygons or dots representing 5–10% of the total area mapped. This can be done by plotting transects through infestations, and mapping only intersected polygons. Normally, this should not amount to more than the equivalent of 1 week's flying for all of areas of British Columbia.

5. Analyze and compare both maps against established criteria such as pest and host identification and damage intensity levels.
6. Ensure that the level of accuracy is proportional to the degree of mapping difficulty (e.g., scattered occasional defoliation versus extensive defoliation mapping). However, acceptable limits of accuracy are expected to be within 30% plus or minus the check flight assessment. When those limits are exceeded, the observer should be re-assessed to determine the source of discrepancy.

Survey for Pest Incidence (SPI) Procedure

The scheduling of harvest and management of the forest resource is largely based on the information available in the BCMOF forest inventory system (FIS).[1] This inventory is used to generate forest cover maps, and displays information by polygon of tree species composition, age, site index, area, and other information. Long-term planning is based on the information obtained from the FIS; however, this inventory lacks some information on forest health factors (pests). The incidence and relative severity of pests must be quantified at the forest landscape level in order to incorporate their management in the planning process.

The survey for pest incidence (SPI) identifies pest-specific incidence and severity at the landscape level, based on a continuous series of 100-m-long plots that vary in width depending on the age and density of the stand.

The SPI identifies pest-specific incidence and severity at the landscape level. It is designed to build a database of accessible information, linked to forest inventory type groups, that can be used in the planning process to enhance existing annual aerial survey information and hazard/risk rating systems.

The survey attempts to record and quantify incidence and severity of all damaging agents within an area and gather stand information, including stem density, species composition, and stand structure and age. Pest incidence can be assessed on a simple presence or absence basis or by severity. For some forest health factors, there is relatively little information correlating incidence and impact; therefore, only occurrence (detection) is noted. For other forest health factors, this information is available, and specific severity categories are available that can give an estimate of impact. Although a SPI may be done in any stand type or age class, it is not intended to be used in very young regeneration, but rather in established plantations and forested areas (greater than 10 years old).

The land use priorities of the area to be surveyed should be known to the surveyors, because this might affect the forest health factors that are given

[1] Tree Farm Licences will have separate forest inventories retained by the holder of the licence.

priority for identification. For example, if the survey area includes identified valuable wildlife habitat, forest health factors that may be affecting vegetation particularly important to the habitat should be identified in the survey.

Results from SPI provide an overview of the state of forest health within the area of interest by providing a snapshot in time of the forest health factors that are present and that have occurred in the past. As the database becomes more comprehensive, the confidence level for predicting the occurrence of forest health factors in specific forest types will improve, thereby highlighting forest health opportunities in the planning process.

The SPI can also yield information on stand dynamics if survey lines are re-visited at specific time intervals (e.g., 5- to 10-year intervals). More detailed studies (e.g., permanent sample plots), usually done over a period of time, are required to quantify the impact of a specific pest or pest complex.

Area stratification

The following procedures are recommended for a landscape-level assessment of pest incidence. First, identify the geographic area of interest. The area of interest can range from a cutblock, a mapsheet unit, and a single drainage to even larger geographic units. Second, determine the number, distribution, and relative proportion of inventory type groups (ITGs) in the interest area (Appendix 2). This information can be retrieved in digital format from the forest inventory database. Plot intensity per ITG should be proportional to the area (ha) occupied by each ITG. The total number of plots is dependent upon the confidence level desired. The SPI can also be applied at the stand level to determine pest incidence and severity for writing prescriptions. The intensity of sampling should be higher in this case, to obtain the detail of information required.

The area of interest will be defined as one mapsheet unit for the purpose of describing the following SPI procedures.

a) For the mapsheet, retrieve the following inventory information, by polygon;

- polygon number;
- polygon forest cover label;
- age class;
- inventory type group (ITG);
- site index;
- UTM grid;
- polygon area (ha); and
- any other information that may be useful.

A forest cover "1" map file (FC1) may be obtained from BCMOF Resource Inventory Branch - Forest Resources Geographic Information Systems (FRGIS) with an accompanying Forest Inventory Planning (FIP) summary report file. The FIP file is sorted by species, ITG, and age class, and gives the total area for each grouping (Table 3). Please note that these files are gradually being replaced by the Vegetation Resource Inventory system (FIP by Vegetation Inventory Files [VIFs], and FC1 by Vegetation Inventory 1 File [VG1]).[2]

Table 3. Example of a FIP map summary report, showing forest cover data from the FRGIS system

		Age class									
Species	ITG	1	2	3	4	5	6	7	8	9	Total area (ha)
F 81%+	1	42.1	5.0	16.1		21.6		108.4			193.2
F,C,Cy	2								41.9		41.9
F,S	4					7.0					7.1
F,Pl	5						0.6				0.6
F,L	7				18.8		29.7	62.7			111.2
C,F,L	10							54.8			54.8
C,H,B,S	11					562.4					562.4
Pl 81%+	28	68.5					25.8	62.7			157.0
Pl,F,L,Py	29	17.6				4.1	188.0				209.7
L,F	33			18.6		18.4	2.0	2.6		31.6	73.2.
L Any	34					61.1				61.1	61.1
Total		128.2	5.0	34.7	18.8	674.7	246.1	291.2	41.95	92.7	1430.6

The data summary obtained from the FIP file also gives discrete polygon information useful for selecting plot locations.

[2] Consult Appendix 1 for a list of acronyms used in this guidebook

Table 4. Example of data from a FIP file listing attributes by polygon

MAP NUMBER - 082L052 POLYGONS MEETING SELECTION CRITERIA INCLUDE:											
POLY NO.	1	2	3	4	5	6	7	8	9	10	11
SPECIES Fd	PLAT	ATPLFD	S ATB	ATE	FDS B	S FDE	PLS	S FD	FDS	S FD	S FD
A/H/S/S	530M	531M	630M	531M	420P	640G	731G	110M	851G	831P	831P
AREA HA	12.3	48.4	70.2	2.6	17.4	40.9	2.9	16.4	5.0	32.7	8.1
TOT VOL. 1	768	5457	17662	321	974	15959	1167	0	2655	9339	2729
% CONTR. 1	0	100	100	100	100	100	100	100	100	100	100
UTM GRD.	3025608	3025608	3025608	3025608	3025608	3025608	3025608	3025608	3025608	3025608	3025608

b) Sort the above inventory information in a hierarchical fashion by:
- ITG;
- age;
- site class; and
- area.

Exclude all land attributes that are not within the forest to be surveyed, such as alpine, inoperable, lakes, private land, and open range.

c) The inventory data are grouped into strata of similar attributes for the purpose of determining a sampling matrix. Division into sampling strata is a subjective exercise based upon management objectives, composition or diversity of the mapsheet, desired sampling intensity (Appendix 2), and relative size (ha) of strata breakdowns.

The following is a decision matrix for creating sample strata:

- sort by ITG, summing total area in each ITG grouping;
- depending on number of strata desired (management objectives, cost, location), divide ITG groups by age categories (sum total area of each new grouping); and
- continue subdividing the inventory information until the desired number of strata is met.

d) Determination of the optimum number of strata is dependent on several criteria;[3]

- management objectives;
- size of area;
- heterogeneity of area;

3 The SPI survey was developed on a mapsheet basis and typically 20–25 strata per mapsheet were selected. A 1:20 000 forest cover mapsheet has approximately 16 000 ha gross area.

- previously collected forest health information; and
- cost and economics.

Regardless of the number of strata selected, each plot within a stratum is ultimately tied to polygon number, ITG, and mapsheet. Therefore, this is simply an exercise to achieve proportional sampling distribution over the interest area.

Sampling intensity determination

Each mapsheet is divided by ITGs so comparisons can be made among mapsheets. This gives the SPI a common language. The total area in each stratum is compared to the netted-down mapsheet area and is then assigned a proportional number of plots for that stratum.

Use the following steps in Figure 3 to determine optimal number of plots (see also Appendix 2):

1) Total area of interest = 4221 ha

2) @ 0.05% coverage = 0.0005 x 4221 ha = 2.11 ha

3) For plot area of 0.02 ha (2 x 100 m):

$$\frac{2.11 \text{ ha}}{0.02 \text{ ha}} = 105.5 \text{ plots (round to 106)}$$

4) Divide plots proportionally among the strata (Appendix 3): for example:

$$\frac{749.7 \text{ ha}}{4221 \text{ ha}} = \frac{x}{106}\text{; therefore } x = 18.8 \text{ (round to 19)}$$

Strata total	**Estimated number of plots**
749.7 ha	19
1114.0 ha	28
2286.3 ha	57
71.0 ha	1.8 = 5[a]

a The minimum number of plots in a stratum is five.

Figure 3. Calculation of optimal number of SPI plots.

Planning line and plot locations. Location of SPI lines and plots are determined as follows:

- Use maps and aerial photographs to choose clear and precise points of commencement (POCs) for lines;

- Distribute lines and plots systematically over the interest area—do not clump all SPI lines in one corner;
- Take into consideration access and topography—utilize topographic maps, forest cover maps, aerial photographs, and UTM grids for polygon locations;
- Consider polygon size and shape—small, long, or narrow polygons are difficult to assess due to inaccuracies in locating the exact forest cover type;
- Place 2–15 plots per polygon—range is based on the relative size of polygon;
- Draft all line and plot locations on forest cover map prior to commencement of field work, noting “no tally” portions of lines.

If a line continues from one stratum into another, have at least a 100-m “no tally” portion between the strata break to allow for compass or map error. This will ensure that the next plot is actually within the new stratum.

Plot establishment

Each SPI line needs a unique POC that is clearly marked and labelled with SPI line number, compass bearing and distance to Plot 1, date of survey, and area identification (mapsheet and polygon number). Plots must be numbered consecutively along lines and require only a semi-permanent marker between plots. At the beginning and end of each plot, or “no tally” portion between plots, record line number, plot or “no tally” section completed, plot or “no tally” portion to commence, bearing, and distance from the POC. “No tally” sections include the portion of the SPI line from the POC to the start of Plot 1 and any other portions of the line between plots that are not surveyed. The surveyor should insert a “no tally” section when crossing from one stratum type into another (minimum 100 m) or when features such as swamps, roads, or other significant non-forested types are encountered.

The SPI is a continuous series of 100-m-long plots. Plots can vary in width from 1 to 5 m and should contain between 20 and 50 trees, depending on the age and density of the stand (Table 5). At the beginning of each 100-m plot, the width can change, but the width cannot change within a plot. A more detailed description of plot widths is provided in the subsection entitled “Plot parameters.” Every tree greater than 1 m in height within the plot boundaries will be examined and tallied, by species, for pest occurrence and severity. The POC for all SPI plots and the point of termination (POT) should be a minimum of 25 m from the edge of forest cover polygons, roads, and unnatural openings.

The plot centre-line should be marked with ribbon accurately and clearly in a highly visible colour. Endeavour to place ribbons exactly on the centre-line, and at least the last two ribbons placed must be visible. This ensures that the line will be straight for accuracy of plot assessment. A different ribbon colour should be placed at the commencement of each new plot or “no tally” section.

The SPI line is established using a hip-chain measuring device. The line should be measured and marked prior to recording pest incidence and tree data. While establishing the line, the surveyor should note stand density and composition per plot in order to estimate the plot widths that will yield the minimum number of required trees, and to identify potential sample trees. On field notepaper, sketch the location of the line, noting bearing, plot locations, “no tally” sections, and any pertinent physical features.

Plot parameters

The objective of the particular SPI survey will affect the plot parameters. You should decide what are the forest health factors and host trees of interest. Decisions should also be made on the need to collect data on tree layers (including seedlings and vets), and any other information on the stands.

Tree layers. Depending on stand age, SPI plots may be divided into two layers. In mature stands, layer 1 (L1) includes overstorey trees (dominant, co-dominant, intermediate, and vets). Layer 2 (L2) is defined as understorey or suppressed trees (Figure 4). In a mature, single-layer stand, there is often no true L2; therefore, simply assess understorey trees as they are encountered within the width of the mature strip. In this case, as long as L1 tree minimums are met, the 10-tree L2 minimum is not critical. In a true multi-storeyed stand, 10 trees in the L2 layer should be tallied. Note that the SPI procedure is not designed to examine regeneration; therefore, there is no L3 layer.

Immature stands usually contain only one layer or age class, and this layer is designated as L1. If two distinct layers (age classes) are present, then both an L1 and L2 layer are recorded, as in mature stands.

A minimum number of trees must be assessed in each 100-m plot. Minimum tree numbers have been set for L1 and L2 (Table 5). Plot width is chosen by considering the density of the stand and the minimum number of trees needed. The strip width of L1 and L2 can differ in any given plot to achieve the minimum number of trees. For L1, the minimum strip width is 1.0 m and the maximum is 5 m. However, if the minimum number of trees has not been met, do not exceed the plot width of 5 m. Layer 2 often (and Layer 1 rarely) has high stem densities; therefore, the minimum strip width for L2 (or L1) can be as low as 0.5 m. For example, L1 could be 4 m and L2 could be 0.5 m in a mixed-age stand with a relatively open overstorey, and a dense understorey. Tally trees in the L2 layer only for the first 10 m of the plot if the L2 density is exceedingly high.

Table 5. Target number of trees per 100 m SPI plot, by stand type

Type	Target number of trees per plot
Immature stands (single age class)	SPI layer 1 = 50
Mature single-age stands / mixed age stands	SPI layer 1 = 20, excluding vets
Understorey or suppressed trees	SPI layer 2 = 10

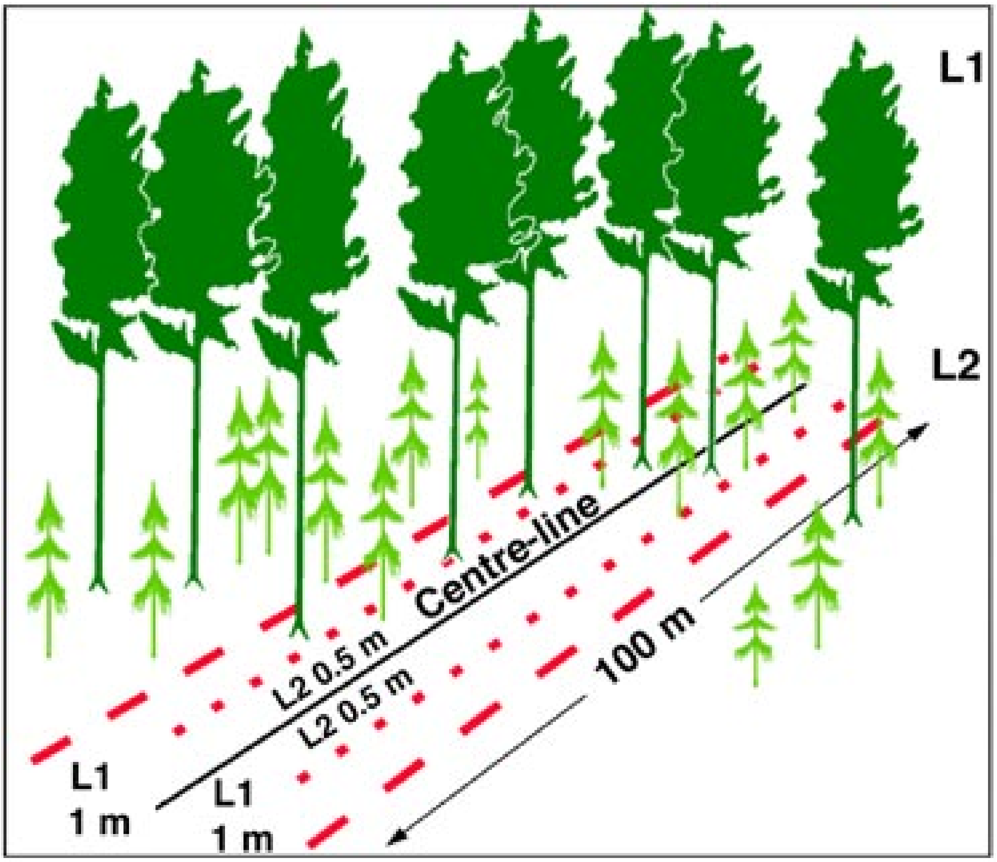

Figure 4. SPI plot showing minimum plot length and widths for L1 and L2 layers.

Data recording procedures for SPI form

The following describes the procedures and type of information needed for completing a SPI form (Appendix 4).

a) Line Location Information:

- District code—1st digit region number, 2nd digit district number;
- Map reference—the forest cover map designation;
- Reference year—year the survey was completed;

- POC to tie tree—distance and compass bearing from a clearly distinguishable photo POC to tie tree of Plot 1;
- Tie tree description—species and diameter at breast height (dbh) of the tie tree for plot 1 (mark the tree for relocation and note on the plot card how to relocate the tree); and
- POC description—any pertinent access notes and POC site descriptions necessary to locate line POC.

b) Pest Incidence Information:

- Polygon number from the forest cover map;
- Plot number—number consecutively along the line;
- Plot bearing—compass bearing of plot;
- Plot width—width (m) chosen for each layer;
- Plot layer—“1” for layer 1, and “2” for layer 2;
- Tree species;
- “Clear” and “dead”—record number of trees by layer and by species that are clear of pest-caused damage, or dead from unknown causes;
- Code—damage agent codes (Appendix 4) as encountered;
- Columns 1,2,3—number of trees affected by pest at described severity level. Area under the “Code” and “Columns 1–3” headings has been dash-divided into three working spaces (Figure 5) where a running tally for the plot can be kept. Below the working space, final column tallies are to be entered at the completion of each plot; and
- Total Trees—record total number of live trees by layer and by species.

PEST INFORMATION							PEST 1				PEST 2				PEST 3				PEST 4			
PLOT NUMBER	PLOT WIDTH	PI Residual	SPP.	CLEAR	DEAD	CODE	COL. 1	COL. 2	COL. 3	CODE	COL. 1	COL. 2	COL. 3	CODE	COL. 1	COL. 2	COL. 3	CODE	COL. 1	COL. 2	COL. 3	TOTAL LIVE TREES
01	4.0	4	P1	26	2	1WP		6	1	1WW	2	2		DMP	2	8		DFL	40			79

Figure 5. Enlargement of pest code and severity section of SPI form.

(see Appendix 4 for a copy of the SPI form and Appendix 5 for a list of damage agents, their codes, and pest severity ratings.)

The following describes the example information contained in the Figure 5 example form:

- IWW 2 2: Warren's root collar weevil (IWW) was found on two trees at a severity high enough to cause mortality, tallied in column 1; and on two trees at a severity high enough to cause major volume loss, tallied in column 2.
- DMP 2 8 1: lodgepole pine dwarf mistletoe (DMP) was found on two trees at the highest Hawksworth scale severity likely to cause major volume loss, and tallied in column 1; on eight trees at a moderate Hawksworth scale severity and also likely to cause major volume loss, tallied in column 2; and one tree at a low Hawksworth scale severity likely to cause minor volume loss, tallied in column 3.
- DFL 15: pine needle cast (DFL) was found on 15 trees at the only severity rating available, likely to cause major volume loss, and tallied in column 1.

c) Sample Tree Information:

- Plot number;
- "% LC" is percent live crown;
- Height and age (optional);
- Species of tree measured;
- dbh—diameter at breast height; and
- Remaining columns are for field calculation of tree height and age (optional).

Tree tally. The surveyor tallies all trees and stumps, by species, within the plot. Trees are in the plot if more than 50% of the tree base diameter falls within the plot boundary. Assess each tree or stump for pest occurrence. Individual pest codes incorporate the tallying of dead trees and stumps uniquely according to causal agent. When no pests or damage are detected, tally live and dead trees by species and layer. When pests or damage are identified, record (Appendix 4):

- host tree species;
- SPI layer (L1 or L2);
- pest code and severity (Appendix 5); and
- any other relevant information or comments concerning the stand.

The objectives of the particular SPI survey should be determined in detail prior to the field work. For example, young tree regeneration is not normally included in the tree assessment and tally. If it were included, it would probably be an L3 layer (separate plot). Normally, the survey will consider trees either as part of a one-layer stand (L1), or a two-layer (L1 and L2) stand.

The tally and assessment for the layers should be recorded as separate overlapping plots. Plot widths for the layers may differ, and the minimum tally number for plot trees may have to be achieved separately.

Tally the total number of live trees per plot. Tally dead trees, where the cause of mortality is known, with the particular damage agent codes. Tally dead trees in the "dead" column (where no damage agent code is identified) only where the cause of mortality is unknown.

All standing trees in a 100 m transect plot area are assessed as living or dead. Dead trees greater than 3 m in height are considered trees, and dead trees or stumps less than 3 m in height are considered stumps. Recently created stumps must be assessed for pathogens. Recent windthrow, whose point of germination lies within the plot boundary, must be assessed for pest occurrence (Appendix 5).

Tally every standing, live tree encountered, by layer, in the total live trees column. This will avoid "double-tallying" of trees that have more than one pest. Trees with multiple pest occurrences get tallied once under each appropriate pest and severity column. Therefore, a tree with three different pest problems would be tallied three times but only once in the total tree column. You cannot sum the number of trees unaffected by pests (clear) and the trees tallied for each damage agent and expect to correctly determine the number of live trees per plot.

When a tree is free of any pests, it will be tallied as "clear" in the pest incidence information section. If a dead tree, stump or windthrow is encountered and the causal agent cannot be determined due to the tree being "dead" for some time, tally in the dead column in the pest incidence information section.

Within each plot, one relatively pest-free tree representing the majority species and size of the dominant or co-dominant layer will be chosen. For this tree, the following data will be taken and recorded in the sample tree information portion:

- plot number;
- percent live crown;
- height (m ± 0.1 m);
- species;
- dbh (± 0.001 cm); and
- total age (corrected for height of boring).

Vets are not to be chosen as sample trees.

This information can be used for inventory purposes, and for SPI analysis of plot data.

Severity is a measure of the forest health factor's impact or abundance on the host tree. For each pest encountered, an assessment of severity is done. This assessment is reflected in the column (1, 2, or 3) under which the tree is tallied on the SPI form (Figure 5; Appendix 4). Columns 1, 2, and 3 reflect most severe to least severe impact or abundance of the pest, respectively. Not all forest health factors are necessarily divided into three severity categories. Some may have only one or two severity categories. For example, balsam woolly adelgid (IAB) is tallied only under column 1, indicating presence of the pest. No further assessment of its impact or abundance is noted because there is presently little information on this pest's impact. Lodgepole pine dwarf mistletoe (DMP) on the other hand, is recorded in columns 1, 2, or 3 as follows:

Column 1—number of trees rated at 5 or 6 on the Hawksworth scale.

Column 2—number of trees rated at 3 or 4 on the Hawksworth scale.

Column 3—number of trees rated less than 3 on the Hawksworth scale.

Follow the example below to rate the tree:

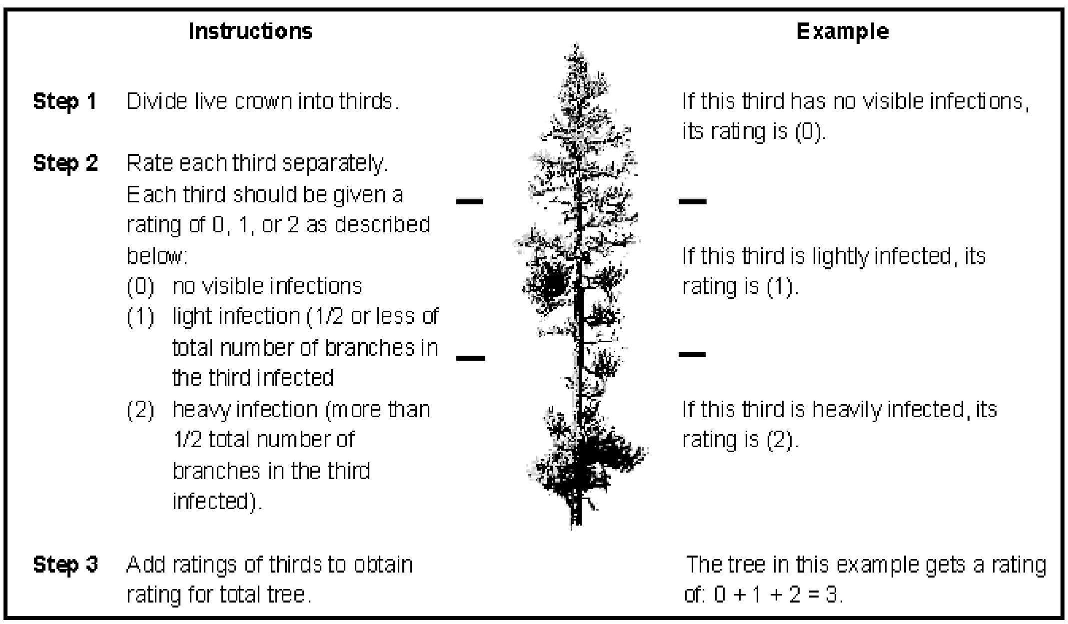

Figure 6. Hawksworth dwarf mistletoe severity scale.

In the case of lodgepole pine dwarf mistletoe, all three columns are utilized because the Hawksworth scale is a well-quantified methodology for assessing dwarf mistletoe impact.

For the survey area, determine the overall Hawksworth scale rating by summing the trees per column and averaging the ratings.

To interpret pest incidence and impact at the landscape level, a common measure of comparison must be used. To facilitate this comparison, a numerical pest severity rating (PSR) was developed (Table 6; Appendix 4).

The PSR has four categories:

1 = Mortality;

2 = Major volume loss;

3 = Minor volume loss; and

4 = Insignificant volume loss; defect.

A PSR was assigned to each assessment level (columns 1, 2 and 3 on the SPI form) for each pest. For example, when the number of trees with lodgepole pine dwarf mistletoe is recorded in column 1 or 2 on the SPI form, this identifies a PSR of 2, reflecting that this pest causes a major volume loss. When the number of trees with DMP is recorded in column 3 of the SPI form, a PSR of 3 is identified, indicating a minor volume loss (Table 6).

Table 6. Example of a selection of pests according to types of damage

(see Appendix 5 for complete list)

	SPI form column		
Pest code	**1**	**2**	**3**
DRA	1	1	0
DSG	2	3	0
DMP	2	2	3
IBM	1	1	1
IDW	3	2	2
IWS	4	3	0

Data entry

Microsoft ACCESS® could be used for the storage and analysis of SPI data. Quoting the ACCESS® Help introduction: "Using Microsoft ACCESS, you can manage all your information from a single database file. Within the file, divide your data into separate storage containers called tables; view, add, and update table data using online forms; find and retrieve just the data wanted using queries; and analyze or print in a specific layout using reports."

Someone suitably trained on ACCESS could develop a series of linked "tables" of the SPI data. Alternately, a generic ACCESS database has been developed in the Kamloops Forest Region, and a copy can be obtained from the region. Local modifications of that database to suit your needs can be made without great difficulty.

The database will have the following six elements:

- plot description data, with links to mapsheet, ITG, forest cover label, polygon number, plot number, and layer;
- plot tree data, including information on tree species, percent live crown, height, dbh, and age;
- pest data, including information on the number of trees that are clear of pests, number of trees that are dead due to unknown causes, and pest occurrence and severity by host tree, mapsheet, ITG, forest cover label, polygon number, plot number, and layer;
- reference data for pest codes;
- reference data for severity codes; and
- a reporting function.

Technical staff can obtain data-loggers to enter data in the field. On the data-loggers they would have four worksheets:

- descriptor: including polygon information, point of commencement, and bearing;
- plot: including plot data;
- pest: including pest incidence data, and pest and severity tables; and
- tree: including sample tree data.

From the data-logger, the data can be easily downloaded to EXCEL®, reviewed and edited, and then imported into the ACCESS program. ACCESS files can also be read by ARCVIEW® and other programs to create geographically referenced reports.

Data analysis

The data collected from SPI give a wide variety of information about the interest area. This ranges from information on species composition and stem density, to pest incidence and severity, to tree volumes. The number of trees affected by a given forest health factor gives incidence in percent of trees affected (by species) and number of trees affected per hectare.

The PSR can be used in the analysis phase to show general trends and highlight problem areas or ITGs. For instance, a frequency distribution of PSRs by ITGs could be done. A high frequency of PSR1 in a particular ITG would indicate a high-priority management concern.

The various types of summaries (using both the query and reports functions of ACCESS) and analysis that can be obtained from SPI data are listed below:

- area surveyed (either ha or % area) by mapsheet, ITG, and polygon;

- incidence of pest-free (clear) trees (% trees or number of trees/ha) by polygon, ITG, and mapsheet;
- incidence of dead trees, of known or unknown causes (% trees or number of trees/ha) by polygon, ITG, and mapsheet;
- total live trees tallied (number or trees/ha) by species, layer, polygon, ITG, and mapsheet;
- list of forest health factors encountered by polygon, ITG, or mapsheet;
- frequency distribution of forest health factors encountered by polygon, ITG, or mapsheet (% or number /ha);
- frequency distribution by PSR, of forest health factors encountered by polygon, ITG, or mapsheet (% or number /ha);
- frequency of occurrence of specific pest(s) (% or number /ha) by polygon, ITG, or mapsheet;
- for a given pest, the frequency of occurrence in columns 1, 2, and 3;
- sample tree information—inventory summaries by species, polygon, ITG, or mapsheet on height, dbh, percent live crown, and age;
- graphical representation of any of the above summaries; and
- spatial plots of pest occurrence or PSRs.

Interpretation of data

Relative frequency of forest health factors (must interpret):

- low frequency of "important" site resident forest health factors (e.g., DRA, IBM, IDT);
- high frequency of "not important" forest health factors (e.g., DFL, IAG) (Appendix 5); and
- other combinations in-between.

Relative severity of forest health factors(s) recorded:

- many or few of PSR 1s; and
- many or few of PSR 3s, and 4s;

GIS display of data:

- theme map by ITG, species, etc.;
- display areas where high frequency of forest health factors occurs;
- display distribution of forest health factors, PSPs, etc.; and
- spatial relationship of cover type, pest, etc.

In conclusion, data gathered from the SPI must be interpreted in the context of the management objectives for the area. Sampling at the landscape level will usually not give enough resolution to make a stand-level prescription. As more areas are surveyed and the database grows, the confidence level of interpretation will also increase.

Forest Health Walkthrough

As a part of the FDP, the purpose of the walkthrough is to verify forest health factors identified during operational aerial surveys. A walkthrough would likely be undertaken if the district manager requested a forest health assessment of the area under the FDP. In addition, other damaging agents not visible from the air may be identified during the walkthrough. The scope of this survey differs from other similar walkthrough surveys in that it is conducted at the landscape rather than the stand level.

Landscape-level, generic forest health walkthroughs that may be requested by a district manager are done to the standard set by the district manager. Currently, there is no specific generic walkthrough procedure that is widely used. Survey procedures for specific forest health factors are available in forest health guidebooks. A list of available surveys and the guidebooks in which they are published is presented in Table 1. Standardized procedures have been created in the past, and are available from the Forest Practices Branch.

Walkthroughs or probes related to silviculture prescription approval, particularly for bark beetles, may also be undertaken at the request of a district manager. Procedures associated with stand bark beetle walkthroughs or probes are provided in the *Bark Beetle Management Guidebook*.

Windthrow Risk Evaluation

Windthrow is an important abiotic forest health factor (abiotic pest) in numerous timber supply areas, and an assessment of the consequences of windthrow may be needed for both the FDP and the silviculture prescription. Survey information on windthrow is provided in this guidebook because the survey techniques lend themselves to general forest health factor assessments, and there are no other more specific guidebooks appropriate to this topic. The survey information provided in the guidebook can be applied equally well to a landscape or to a cutblock.

There are three basic approaches to windthrow risk evaluation: observational, empirical, and mechanistic.

- In observational methods, the presence of factors known to be associated with higher incidence of damage is tallied. The relative risk of windthrow increases with number of risk indicators observed but is not quantified.

- In empirical modelling of windthrow risk, regression models are built that relate the presence or magnitude of wind damage in sampling units to environmental and management attributes. GIS-based techniques enable construction of landscape-level empirical models and maps using forest cover and topographic attributes.
- Mechanistic models predict the likelihood of damage based on an evaluation of the critical windspeed for tree failure and the probability of such a wind occurring at a given location. No mechanistic models are calibrated for British Columbia forests at present.

The FS 712 windthrow field cards (Appendix 6) use the observational approach and therefore indicate relative windthrow risk. The assessment can be made more quantitative by first calibrating along the boundaries of existing cutblocks. This feedback process improves prediction of future outcomes based on past experiences in similar situations. The FS 712 field cards are based on the premise that the management and biophysical (environmental) factors contribute to the wind loading and wind resistance of trees. The biophysical factors can be further subdivided into topographic (wind exposure), soil (strength of anchorage), and stand (acclimation to windloads) components. Each of these components is individually assessed and then integrated into an overall assessment of biophysical hazard that is the inherent susceptibility of the stand in a given location to windthrow. The degree to which management activities will increase wind loading is then considered. For example, windward boundaries on large cutblocks will experience greater wind loads than will parallel or leeward boundaries following harvesting, and therefore have a greater windthrow risk.

Healthy trees are capable of acclimating to routine wind loads. Healthy, open-grown trees are seldom damaged by routine winds, and are typically resistant even to extreme winds. As stand density increases, trees are sheltered by their neighbours, and shed wind loads through inter-tree contact (damping) as they sway. Competition also reduces the resources available for structural increment. It is commonly observed that stand vulnerability to wind increases as stands grow taller. However, veterans, emergents, and large dominant trees within stands are generally more windfirm than other crown classes. Very high density stands of sapling and pole-sized trees are often relatively windfirm if left unthinned because damaged trees hang up in the canopy during windstorms. Prior to thinning high-density stands, consider the importance of inter-tree shelter and damping.

Where soils restrict the depth of anchorage, trees form plate-like supporting root systems. However, plate root systems do not provide a high degree of stability. Deep, well-drained soils provide the best anchorage, and soils with highly fluctuating water tables the worst. The strength of fine-textured soils is lower when the soils are wet. This leads to site-, season-, and weather-related variations in rooting strength. Stem and root decays reduce wind firmness.

Rootwads of overturned trees should be examined for evidence of rooting restriction or root decay. Road cuts also provide an opportunity to examine the soil profile and restricting conditions.

Most high wind events in British Columbia are generated by large-scale weather systems such as Pacific low-pressure systems or the movement of arctic air masses. Endemic windthrow is caused by peak winds that recur regularly (e.g., every 1–3 years), while catastrophic windthrow is caused by infrequent peak winds. The FS 712 cards evaluate risk from endemic winds. Regional winds are accelerated or slowed by local topography. The relationship between wind speed and direction and local topography is complex. Analysis of the orientation of existing windthrow within the forest, or along edges created by harvesting, assists greatly with identifying local wind patterns. The severity of damage along existing windward cutblock edges is a very good indicator of biophysical hazard. Uprooted trees typically create pit-mound pairs. The orientation of pit-mounds can indicate damaging wind directions long after stems have decayed.

The components of biophysical hazard are not necessarily additive. Trees in open-grown stands of healthy trees generally compensate for high wind loads in areas of high topographic exposure by forming short stocky stems or flagged crowns. Similarly, they often compensate for soils that restrict rooting through buttressing or root interlocking. The most susceptible stands are tall, high-density stands growing on high-productivity sites where rooting is partially restricted. Evidence of recent windthrow in such stands prior to harvesting indicates a high degree of instability.

The design of openings or partial cuts can greatly increase the wind loading on stand edges and residual trees. For example, on level ground, windward edges are partially sheltered if openings are less than five tree lengths wide. In uniform thinned stands, wind loads increase in direct proportion to inter-tree spacing. Crown modification techniques can be used to reduce wind loads on residual trees. Removal of 30% of the upper crown mass can reduce wind loads by 50%. Windthrow is a natural disturbance agent, and potential impacts and the level of acceptable damage should be incorporated into prescriptions for damage mitigation.

It is a good practice to maintain a landscape-level map showing windthrow and windthrow salvage locations. Over time this will assist in identifying local wind patterns and those portions of the landscape that are more susceptible to damage. Windthrow can be observed on 1:15 000 scale photographs, and these can be used to examine the edges of cutblocks adjacent to areas proposed for harvest.

Because of the complex interactions of climatic, biophysical, and management factors that contribute to windthrow risk, there is always uncertainty in prediction. The wisest approach is one of prediction, experimentation, observation, and feedback.

Stand-level Surveys

Post–free growing, generic stand level forest health surveys are rarely conducted. Where specific problems are seen to exist, surveys focused on the problems are more commonly conducted. These focused surveys are discussed in the following section, Stand Management Prescription: Forest Health Assessment. The procedures for those surveys are detailed in the relevant forest health guidebooks.

Stand Management Prescription: Forest Health Assessment

Assessment of forest health should begin by reviewing the silviculture prescription and past silviculture surveys, in particular the free growing survey. Where the past survey information is recent, a walkthrough of the site to confirm the information should suffice. Where past information is dated, a survey, analogous to the silviculture prescription free growing survey, should be conducted. Refer to the *Silviculture Surveys Guidebook* for methods.

Complete the forest health component of the stand management prescription with current survey information. The prescription should identify the location and incidence of forest health factors. Where the incidence of these factors exceeds treatment thresholds, treatment options should be included in the prescription. Stand management prescription monitoring should occur on a regular basis to ensure that the prescription continues to adhere to forest health objectives.

Forest health thresholds and treatment option recommendations for stand management prescriptions are summarized below. Greater detail regarding these thresholds and treatments may be presented in the relevant forest health guidebooks.

Diseases

Root diseases

Thresholds for treatment of armillaria, phellinus, and tomentosus in stand management prescriptions are presented in the *Root Disease Management Guidebook*. Particularly for the Nelson Forest Region, refer also to the publication by Norris et al (1998). Contact the regional pathologist for guidance on the selection and use or root rot surveys methods.

Dwarf mistletoes

Any residual, over-topping, dwarf mistletoe–infected tree that jeopardizes the health of young crop trees should, if possible, be removed. The prescription and/or local forest district staff must be consulted about why the residual trees were retained at the time of harvesting before a recommendation is made to remove them. Once over-topping infection sources are removed, free growing trees should out-grow the dwarf mistletoe infections. Refer to the *Dwarf Mistletoe Management Guidebook* sections on partial cut harvesting, stand management assessment, and assessing strata not treated for dwarf mistletoe due to other resource management objectives.

Comandra and stalactiform blister rusts and western gall rust

A five-step process for the evaluation of stand, site, and disease conditions for plans and prescriptions is included in the *Pine Stem Rust Management Guidebook.* Disease incidence and treatment levels for rusts infecting lodgepole pine vary with the age of stand. Particularly for the Prince George Forest Region, refer also to the regional Standard Operating Procedures (BCMOF 2000).

White pine blister rust

Where there is a significant component of the pine to be managed, consult the *Pine Stem Rust Management Guidebook.* For stands with ≤10% of western white pine and where there is no specific intention to manage for it, do not take action to control the disease.

Insects

Defoliators

Consult the forest district regarding the expected trend of defoliator infestations. Where current or expected (based on an existing infestation) defoliation is greater than 50 %, including terminal bud death, undertake silvicultural treatments, such as spacing, with concurrent direct defoliator control treatments or wait until the infestation has subsided. Consult the *Defoliator Management Guidebook* for additional information.

Bark beetles (in partial cutting silviculture systems)

Consult forest district staff to advise them of identified infestation(s) and to get recommendations for treatment. The likely treatment recommendation will be to remove all current attack trees before the next beetle flight. The practicality of this will depend on the timing of the beetle survey and the prescription harvesting options for the site. Consult forest district staff regarding other beetle containment options, such as pheromone baiting or creation of trap trees (see the *Bark Beetle Management Guidebook*).

Terminal weevils

Weevil attack rates vary with stand age and height. Surveys for weevil damage should be delayed until the stand is at least 15 years old, for both the interior and coast, in order to detect the peak annual attack intensity.

Surveys specifically recording spruce weevil damage are conducted with two objectives:

- to assess attack levels in a watershed or subzone in order to update the hazard rating and species selection guidelines; and
- to determine whether weevil damage has exceeded the thresholds set for treatments to minimize the weevil's impact.

Based on initial surveys, a decision "tree" for the management and rehabilitation of stands attacked by the spruce weevil is included in the *Terminal Weevil Guidebook.*

Other insects

No provincial treatment thresholds have been established; please consult regional forest health staff.

Wildlife

No provincial treatment thresholds have been established; please consult regional BCMOF staff. Ministry of Environment wildlife biologists may also offer assistance.

References

British Columbia Forest Service. 2000. Ground detection and assessment procedures for lodgepole pine stem rusts, western gall rust, comandra blister rust and stalactiform blister rust, in the Prince George Forest Region. Prince George Forest Region Standard Operating Procedure #7.1 – 1.

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(BCMOF 1997b) British Columbia Forest Service. 1997. Aviation safety manual, Aviation Management Protection Program, B.C. Ministry of Forests.

(CFS and BCMOF 2000) Canadian Forest Service. and B.C. Ministry of Forests. 2000. Forest health aerial overview survey standards for British Columbia. Pacific Forestry Centre, Canadian Forest Service, and B.C. Ministry of Forests, Forest Practices Branch.

Gimbarzevsky P., A.F. Dawson, and G.A. Van Sickle. 1992. Assessment of aerial photograph and multi-spectral scanner imagery for measuring mountain pine beetle damage. Pacific Forestry Centre. Information Report BC-X-333.

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Harris J.W.E., A.F. Dawson, and R.G. Brown. 1982. Evaluation of mountain pine beetle damage using aerial photography, Flathead River, B.C. 1980. Pacific Forest Research Centre. Report BC-X-228.

Howse, K.1995. Aerial pest survey procedures. Cariboo Forest Region.

Norris D., J. McLaughlin, and M. Curran. 1998. Armillaria root disease management guidelines for the Nelson Forest Region. Technical Report 14, B.C. Ministry of Forests, Resource Management Section, Nelson Forest Region.

Glossary

Current attack (also called green attack): a tree attacked by bark beetles that still contains beetle life stages. The tree may still appear healthy, but show signs of beetle attack.

Forest health factor: biotic and abiotic influences on the forest that are usually naturally occurring components of forest ecosystems. Biotic influences include fungi, insects, plants, other animals, bacteria, and nematodes. Abiotic influences include frost, snow, fire, wind, sun, drought, pollution, nutrient problems, and human-caused injury.

Geographic Information System (GIS): a computer system designed to allow users to collect, manage, and analyze large volumes of spatially referenced information and associated attribute data. The major components of a GIS are the user interface, database management, data entry, product generation, and spatial data manipulation and analysis. These functions may be centralized, or distributed across a network.

Global Positioning System (GPS): a navigational tool that allows the user to determine their location on the surface of the earth (usually within metres), using a hand-held or aircraft-mounted instrument linked to radio signals from several satellites.

Hazard: the degree to which the characteristics of the sampling entity (usually a tree or a stand) make it vulnerable to damage. It is equivalent to susceptibility.

Hawksworth Six-class Rating System: a standardized method of assessing the severity of dwarf mistletoe infestations on a tree. The method is fully described in the *Dwarf Mistletoe Management Guidebook*, Section 5.3.

Incidence: the proportion (0–1) or percentage (0–100%) of damage agent–affected sampling entities (normally a tree) within a sampling unit (normally a plot or a stand). To avoid confusion when using incidence, always indicate the sampling entity and sampling unit in order to ensure clarity. Where the proportion of damaging agent–affected stands or polygons (sampling entity) is of interest in a higher-level sampling unit, use occurrence.

Intensity: a general characterization of the total amount of a damage within a specific population and a function (not necessarily arithmetic) of incidence and severity.

Inventory Type Group (ITG): the designation of species composition by one of 42 type groups, each one being a unique combination of pure or mixed tree species.

Multi-storey: A stand is considered multi-storey if the layers 1 or 2 have a crown closure >6% and one of these layers is in combination with layer 3 and/or 4. In order to survey using the multi-storey method, an opening must have at least a minimum of three layers present or one of the following combinations: layers 1 and 4, layers 2 and 4, or layers 1 and 3.

Occurrence: the proportion of damage agent–affected stands or polygons within a higher-level sampling unit (e.g., inventory or growth type groups, or BEC zone subzones or variants).

Pest: any forest health factor designated as detrimental to effective resource management.

Pixel: a type of fixed plot used to estimate prevalence as the percentage area infected; often only the presence or absence of the damaging agent is recorded for each pixel.

Population: a collection of sampling entities about which we wish to make an inference.

Prevalence: the proportion of sampling entities (in a given population of interest) affected by a particular damaging agent.

Probe (beetle): a systematic strip transect survey through a stand to obtain detailed information on infestation levels, history, and stand data needed to make management decisions.

Risk: the probability and expected severity of sampling entity damage. It is a function of numerous components, including sampling entity, hazard, sampling unit conditions, proximity to damaging agents, and the incidence of those agents.

Sampling entity: an object on which a measurement is taken (normally a tree or a stand).

Sampling unit: a non-overlapping collection of sampling entities from a population.

Severity: the quantity of damage, or the quantity of a damaging agent, affecting sample entities within a sampling unit. It is a damage-rating measurement, (an average) that considers only affected entities and is damage type or agent specific. Severity cannot be applied at the stand level. The terms intensity, yield/growth effects, or impacts should be applied at the stand or higher levels.

Strip: a sampling unit laid out by measuring an equal distance on either side of a transect; a special type of fixed plot; other names include strip transect, probe line, and strip plot.

Susceptibility: term equivalent to hazard.

Walkthrough: an initial reconnaissance of an area; for bark beetles a non-systematic, low-intensity type of ground survey assessing damage. Used to make initial assessment of situations and confirm aerial survey information.

Appendix 1 List of abbreviations used in this guidebook

.e00:	ArcInfo export file
BCMOF:	British Columbia Ministry of Forests
BEC:	biogeoclimatic ecosystem classification
CFS:	Canadian Forest Service
dbh:	diameter at breast height
DM:	district manager
FC1:	forest cover map file (#1)
FDP:	forest development plan
FIP:	forest inventory planning
FIS:	forest inventory system
FRGIS:	forest resources geographic information system
FTP:	file transfer protocol
GIS:	global information system
GPS:	global positioning system
ITG:	inventory type group
L1, L2, L3:	tree layer, 1, 2 and 3
LC:	live crown
OPR:	*Operational Planning Regulation*, (*Forest Practices Code Act*)
POC:	point of commencement
POT:	point of termination
PSR:	pest survey rating
RIC:	Resource Inventory Committee
SPI:	survey for pest incidence
UTM:	universal transverse Mercator (map grid system)
VG1:	vegetation inventory map file (#1)
VIF:	vegetation inventory file

Appendix 2 Composition of Inventory Type Groups (ITGs)

Note: For all inventory type groups, any third species is possible.

INVENTORY TYPE GROUP		FIRST SPECIES	SECOND SPECIES	EXAMPLES
1	F	F 81%+	Any	F, FPw, FPwC
		F	Pw	FPw, FPwc
2	FC	F	C or Cy	FC, FCy, FCH
3	FH	F	H or B	FH, FB, FHC, FBH
4	FS	F	S	FS, FSB, FSH
5	FPl	F	Pl	FPl, FPlH, FPlPy
6	Fpy	F	Py	FPy, FPyL, FPyPl
7	FL	F	L	FL, FlPy, FLS
8	Fdecid.	F	Deciduous	FMb, FCot, FA
9	C	C or Cy, 81%+	Any	C, Cy, CCy, CPl, CD
		C or Cy	C, Cy, Pw, Pl, or Decid.	CyPl, CyC, CyCH
10	CF	C or Cy	F or L	CF, Cl, CyF, CFH
11	CH	C or Cy	H, B, or S	CH, CB, CS, CyH
12	H	H 81%	Any	H, HPw, HPl, HPlCy
		H	Pw or Pl	HPw, HPl, HPlCy
13	HF	H	F or L	HF, HL, HFC
14	HC	H	C or Cy	HC, HCy, HCCy, HCB
15	HB	H	B	HB, HBS, HBC
16	HS	H	S	HS, HSB, HSCot
17	Hdecid.	H	Deciduous	HCot, HD, HCotB
18	B	B 81%+	Any	B, BF, BPw, BPl, BL
		B	F, Pw, Pl, L, or Decid.	BF, BPw, BPl, BL, BA
19	BH	B	H, C or Cy	BH, BC, BCy, BHC
20	BS	B	S	BS, BSPl, BSA
21	S	S 81%	Any	S, SCy, SPw
		S	Cy, Pw	SCy, SPw
22	SF	S	F, L, or Py	SF, Sl, SPy, SFB
23	SH	S	H or C	SH, SC, SHCot

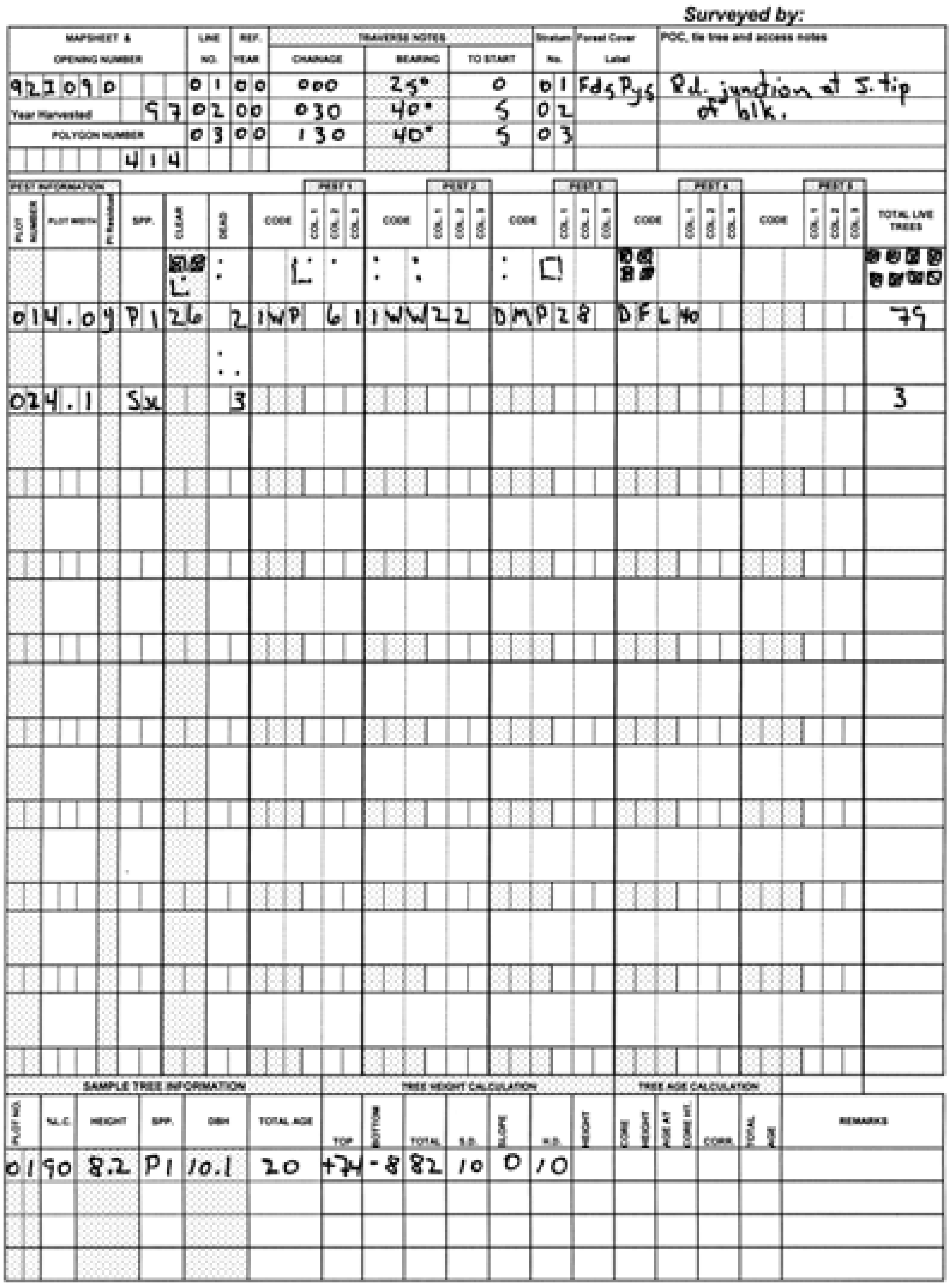
INVENTORY TYPE GROUP		FIRST SPECIES	SECOND SPECIES	EXAMPLES
24	SB	S	B	SB, SBCot, SBH
25	SPl	S	Pl	SPl, SPlB, SPlF
26	SDecid.	S	Deciduous	SA, Scot, SCotB
27	PwPa	Pw or Pa	Any	Pw, PwF, PwCH
28	Pl	Pl 81%+	Any	Pl
29	PlF	Pl	F, Py, or L	PlF, PlPy, PlL, PlFH
30	PIS	Pl	S, B, H, Pw, C, or Cy	PlS, PlB, PIH, PlBS
31	PlDecid.	Pl	Deciduous	PlA
32	Py	Py	Any	Py, PyF, PyL, PyPlF
33	LF	L	F	LF, LFPy
34	L	L	Any except F	L, LPy, LPl, LPyF
35	CotConif.	Cot	Coniferous	CotS, CotH
36	CotDecid	Cot	Deciduous	Cot, CotA
37	DConif	D	Coniferous	DF, DCH
38	DDecid	D	Deciduous	D, DMb
39	Mb	Mb	Any	Mb, MbD, MbF
40	Bi	Bl	Any	Bi, BiA, BiS
41	AConif	A	Coniferous	APl, As, AF
42	ADecid	A	Deciduous	A, ACot, ABi

Appendix 3 Example inventory data from a Survey for Pest Incidence stratified map sheet

(see Figure 3)

ITG	AGE	SITE CLASS	AREA (HA)	STRATA TOTAL	METRES	PLOTS	MIN. PLOTS
1	2	P	118				
1	3	P	357.6				
1	4	P	274.1	749.7	2621.5	19	19
1	5	M	72.3				
1	5	P	302.2				
1	6	P	739.5	1114	3895.4	28	28
1	7	P	315.6				
1	8	M	174.9				
1	8	P	1795.8	2286.3	7994.7	57	57
29	3	M	71.0	71.0	249.0	2	5
			4221			106	109

Appendix 4 Example of the SPI field form



Surveyed by:

MAPSHEET & OPENING NUMBER	LINE NO.	REF. YEAR	TRAVERSE NOTES CHAINAGE	BEARING	TO START	Stratum No.	Forest Cover Label	POC, tie tree and access notes
92I090	01	00	000	25°	0	01	Fd5Py5	Rd. junction at S. tip of blk.
Year Harvested 97	02	00	030	40°	5	02		
POLYGON NUMBER	03	00	130	40°	5	03		
414								

PEST INFORMATION

PLOT NUMBER	PLOT WIDTH	Pl Residual	SPP.	CLEAR	DEAD	PEST 1 CODE	COL 1	COL 2	COL 3	PEST 2 CODE	COL 1	COL 2	COL 3	PEST 3 CODE	COL 1	COL 2	COL 3	PEST 4 CODE	COL 1	COL 2	COL 3	PEST 5 CODE	COL 1	COL 2	COL 3	TOTAL LIVE TREES
01	4.0	y	Pl	26	2	IWP	6	1		IWW	22			DMP	28			DFL	40							79
02	4.1		Sx		3																					3

SAMPLE TREE INFORMATION: PLOT NO.	%L.C.	HEIGHT	SPP.	DBH	TOTAL AGE	TREE HEIGHT CALCULATION: TOP	BOTTOM	TOTAL	S.D.	SLOPE	H.D.	HEIGHT	TREE AGE CALCULATION: CORE HEIGHT	AGE AT CORE HT.	CORR.	TOTAL AGE	REMARKS
01	90	8.2	Pl	10.1	20	+74	-8	82	10	0	10						

Appendix 5 Damage agents and associated Pest Severity Ratings (PSRs)

Field code	Description	Pest Severity Rating Col. 1	Col. 2	Col. 3
A	ANIMAL DAMAGE			
AB	bear	1	3	
AC	cattle	1	3	
AD	deer	1	3	
AE	elk	1	3	
AH	hare or rabbit	1	3	
AM	moose	1	3	
AP	porcupine	1	3	
AS	squirrel	1	3	
AV	vole	1	3	
AX	birds	1	3	
AZ	beaver	1	3	
D	DISEASES			
DB	BROOM RUSTS			
DBF	fir broom rust, *Melampsorella caryophyllacearum*	3		
DBS	spruce broom rust, *Chrysomyxa arctostaphyli*	3		
DD	STEM ROT			
DDA	artists conk, *Ganoderma applanatum*			
DDB	birch trunk rot, *Fomes fomentarius*			
DDD	sulphur fungus, *Laetiporus sulphureus*			
DDE	rust-red stringy rot, *Echinodontium tinctorium*	2		
DDF	brown crumbly rot, *Fomitopsis pinicola*			
DDH	hardwood trunk rot, *Phellinus ignarius*	2		
DDO	cedar brown pocket rot, *Poria sericeomollis*			
DDP	Pini (red-ring) rot, *Phellinus pini*	2		
DDQ	quinine conk, *Fomitopsis officinalis*			
DDS	Schweinitz butt rot, *Phaeolus schweinitzii*			
DDT	aspen trunk rot, *Phellinus tremulae*			
DF	FOLIAGE DISEASES			
DFA	western pine-aster rust, *Coleosporium asterum*	4		
DFC	large-spored spruce-Labrador tea rust, *Chrysomyxa ledicola*	3		
DFD	spruce needle cast, *Lirula macrospora*	4		
DFE	elytroderma disease, *Elytroderma deformans*	3		
DFH	larch needle blight, *Hypodermella laricis*	3		
DFL	pine needle cast, *Lophodermella concolor*	3		
DFM	larch needle cast, *Meria laricis*	4		

Field code	Description	Pest Severity Rating Col. 1	Col. 2	Col. 3
DFP	fir-fireweed rust, *Pucciniastrum epilobi*	4		
DFR	Douglas-fir needle cast, *Rhabdocline pseudotsugae*	4		
DFS	red band needle blight, *Mycosphaerella (Scirrhia) pini*	4		
DL	DISEASE-CAUSED DIEDBACK			
DLD	dermea canker, *Dermea pseudotsugae*	3		
DLF	red flag disease, *Potebniamyces balsamicola*			
DLP	phomopsis canker, *Phomopsis lokoyae*	4		
DLS	sydowia (sclerophoma) tip dieback, *Sclerophoma pithyophila*	2		
DLV	aspen-poplar twig blight, *Venturia* spp.	3		
DM	DWARF MISTLETOES			
DMF	Douglas-fir dwarf mistletoe, *Arceuthobium douglasii*	2	2	3
DMH	hemlock dwarf mistletoe, *Arceuthobium tsugense*	2	2	3
DML	larch dwarf mistletoe, *Arceuthobium laricis*	2	2	3
DMP	lodgepole pine dwarf mistletoe, *Arceuthobium americanum*	2	2	3
DR	ROOT DISEASES			
DRA	armillaria root disease, *Armillaria ostoyae*	1	1	1
DRB	black stain root disease, *Leptographium wagenerii*	1	1	1
DRC	laminated root rot, cedar strain, *Phellinus weirii*	3	1	1
DRL	laminated root rot, *Inonotus sulphurascens*	1	1	1
DRN	annosus root disease, *Heterobasidion annosum*	1	1	1
DRR	rhizina root disease, *Rhizina undulata*	1	1	
DRT	tomentosus root rot, *Inonotus tomentosus*	1	1	1
DS	STEM DISEASES (cankers and rusts)			
DSA	atropellis canker, *Atropellis piniphila*	2	3	
DSB	white pine blister rust, *Cronartium ribicola*	1	1	1
DSC	comandra blister rust, *Cronartium comandrae*	1	1	1
DSG	western gall rust, *Endocronartium harknessii*	2	3	
DSE	sooty barker canker, *Encoelia pruinosa*			
DSH	hypoxylon canker, *Hypoxylon mammatum*			
DSP	cryptoshaeria canker, *Cryptosphaeria populina*			
DSR	ceratocystis canker, *Ceratocystis fimbriata*			
DST	target canker, *Nectria galligena*			
DSY	cytospora canker, *Cytospora chrysosperma*			
DSS	stalactiform blister rust, *Cronartium coleosporoides*	2	3	
I	INSECTS			

Field code	Description	Pest Severity Rating Col. 1	Col. 2	Col. 3
IA	APHIDS			
IAB	balsam woolly adelgid, *Adelges piceae*	1		
IAC	giant conifer aphid, *Cinara* spp.	3	4	
IAG	Cooley spruce gall aphid, *Adelges cooleyi*	4	4	
IAS	green spruce aphid, *Elatobium abietinum*	1	3	
IB	BARK BEETLES			
IBB	western balsam bark beetle, *Dryocoetes confusus*	1	1	1
IBD	Douglas-fir beetle, *Dendroctonus pseudotsugae*	1	1	1
IBI	engraver beetles, *Ips* spp.	1	1	1
IBM	mountain pine beetle, *Dendroctonus ponderosae*	1	1	1
IBP	twig beetle and others, *Pityogenes, Pityophthorus* spp.	1	3	
IBS	spruce beetle, *Dendroctonus rufipennis*	1	1	1
IBT	red turpentine beetle, *Dendroctonus valens*	1	3	
IBW	western pine beetle, *Dendroctonus brevicomis*	1	1	1
ID	DEFOLIATORS			
IDA	black army cutworm, *Actebia fennica*	1	2	3
IDB	2-year cycle budworm, *Choristoneura biennis*	2	3	4
IDC	larch casebearer, *Coleophora laricella*	3	4	4
IDD	western winter moth, *Erranis tilaria vancouverensis*			
IDE	eastern spruce budworm, *Choristoneura fumiferana*	2	3	4
IDF	forest tent caterpillar, *Malacosoma disstria*	2	3	4
IDG	green-striped forest looper, *Melanolophia imitata*			
IDH	western blackheaded budworm, *Acleris gloverana*	2	3	4
IDI	pine needle sheath miner, *Zellaria haimbachi*	3	4	4
IDL	western hemlock looper, *Lambdina fiscellaria lugubrosa*	2	3	4
IDM	gypsy moth, *Lymantria dispar*	1	2	3
IDN	birch leaf miner, *Fenusa pusilla*			
IDP	larch sawfly, *Pristiphora erichsoni*	2	3	4
IDR	red alder sawfly, *Eriocampa ovata*	2	3	4
IDS	conifer sawflies *Neodiprion* spp.			
IDT	Douglas-fir tussock moth, *Orgyia pseudotsugata*	2	3	4
IDU	satin moth, *Leucoma salicis*	2	3	4
IDW	western spruce budworm, *Choristoneura occidentalis*	2	3	4
IDX	large aspen tortrix, *Choristoneura conflictana*			
IDZ	western false hemlock looper, *Nepytia freemani*			
IS	SHOOT INSECTS			
ISB	western cedar borer, *Trachykele blondeli*	3		

Field code	Description	Pest Severity Rating Col. 1	Col. 2	Col. 3
ISE	european pine shoot moth, *Rhyaconia buoliana*	3		
ISG	gouty pitch moth, *Cecidomyia piniiopis*	4	4	
ISP	pitch nodule moths, *Petrova* spp.	3		
ISQ	sequoia pitch moth, *Synanthedon sequoiae*	3		
ISS	western pine shoot borer, *Eucosma sonomana*	3		
IW	WEEVILS			
IWC	conifer seedling weevil, *Steremnius carinatus*	1	1	
IWP	lodgepole pine terminal weevil, *Pissodes terminalis*	2	3	4
IWS	white pine (spruce) weevil, *Pissodes strobi*	2	3	4
IWW	Warren's root collar weevil, *Hylobius warreni*	1	3	
IWY	*Cylindrocopturus* spp. weevils	4		
IWZ	Yosemite bark weevil, *Pissodes schwarzi*	1		
M	MITES			
M	*Trisetacus* spp.	1	3	
N	NON-BIOLOGICAL INJURIES			
NB	fire	1	3	
ND	drought	1	3	
NF	flooding	1	3	
NGC	frost crack	1	3	
NGH	frost heaved	1	3	
NGK	shoot/bud frost kill	1	3	
NH	hail	1	3	
NK	fumekill	1	3	
NL	lightning	1	3	
NN	road salt	1	3	
NR	redbelt	1	3	
NS	slide	1	3	
NW	windthrow	1	3	
NWS	soil failure	1	3	
NWT	treatment or harvesting related	1	3	
NY	snow or ice (includes snow press)	1	3	
NZ	sunscald	1	3	
T	TREATMENT INJURIES			
TC	chemical	1	3	
TL	logging wounds	1	3	
TM	other mechanical damage (non-logging)	1	3	
TP	planting (incorrect planting)	1	3	
TPM	poor planting microsite	1	3	
V	VEGETATION PROBLEMS			
VH	herbaceous competition	4		
VP	vegetation press	4		

Field code	Description	Pest Severity Rating Col. 1	Col. 2	Col. 3
VS	shrub competition	4		
VT	tree competition	4		

Appendix 6: Windthrow field cards

The three field cards are available in the BCMOF Public Forms Index at URL:
http://www.for.gov.bc.ca/pscripts/isb/forms/forms.asp
Also available in the URL is a Windthrow Assessment Summary Card

BRITISH COLUMBIA Ministry of Forests Forest Practices Branch

Windthrow Field Card
Reference Page A

Windthrow Field Cards: Reference Pages A & B, Assessment Pages A & B, Calibration Page and Prescription Pages can be used in conjunction with the Forest Service Windthrow Management Training, or on a stand-alone basis.

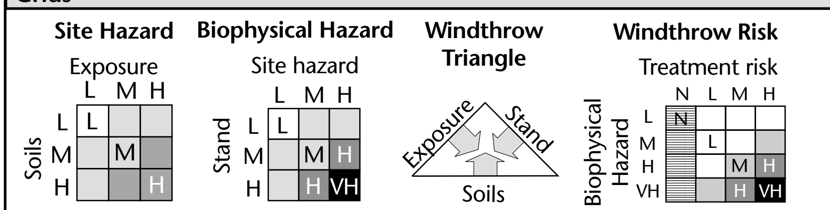
Definitions

- 'Biophysical Hazard' is the combination of the topographic, soils, and stand hazard components. It represents the intrinsic windloading and wind stability of trees on the site prior to treatment.
- 'Treatment Risk' is the way in which a particular treatment increases or decreases the windloading or wind resistance of trees. (For example, boundaries that run at right angles to damaging wind direction at the downwind end of a clearcut are high-risk treatments.)
- 'Windthrow Risk' is the likelihood of damage from endemic winds. It is the combination of Biophysical Hazard and Treatment Risk.
- 'Endemic' winds are peak winds expected to recur every year or so in a given location, as distinct from 'Catastrophic' winds, which recur very infrequently. If a portion of your operating area shows a pattern of repeated edge windthrow or salvage over a period of several years, you have a problem of endemic windthrow.
- 'Impact' is the consequence of wind damage. If wind damage conflicts with your management objectives, the impact is negative. Depending on your objectives, some level of damage may be acceptable.

Assessment Steps

1. Observe windthrow patterns at the landscape and stand level to determine orientation and recurrence of damaging winds.
2. Where there are nearby harvested blocks, calibrate the assessment on a High Treatment Risk boundary, then compare expected damage for the estimated Windthrow Risk Class with the observed damage and adjust Component Biophysical Hazard Classes if necessary.
3 Divide the boundary of a proposed clearcut into segments, or the interior of a proposed partial cut into portions that have similar biophysical and treatment characteristics.
4. i) Assess Treatment Risk for each segment/portion (boundary segments include adjacent stand).
   ii) Assess Biophysical Hazard Components for each segment/portion.
   iii) Integrate Biophysical Hazard Components using Grid.
   iv) Integrate Biophysical Hazard with Treatment Risk to estimate Windthrow Risk
5. Consider the management objectives for each segment/portion, the acceptability of damage, and the level of damage expected for the Windthrow Risk class you have estimated.
6. If the level of expected damage exceeds the acceptable level, recommend treatment modifications.
7. Set up a feedback loop where damage, assessment predictions, and treatments are monitored to enable improved windthrow prediction and management in your area.

Grids



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Windthrow Field Card Reference Page B

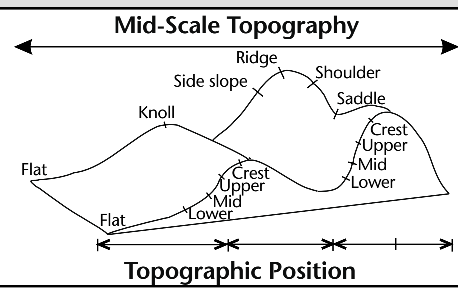
Windthrow Risk Class	Expected Damage Caused by Endemic Winds
None	No stand present to be damaged by winds.
Low	Little or no damage along recent cutblock edges.
Moderate	Partial damage along recent cutblock edges. Between 10 and 70 percent of the trees are uprooted or snapped within the first tree length in from the edge.
High	Heavy damage along recent cutblock edges. More than 70 percent of the trees within the first tree length damaged.
Very high	Very severe damage along recent cutblock edges. More than 70 percent of the trees damaged in both the first and second tree lengths into the edge.

Notes on Field Cards

The field cards can be filled out for each clearcut edge segment or partial cut portion, or simply use these cards as a checklist.

- In the boxes for recording Topography, Soil, and Stand attributes, indicator values are grouped into three columns representing High, Moderate, and Low hazard. This grouping is made to suggest the relative hazard of these indicator values. The relationship between indicators and hazard class will vary from place to place so common sense and local experience (assisted by the Diagnostic Questions) should be used in estimating the component Biophysical Hazards.
- The calibration step is important in refining the Biophysical Hazard classification. The logic underlying the assessment framework is as follows. Where site conditions and management actions in an area proposed for treatment are similar to those of an area treated in the past, a similar pattern of damage is expected.
- A more detailed discussion of the assessment framework can be found in '*A diagnostic framework for windthrow risk estimation.*' S.J.Mitchell In Forestry Chronicle 74 : 100–105 (January/February 1998).
- Card users wanting to improve their knowledge of windthrow assessment and management are referred to the BC Forestry Continuing Studies '*Windthrow Management Workshop*' and '*Windthrow Prescription Workshop.*'

Topographic Terms



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Windthrow Field Card Assessment Page A

Administrative			
Location	Opening	Block #	Examiner/Date	Segment/Portion

Topographic Exposure Description			
	High Hazard	**Moderate Hazard**	**Low Hazard**
Large-scale Topography	☐Coastal plain ☐Plateau ☐Rolling plateau ☐Major coastal inlet ☐Near large water body	☐Large valley ☐Hilly	☐Mountainous ☐Small coastal inlet ☐Far from large water body
Mid-scale Topography	☐Ridge ☐Saddle ☐Knoll ☐Shoulder	☐Flat ☐Side slope	☐Side valley
Topographic Position	☐Crest ☐Upper slope	☐Mid slope ☐Flat	☐Lower slope
Elevation (_________m)	☐High	☐Middle	☐Low
Diagnostic question: Are wind speeds normal for the area, or do they vary due to the presence of a terrain obstacle or constriction?			
Topographic hazard rating	☐High (higher)	☐Moderate (normal)	☐Low (lower)
Soil Description			
	High Hazard	**Moderate Hazard**	**Low Hazard**
Parent material	☐Organic ☐Rock ☐Fine alluvial	☐Till ☐Moderate alluvial	☐Coarse alluvial ☐Colluvial
Texture	☐Fine	☐Medium/ ☐V.Coarse	☐Coarse
Coarse fragment %	☐>70	☐30–70	☐<30
Rooting depth (cm) and pattern	☐< 40 ☐Plate roots	☐40–80 ☐Flattened base	☐>80 ☐Rounded base
Impeding layer	☐Water table	☐Surface fractured rock	☐Deep fractured rock
Soil drainage	☐Poor	☐Moderate	☐Good
Diagnostic question: Is root anchorage restricted by an impeding layer, low strength soil, or poor drainage?			
Soil hazard rating	☐High (severely restricted)	☐Moderate (somewhat restricted)	☐Low (unrestricted)
Stand Description			
	High Hazard	**Moderate Hazard**	**Low Hazard**
Structure	☐Uniform	☐Two-layer ☐Uniform with vets	☐Multi-layer
Height (m)	☐>30	☐15–30	☐<15
Live crown Ratio	☐<30	☐30–70	☐>70
Height diameter ratio	☐>90	☐70–90	☐<70
Stand density	☐Dense	☐Moderate	☐Open
Root/stem rots	☐Significant	☐Some	☐Minor
Species			
Diagnostic question: Are the individual trees within the stand adapted to wind loads?			
Note: If damaged stems would lean back into canopy and be supported by their neighbours instead of working down through the canopy to the ground, then stand hazard is low for clearcut edges.			
Stand hazard rating	☐High (poorly adapted)	☐Moderate (somewhat adapted)	☐Low (well adapted)

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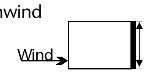
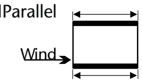
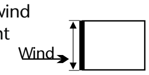
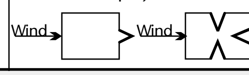
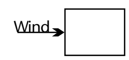
Windthrow Field Card Assessment Page B

Existing Windthrow Pattern				
	Recent	Older	Direction	Comments
Existing edge				
Within timber				

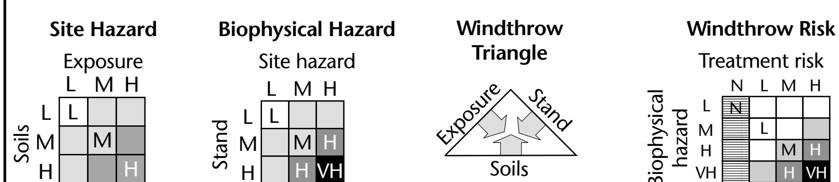
Treatment Description Openings: Group selection, patch cut, clearcut, etc.			
Treatment risk	High Risk	Moderate Risk	Lower Risk
Orientation relative to damaging winds	☐Downwind at right angle 	☐Parallel 	☐Upwind at right angle 
Width of Opening: Upwind Direction	☐>5 Tree lengths	☐2–5 Tree Lengths	☐<2 Tree Lengths
Influence of opening shape on windspeed	☐Funnels or projects into wind 		☐Straight 

For Uniform Retention: Commercial thin, single tree selection, etc.			
Treatment risk	High Risk	Moderate Risk	Lower Risk
Removal level (% basal area)	☐>50	☐30–50	☐<30
Removal criteria	☐Remove veterans, healthy dominants ☐Thin from above	☐Remove across all crown classes	☐Retain veterans, healthy dominants ☐Thin from below
Species	☐Least windfirm		☐Most windfirm

Diagnostic question: Will the proposed harvesting strategy increase wind loading on trees along the stand edge (opening) or retained trees (partial cut)?

Treatment risk rating summary	☐High (large increase)	☐Medium (moderate increase)	☐Low (minimal increase)

Windthrow Risk Evaluation



Estimated Windthrow Potential:

	Very High	High	Moderate	Low	None
Topographic Hazard	•	☐	☐	☐	•
Soil Hazard	•	☐	☐	☐	•
Stand Hazard	•	☐	☐	☐	•
Biophysical Hazard	☐	☐	☐	☐	•
Treatment Risk	•	☐	☐	☐	☐
Windthrow Risk	☐	☐	☐	☐	☐

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Windthrow Field Card Calibration Page

Observed Damage

1. Complete Windthrow Field Card Assessment Pages A and B in a nearby 2–5 year old cutblock on a High Treatment Risk Boundary.
2. Record initial evaluation of windthrow from Assessment Card Page B.

Initial Evaluation (from Assessment Card Page B):

	Very High	High	Moderate	Low	None
Topographic Hazard	•	☐	☐	☐	•
Soil Hazard	•	☐	☐	☐	•
Stand Hazard	•	☐	☐	☐	•
Biophysical Hazard	☐	☐	☐	☐	•
Treatment Risk	•	☐	☐	☐	☐
Windthrow Risk	☐	☐	☐	☐	☐

Calibration of Windthrow Risk Classification

3. Record observed damage on calibration boundary.

Trees Damaged (%):			
First Tree Length	☐>70	☐10–70	☐<10
Second Tree Length	☐>70	☐10–70	☐<10
Third Tree Length	☐>70	☐10–70	☐<10
Describe Damage:	☐Extensive	☐Partial	☐Minimal ☐None

Characteristics of Downed Trees:			
Size (compared to mean tree)	☐Same	☐Smaller	☐Larger
Species Composition	☐Same	☐Different: (describe)________________	
Rot (compared to average in stand)	☐Same	☐Less	☐ More

4. Look up the expected level of damage for your initial Windthrow Risk Class on Reference Page B, and compare with actual damage recorded above.

Diagnostic question: Is the level of damage observed along the calibration boundary consistent with that predicted for the estimated class of Windthrow Risk? (See top of Reference Page B)

If	Action
Yes, damage is consistent with expected level. ☐	Use the values for topographic, soils, and stand indicators to identify threshold values for high, moderate, and low hazard classes for each of the Exposure, Soils, and Stand Hazard components.
No, there is less damage. ☐	Consider which of the component hazards (Exposure, Soils, or Stand) might have been rated too highly. Reduce the rating and raise the hazard class thresholds accordingly.
No, there is more damage. ☐	Consider which of the component hazard (Exposure, Soils, or Stand) might have been rated too low. Increase the rating and decrease the hazard class thresholds accordingly.

5. Use the revised thresholds for classifying Soils, Topographic and Stand Hazards for nearby areas.

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Windthrow Field Card Prescription Page

Summary of Management Objectives and Acceptable Damage		
Management Objectives for Outside Segment/Within Portion		
Environmental	**Recreation/Visual/ Property**	**Timber**
☐Riparian area ☐Terrain stability area ☐Gully ☐Wildlife tree patch ☐Wildlife corridor ☐______________	☐Recreation area ☐Visual reserve ☐Powerline ☐Structure ☐Road ☐Trail ☐Property ☐______________	☐Value ☐Bark beetle ☐__________
Acceptable amount of damage: ☐None ☐Up to ____% of stems	☐None ☐Up to ____% of stems	☐None ☐Up to ___% of stems

Expected Level of Damage			
Windthrow risk:	☐High ☐Very High	☐Moderate	☐Low
Expected damage:	☐Extensive	☐Partial	☐None-Minimal
Is this expected level Acceptable?	☐Yes ☐No	☐Yes ☐No	☐Yes ☐No

Recommended Treatment Modifications	
Recommended treatment	**Comments:**
General:	
☐No treatment	
☐Salvage if damage exceeds acceptable amount	
For clearcuts:	
☐Adjust boundary	
☐Feather	
☐Top	
☐Top-prune	
☐Feather and top/top-prune	
For partial cuts:	
☐Leave more trees	
☐Change leave tree criteria	
☐Other	

Comments:

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